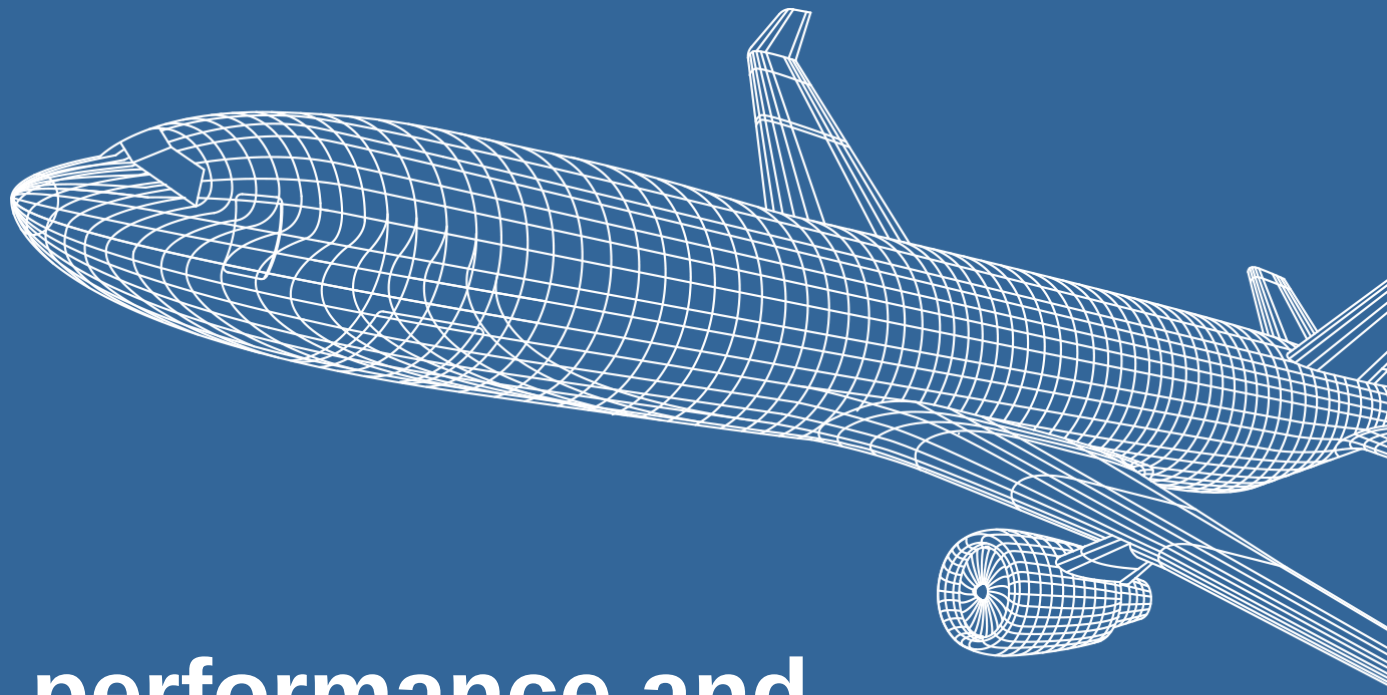

Prognosis performance and management for efficient planning of aircraft engine maintenance

Swedish Aerospace Technology Congress 2016

Veronica Fornlöf | 2016-10-11

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Veronica Fornlöf

M.Sc. in Mechanical engineering, Linköping University 2009

- Advanced knowledge in logistics and production economics

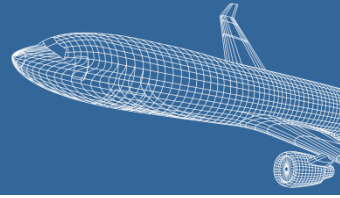
Tekn.lic in Informatics, University of Skövde 2016

- Maintenance of aircraft engines

Begun working at GKN Aerospace (Volvo Aero) in Trollhättan 2011.

Industrial PhD student since January 2013 at the University of Skövde and GKN Aerospace.

Introduction



Presentation based on an on-going PhD project financed by GKN Aerospace, University of Skövde and the knowledge foundation.

The research project were initiated in January 2013.

Licentiate degree in May 2016.

GKN AEROSPACE

1977
HÖGSKOLAN
I SKÖVDE

KK-stiftelsen

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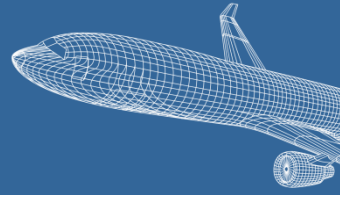
Introduction

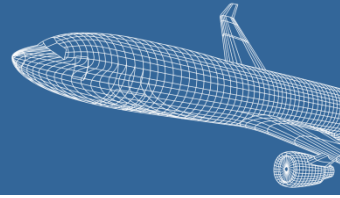


When and to what extent maintenance is performed affects the availability of the system.

An aircraft engine is a complex system and a prerequisite for propulsion of an aircraft. However it is also a part of an even larger system, the air force, that is depending of the availability and readiness of the aircraft engine.

Therefore performing the right amount of maintenance at the right moment is of outmost importance.

Background

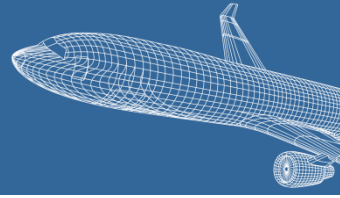


What is maintenance?

- Maintenance is a combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function. (EN 13306:2001)

- Aircraft engine maintenance is actions that can restore an item to a serviceable condition, and consist of servicing, inspection, determination of condition, repair, overhaul, and modification.

Background



Maintenance is a large part of the cost to keep an aircraft in operation.

Maintenance is also prerequisite for passenger safety and the reliability of the airlines time table.

- An unplanned failure must be avoided at all cost

The same applies from an military perspective were the fleet must be ready for military response whenever needed.

Performing the right amount of maintenance at the right moment is of outmost importance!

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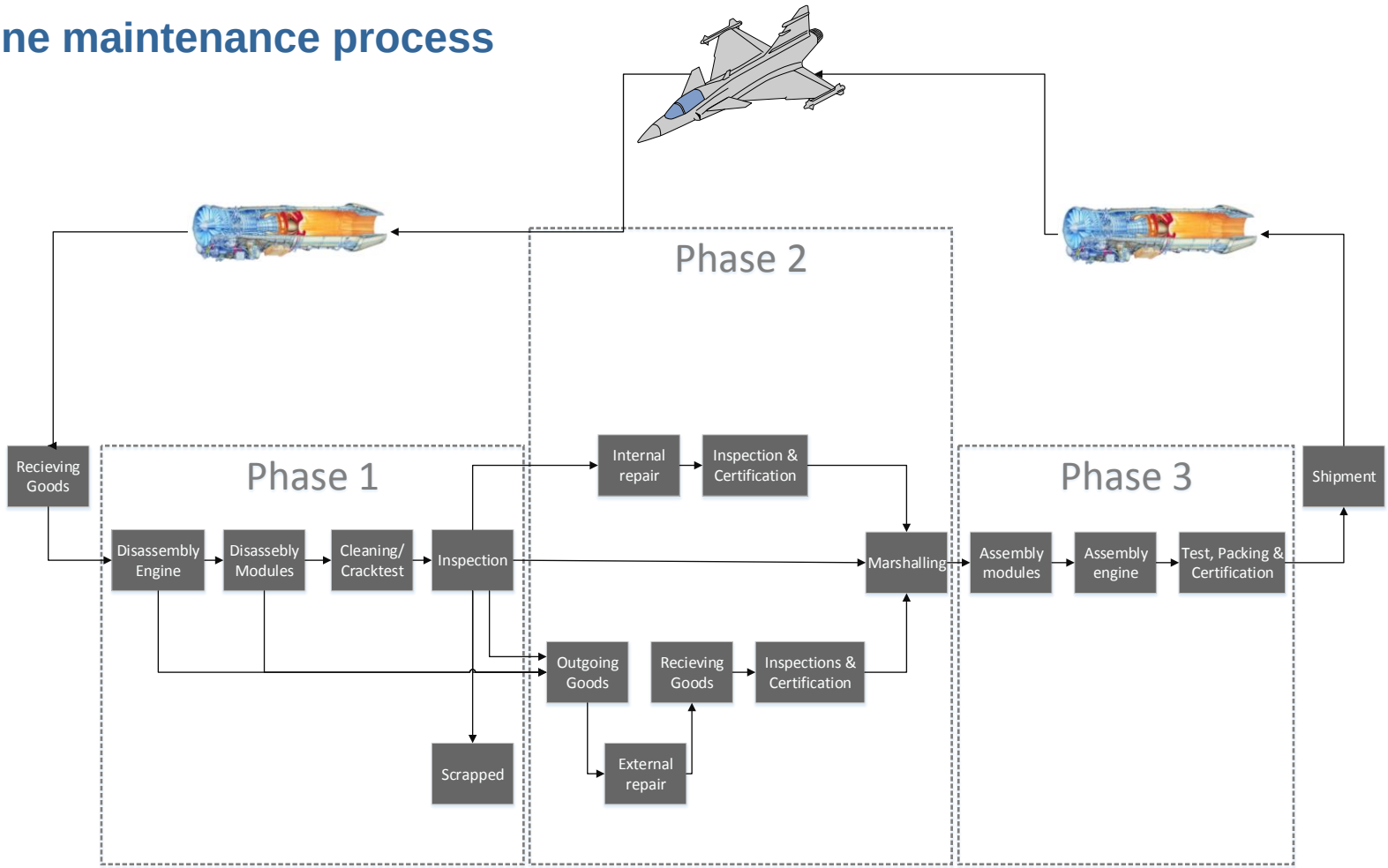
Background

Engine maintenance process



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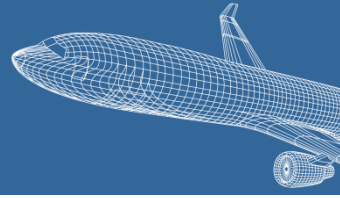
Background



Three different kind of components in an aircraft engine

Life Limited Parts	On-Condition Parts	Consumables
May not exceed a specified time, or number of operating cycles	Approved for continued operations as long as theu are within given limits	Exchanged at each maintenance occasion

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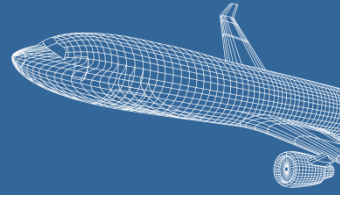
Optimization model



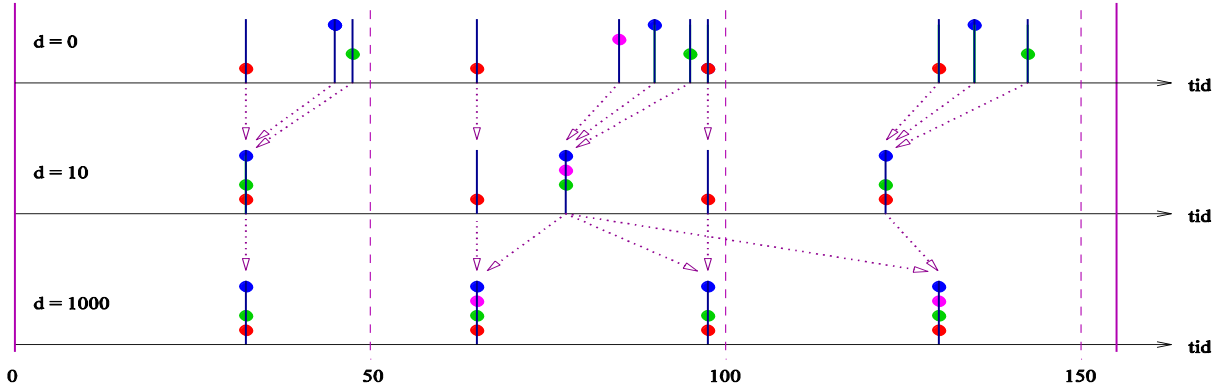
To replace a specific component, removal of other components are often necessary

- An opportunity to perform more maintenance, which can be economic in a longer perspective

In an earlier research project GKN and Chalmers have developed an optimization model related to this area. The optimization model minimizes the total cost for engine life(down time included) , not only costs related to the specific maintenance occasion.

Optimization model

The mathematical replacement model handles engine structure, remaining life for included components, available spare parts and costs related to maintenance.



Required input data:

- Remaining life for included components
- New parts in stock
- Used parts in stock
- Costs related to maintenance
- Costs related to each maintenance occasion

  (I.e. transportation, administration, testing, leasing engines.)

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Optimization model

Results (output data) from the optimization model is a plan for what to replace at the current maintenance occasion, but also a future current plan for upcoming maintenance occasions.

Costs per component

Period	Mo...	PartName	OCLB
0	HPC	Brännkammarmantel	LB
0	HPT	Skovel, HTT	LB
0	COM	Ledskenesegment, HTT, Kpl	OC
0	FAN	Skovel, Fläkt steg 2	LB
0	FAN	Skiva, Fläkt stg 1	LB
0	G/B	BCD-axlar	OC
0	HPT	Skiva HTT	LB
0	HPT	Låsring Främre	LB
0	HPC	SLK Länksystem	OC
0	HPT	Rotorlager 4	LB
0	HPC	Luftledring - Kinahatt	OC
0	FAN	Inloppsdel	OC
0	FAN	Fläktnav Bakre, kpl	LB
0	FAN	Rotorlager 1	LB
0	FAN	Skiva, Fläkt stg 3	LB
0	FAN	Skovel, Fläkt steg 1	LB
0	FAN	Skovel, Fläkt steg 3	LB
0	FAN	Rotor (ej underhållsobjekt)	EU

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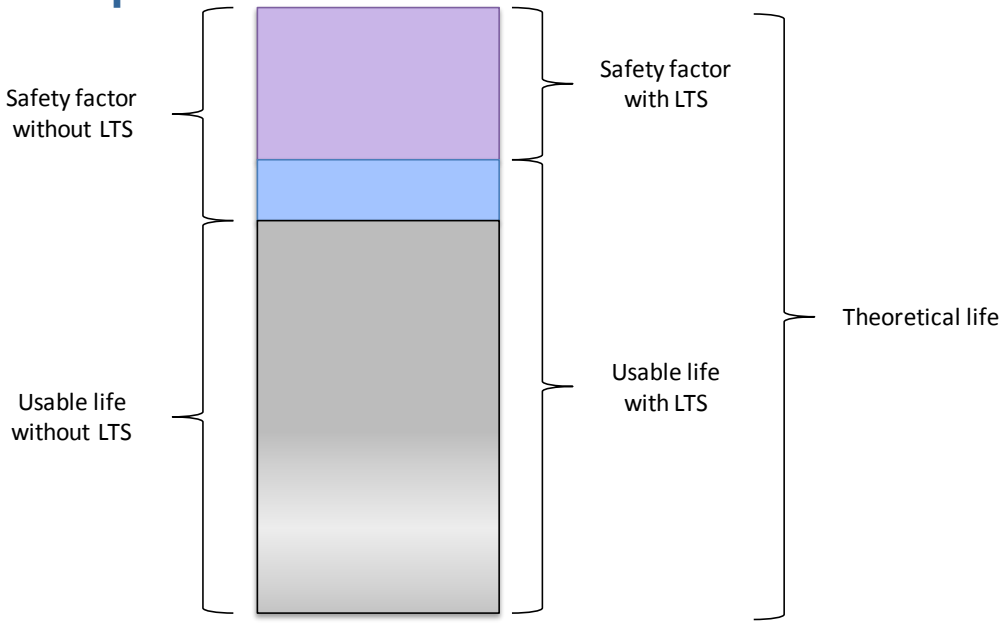
Problem description

With the GKN developed Life Tracking System, LTS, the life consumption for LLPs are calculated depending on what loads, temperatures and pressures the LLP has been exposed to during each flight.

LTS is not applicable for the OC parts. OC parts are instead evaluated against the component maintenance plan when inspected. They are either approved or not for continued operation.



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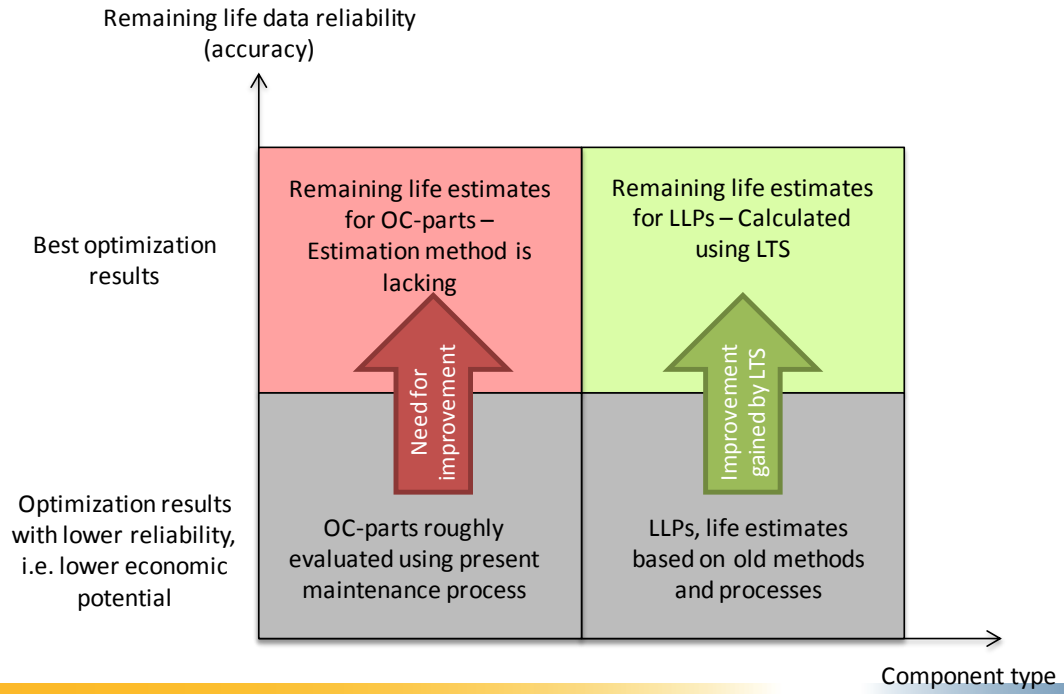
Problem description

Potential to improve the process of maintenance planning has been identified

If maintenance optimization is implemented to decide e what components to replace at each maintenance occasion.

Better estimates of the remaining life for OC parts are needed to get full effect of the mathematical replacement model. OK/not OK is not enough.



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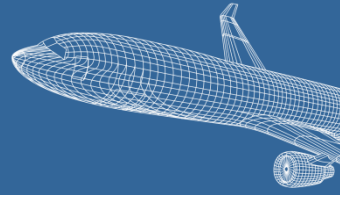
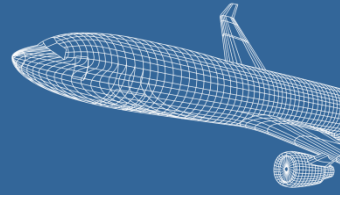
Problem description



This problem is highly relevant, not only from an aircraft engine perspective.

- A general solution for estimations of remaining life of OC-components is missing.
- Better estimates of remaining life is of interest, not only for GKN, but for the complete aircraft industry.
- Other industries with high demands of availability, safety and requirements on performing the right amount of maintenance at the right occasion can benefit from this research.

Purpose



Improve the knowledge of how to estimate the remaining life of OC parts in order to be able to predict how long they can be kept in operation.

- Existing theories and methods within the area is not complete

Better life estimates for OC parts will lower the maintenance cost while keeping the availability and readiness for the aircraft fleet intact.

Research goal

1. **Identify which engine parts that require better life length estimates in order to facilitate efficient use of the replacement model. (I.e. find which parts that should be included in the replacement model in addition to the LLP parts.)**

2. **Describe and evaluate methods to predict the remaining life of the identified parts.**

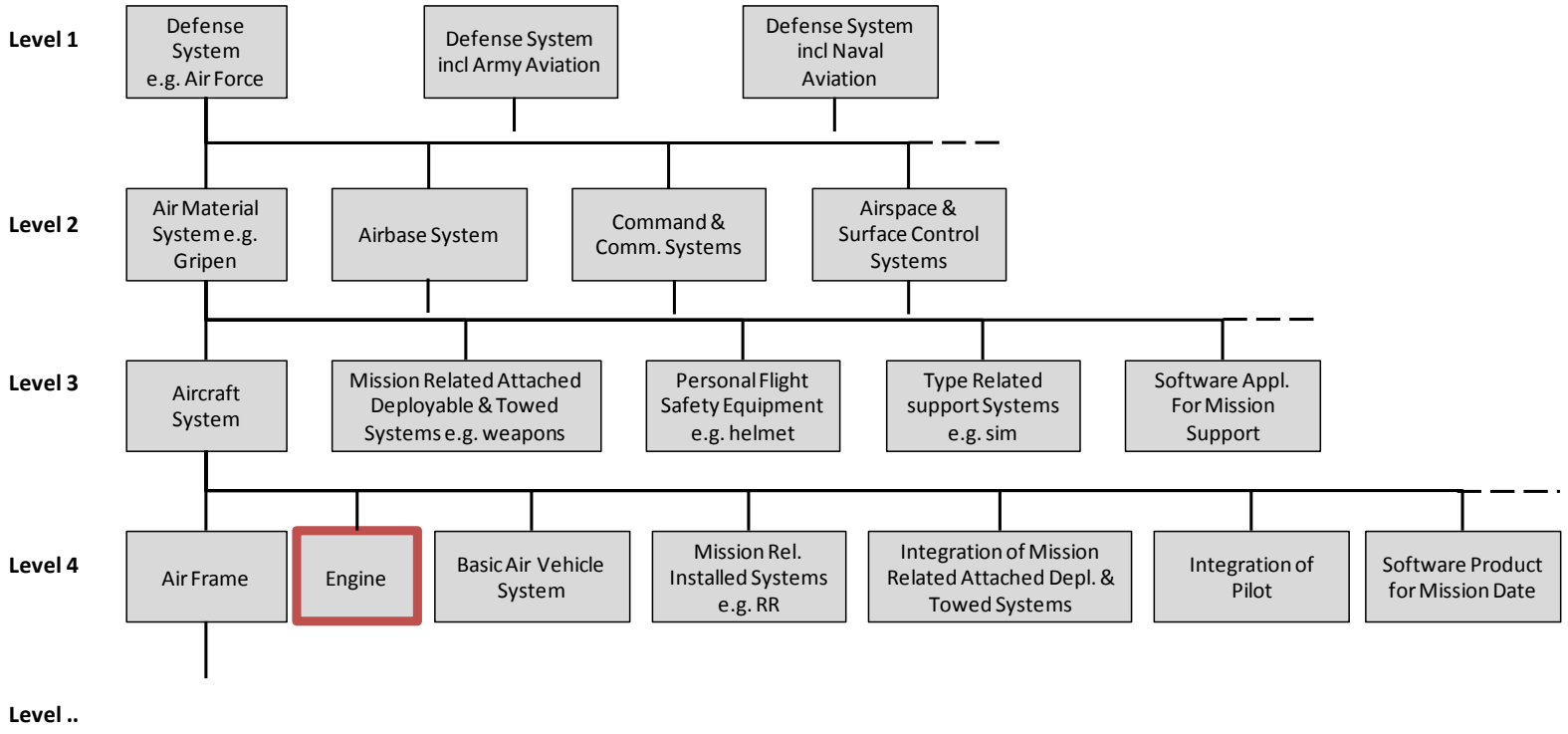
Research goal

3. **Evaluate the resulting overall maintenance cost, calculated by the replacement model, as a function of resolution of the life length estimates, in relation to prediction accuracy and the length of the discrete time steps in the replacement model.**

4. **Choose, and if required adapt, life length estimation methods for the identified part types (i.e. create framework for life length estimation).**

Results

A system of system approach to the aircraft engine has been introduced. The engine is a part of a much larger system



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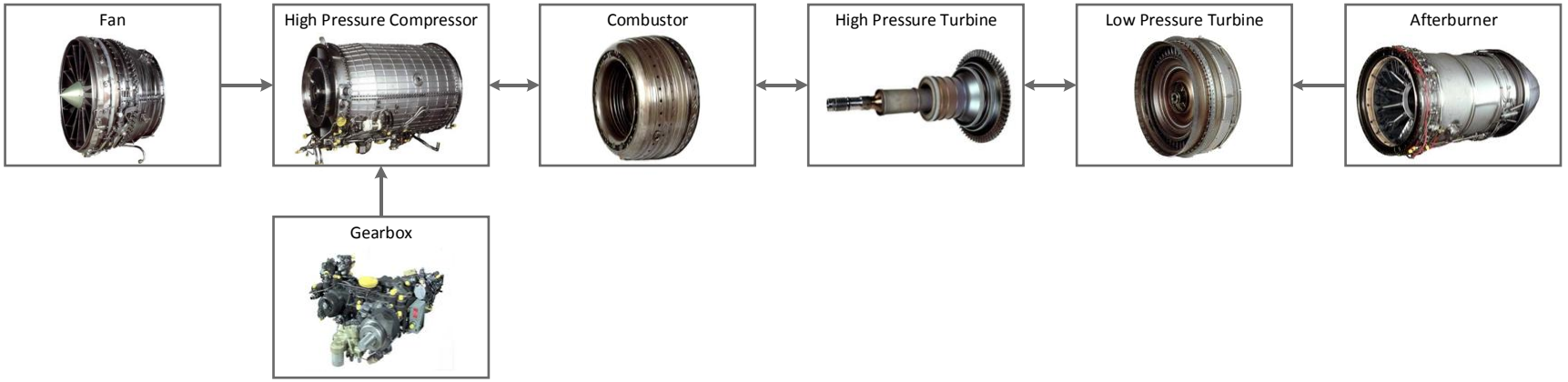
Results

The engine is though also a complex system in itself exposed to high loads, temperatures, pressures, stress and fatigue.



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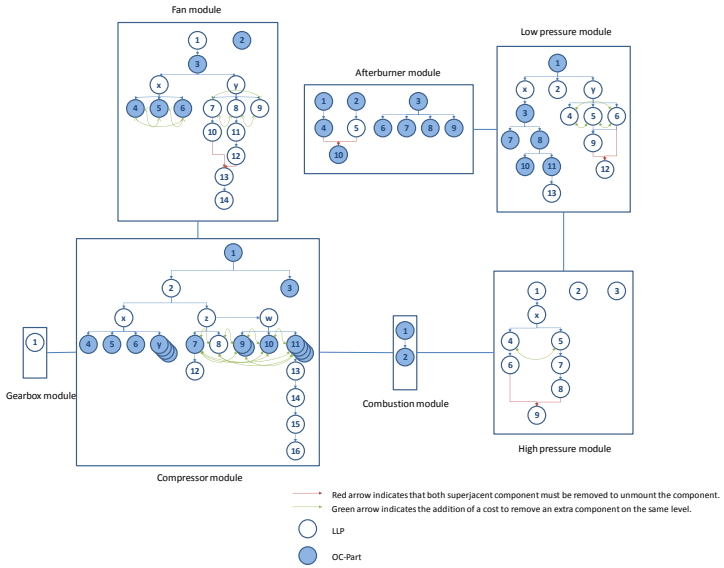
Results

From the system of system approach and a description of how an engine is constructed an review of all component that needs to be incorporated in the mathematical replacement model is presented

- It is stated that reliability of the complete engine will be increased if better life estimates would be presented also for the OC part.

All components that needs to be implemented in the replacement model, no matter if LLP or OC part, is presented.



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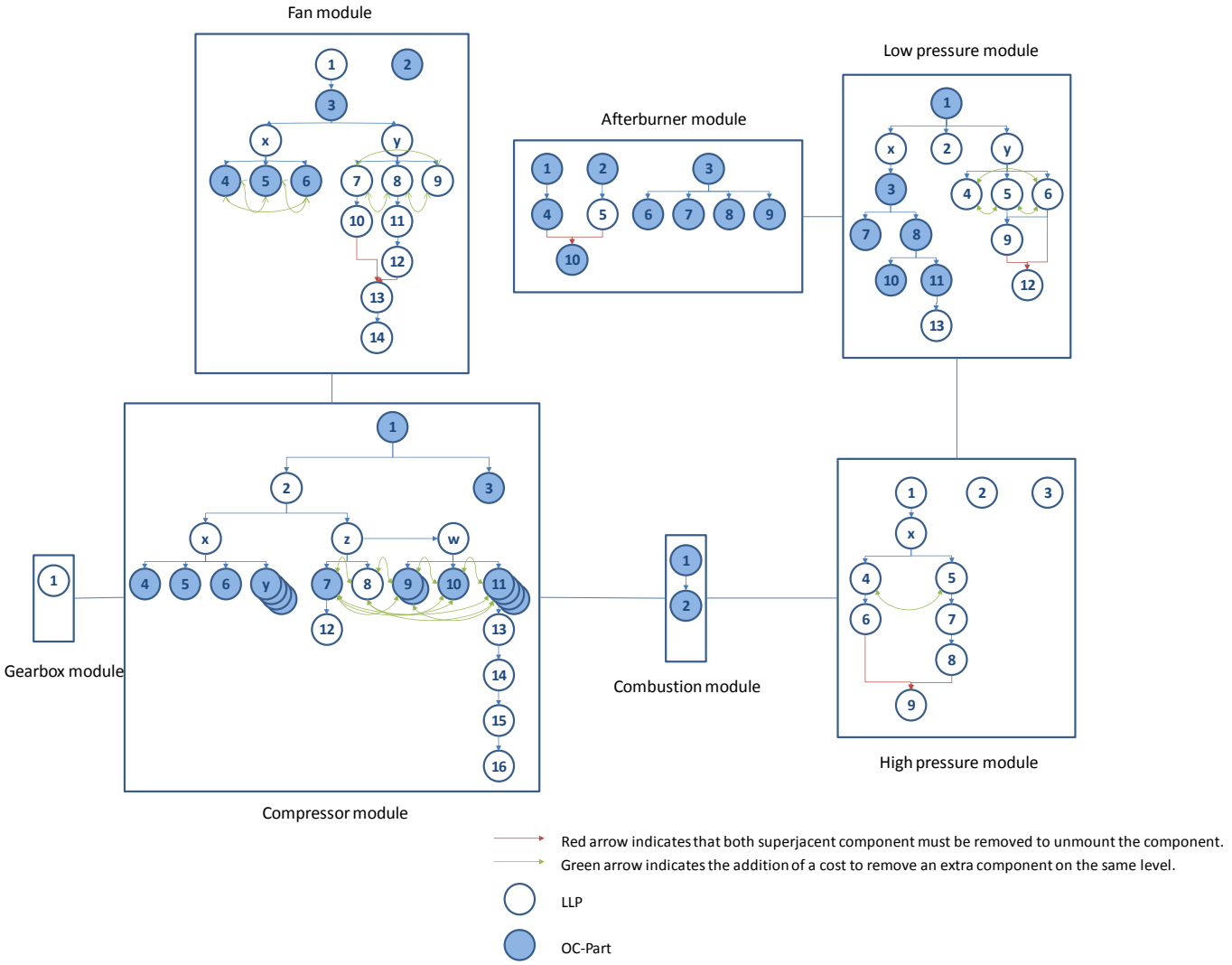
Results



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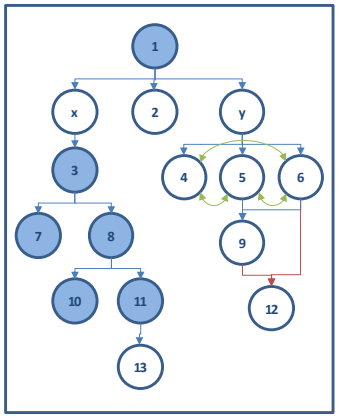
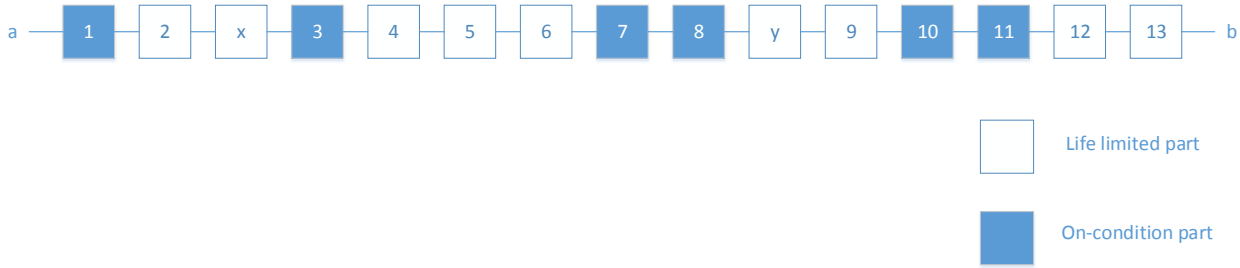
Results

By studying one subsystem/module of the engine potential from increased reliability for the subsystem/module and the complete system (the aircraft engine, is identified, id better life estimates for the OC parts is gained.





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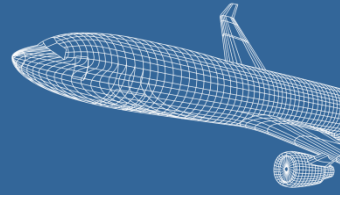
Future reserach



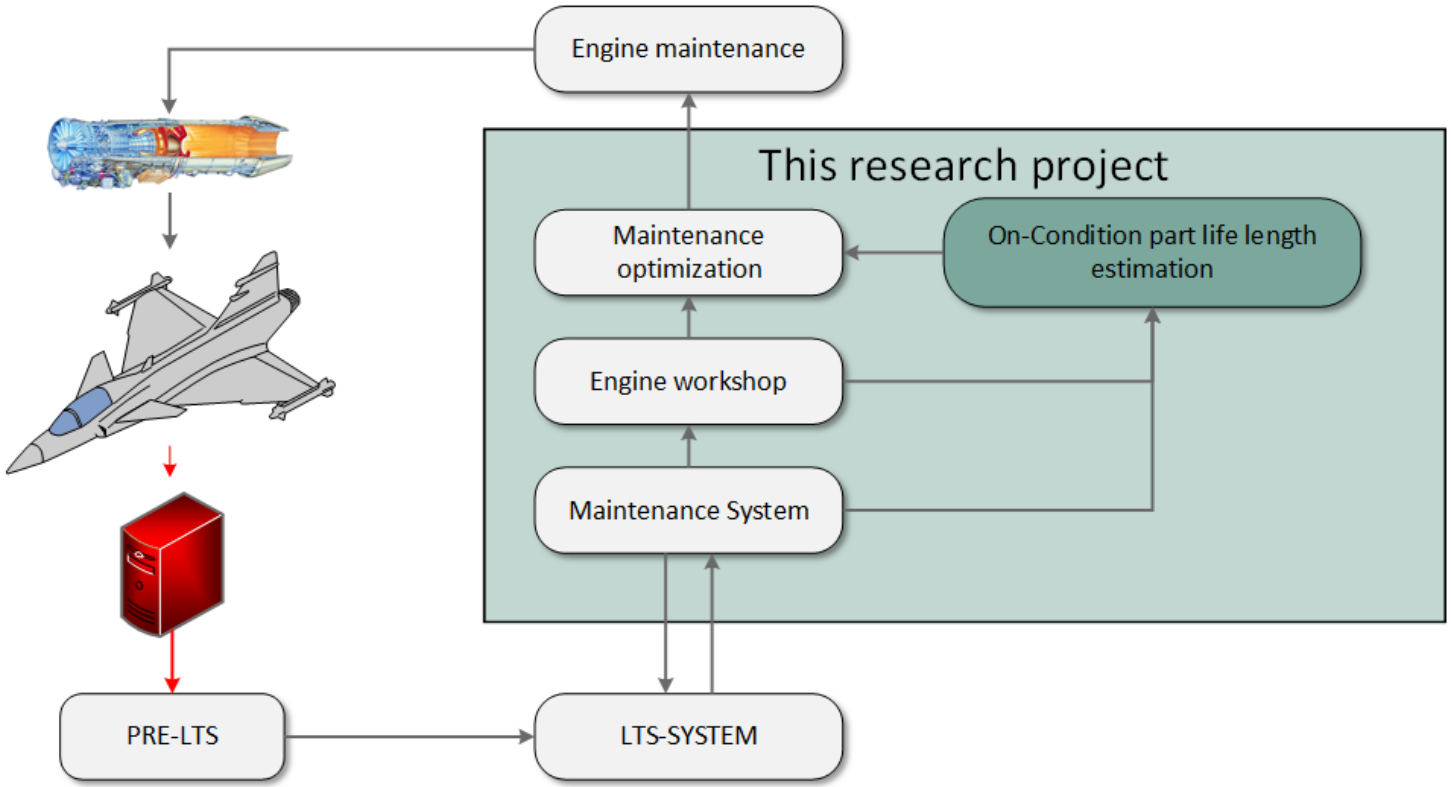
Present a review for potential methods to use for estimation remaining life. This information should then be complemented with requirements so that remaining life estimations can be performed for different component types. This area has been addressed in earlier papers but there is a need for a more detailed review over the actual prognosis methods.

Provide a guideline of which prognosis method to use when. How the methods for estimating remaining life for OC parts can be combined to actually perform life estimates for the OC parts will also be described.

Use the mathematical replacement model to perform a sensitivity analysis to find the balance between the effort to obtain remaining life estimates and what is required to derive reliable plans from the replacement model

Future reserach

Impact of the research project to the maintenance process.



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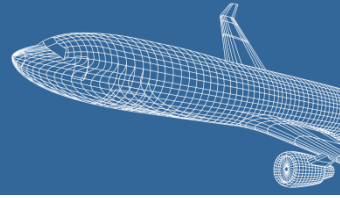

Questions?

Thank you for listening!