Forecasting the Effects of Potential Aero Engine Modifications on Life Cycle Cost (LCC)

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Extended Life and Reduced Costs

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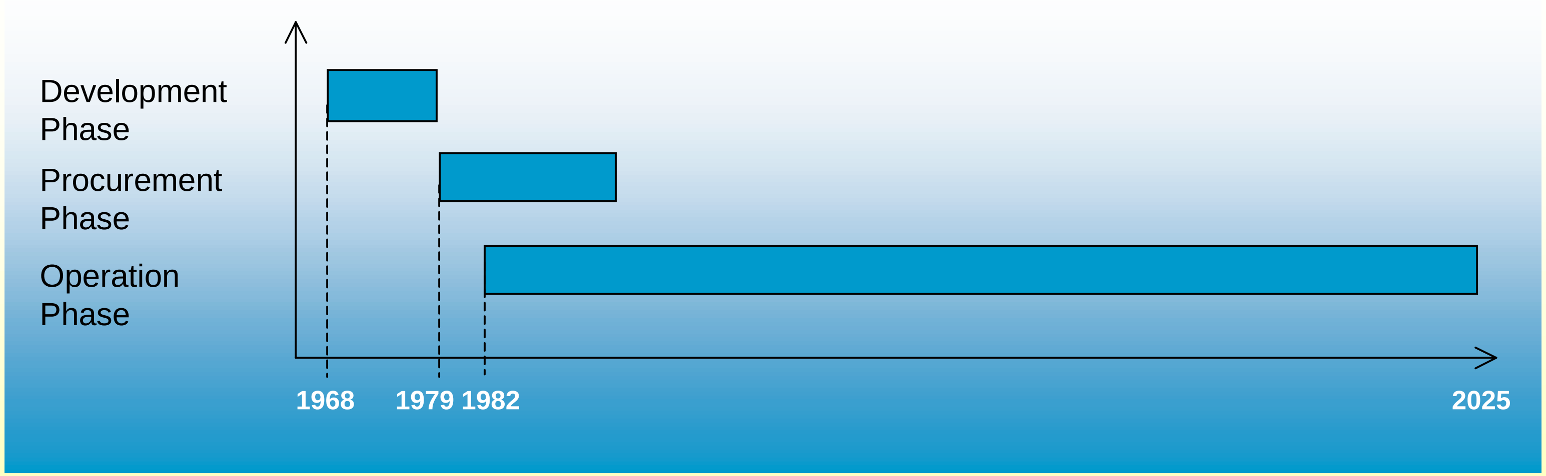
Overview

- Engine Modifications
- Life Cycle Cost (LCC)
- MTU LCC Simulation Model

The life-time of an aero engine extends to over 50 years.

Typical life-time schedule for a military engine:

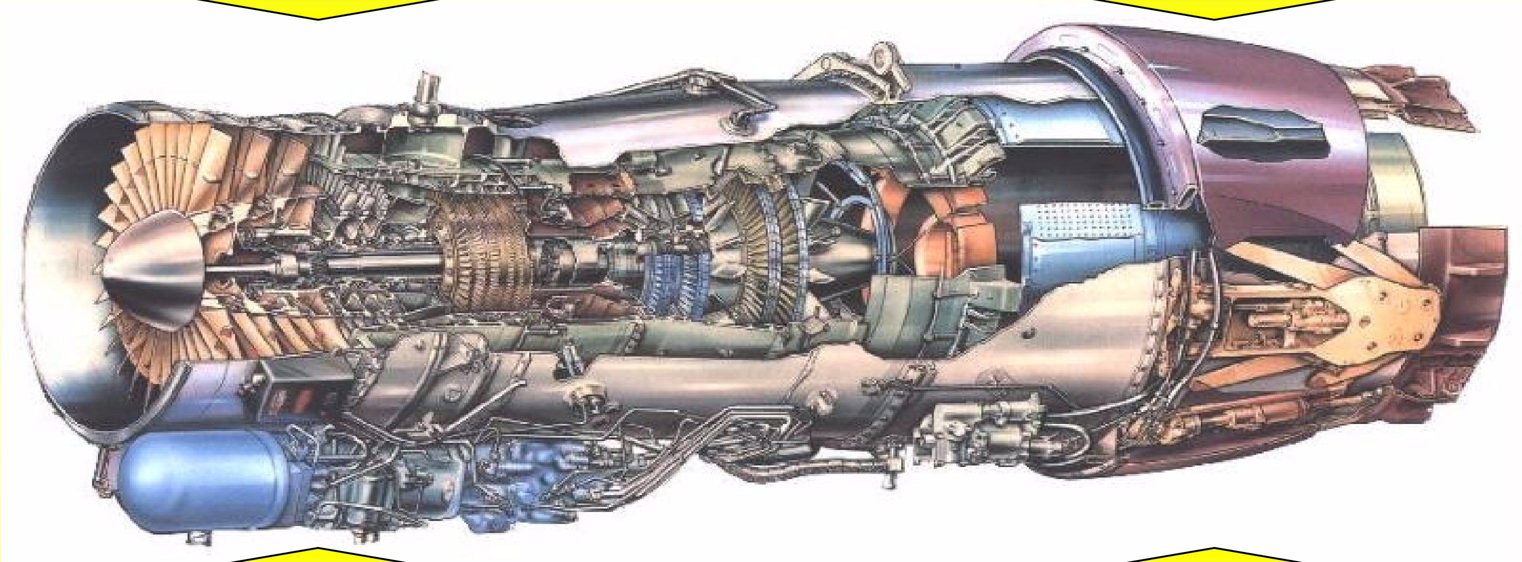


- During engine life-time several **improvements** to the engine are necessary, due to various reasons.
- The most reasonable modifications are **flight-safety** issues, **cost-reduction** topics and **enhanced performance** requirement.
- Engine **technology significantly moves on** in the course of an engine life, and new, more efficient or cost-saving features are available.

Modifications are necessary because of flight safety reasons, cost reduction and enhanced performance requirement.

LCC reduction

Reduction of limitations



Higher reliability

Enhanced performance

CLASSIFICATION OF MODIFICATIONS

A - CLASSIFICATION	⇒	**AIRCRAFT ON GROUND (Aircraft)**
B - CLASSIFICATION	⇒	**FLIGHT SAFETY (Engine)**
C - CLASSIFICATION	⇒	**ON REPAIR (Engine)**
D - CLASSIFICATION	⇒	**FOR FUTURE SPARE PARTS (Engine)**

A - mods „aircraft on ground“ are for safety of aircraft and to avoid performance or operational limitations

B - mods (campaigns) for “flight safety“ reaons have no need for cost analyses because flight safety has ultimate priority.

C - mods with “on repair“ classification need a full cost analysis. All costs have to be reflected in a Life Cycle Cost Study (LCC Study) to find an acceptable break even point.

D - mods “for future spare parts“ are normally cost neutral because of changing raw material or drawings.

Life Cycle Cost (LCC) analyses of modifications result in high contributions to the Business Case.

- Introducing new technological features is easy during the early engine **design phase.**
- With the engine design becoming more mature during the **development phase**, introduction of new features is getting more and more difficult, due to effects of each modification on numerous other components or design parameters.
- During the **operation phase** the benefit of introducing modifications must be thoroughly weighed with respect to a lot of different parameters, such as

  - the number of engines in operation
  - the various existing engine standards
  - maintenance, repair and overhaul procedures
  - spare parts supply
  - documentation

- For an appropriate calculation of a comprehensive **Business Case**, all relevant elements and parameters must be carefully taken into consideration.
- For this purpose, **Life Cycle Cost analyses** are performed**.**

Life Cycle Cost cover all phases of an engine life.

Life Cycle Cost cover

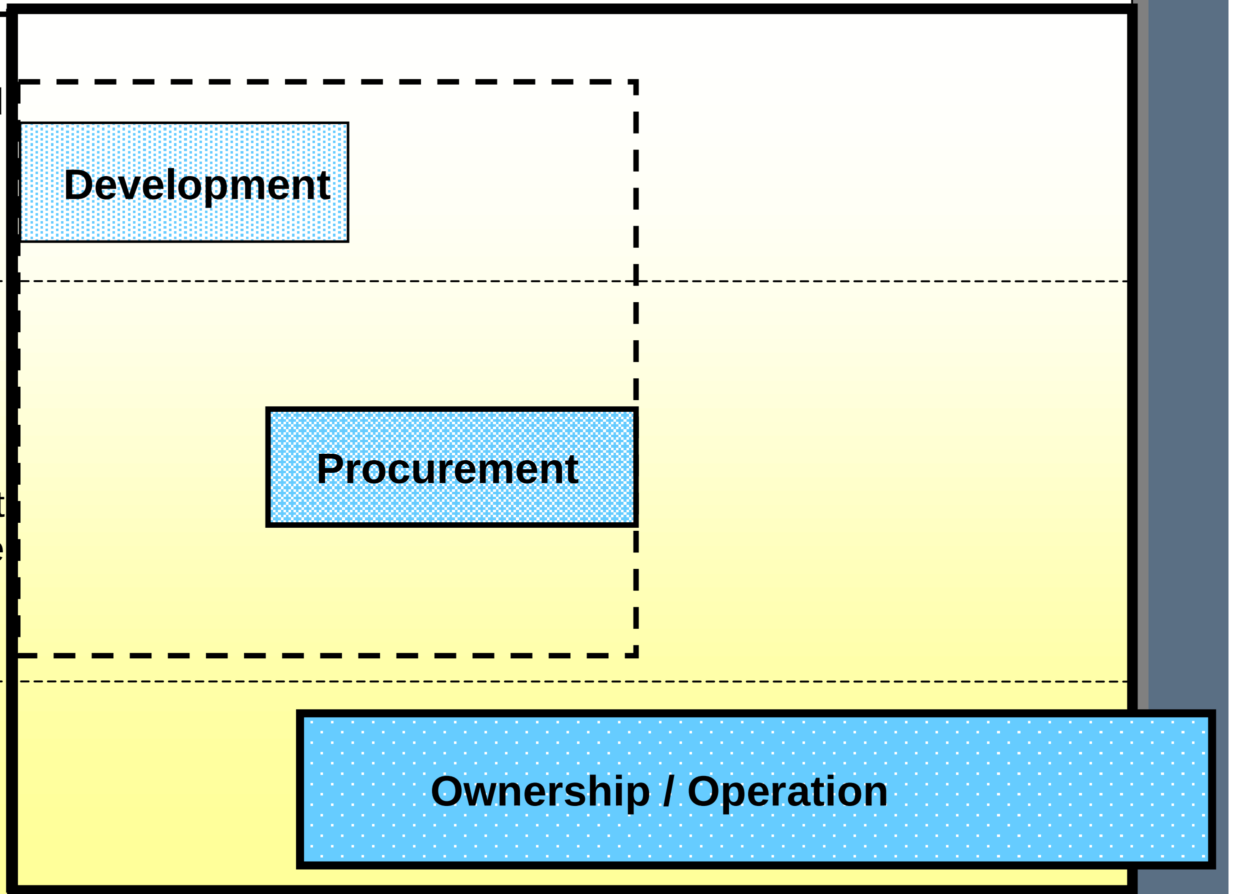
all costs of the equipment, counted from the beginning of its development until its retirement from service, i.e.

the cost of

- **Development**
- **Procurement (Production)**
- **Ownership**

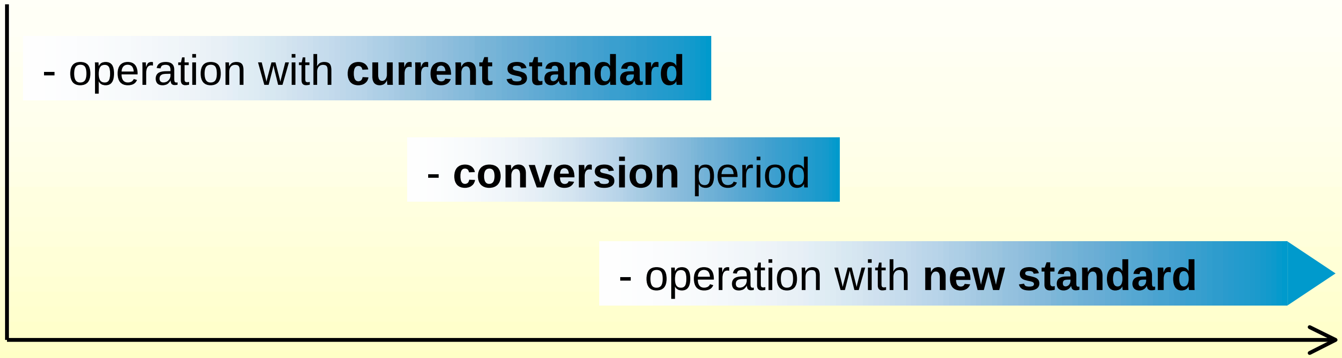
Of major importance for a LCC analysis is the operation phase.

Develop-ment	**Research & Development:** All elements & costs associated during conceptual, validation, development phase
Procure-ment	**Production:** All non-recurring and recurring engineering and support to production, manufacturing, quality control, warranties, profit e.c.t. during procurement phase
Operation & Maintenance	**Operation & Support:** All elements & costs associated with the operation & support phase



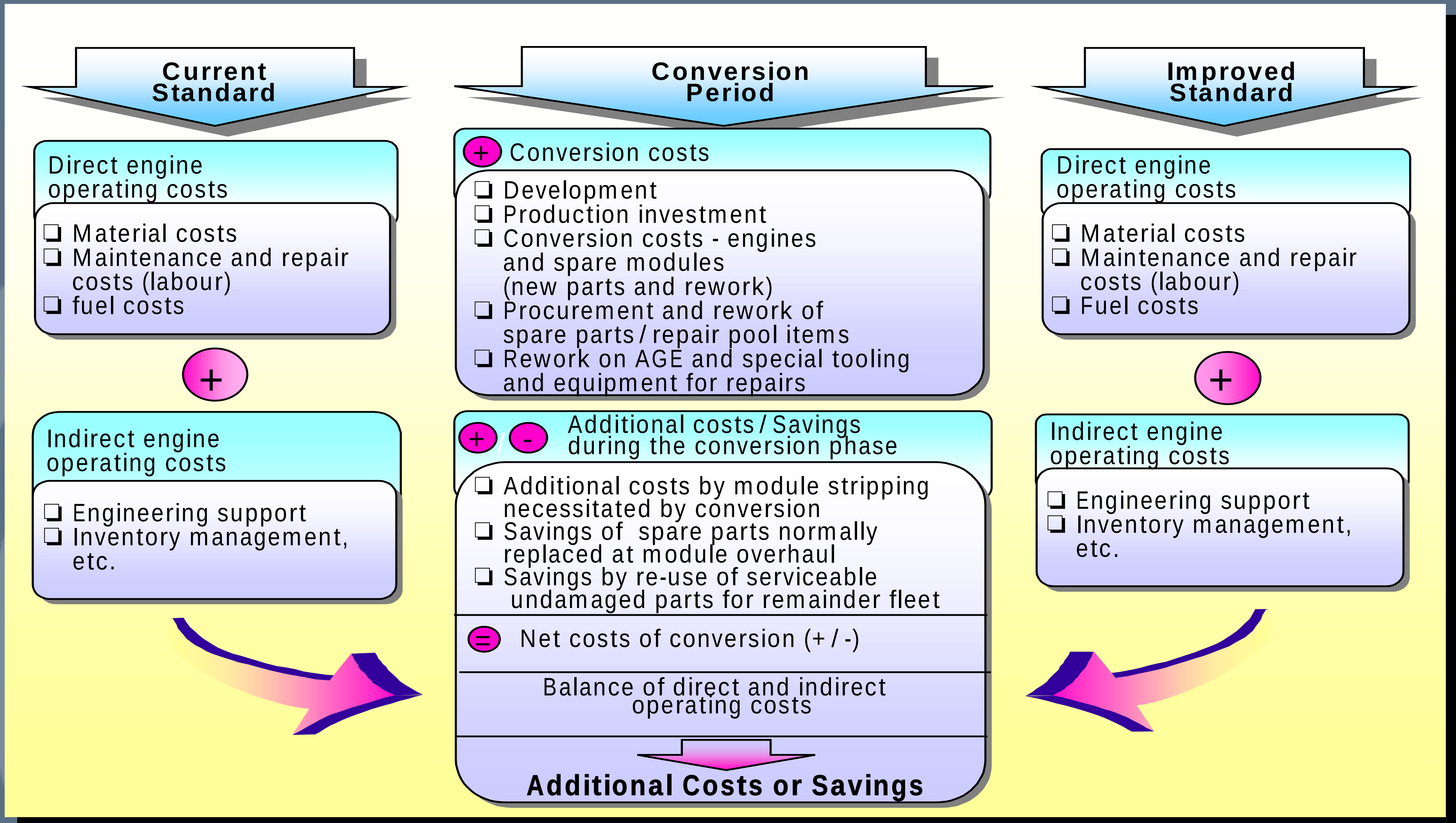
Three phases have to be considered during an embodiment of modification.

- For introduction of a each modification **three overlapping phases** have to be considered:

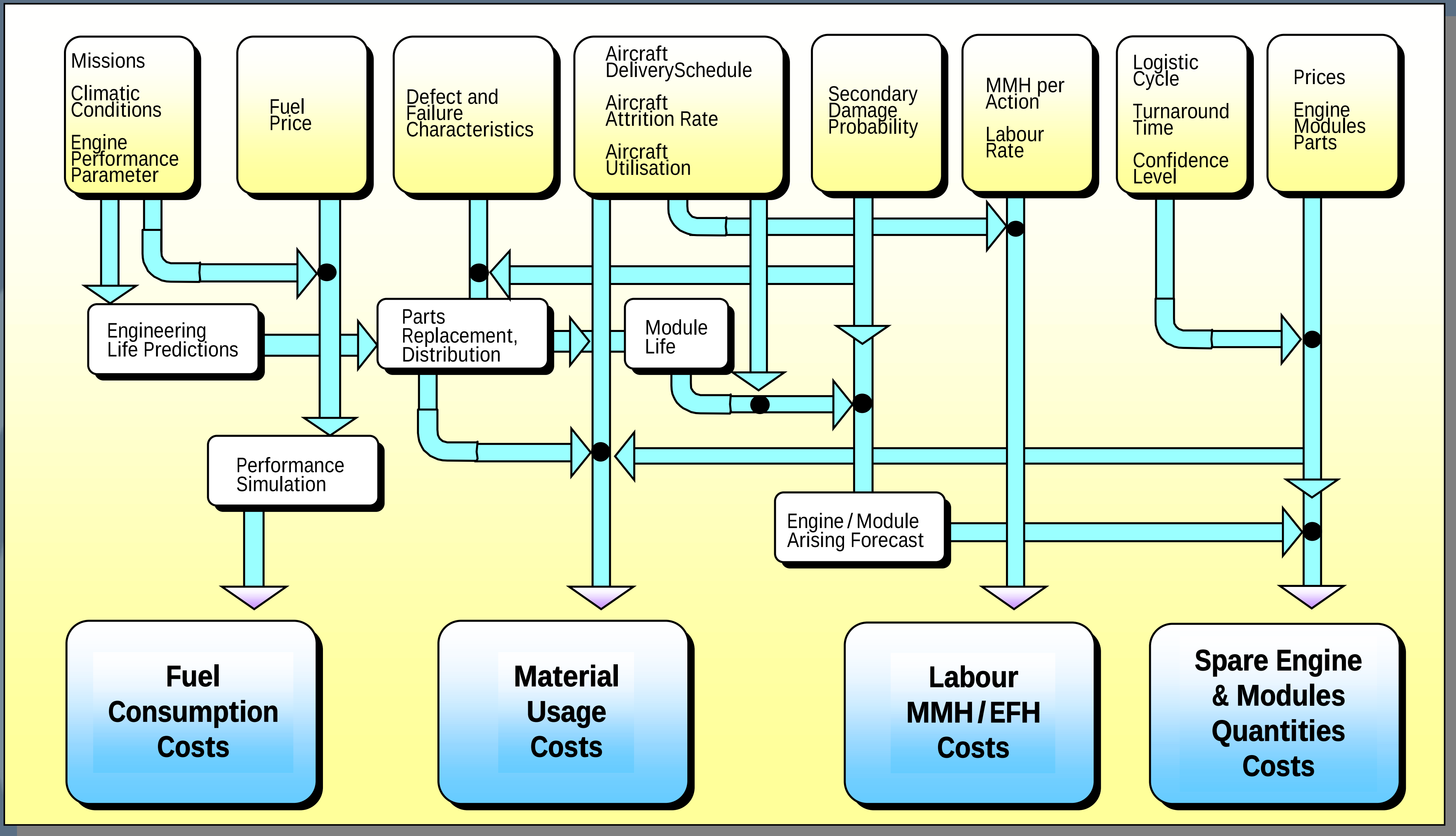


- The phases are dependent on the embodiment procedure and differ in time and money consumption.

Each phase has its specific relevant cost parameters.



The various cost parameters are interdependent.

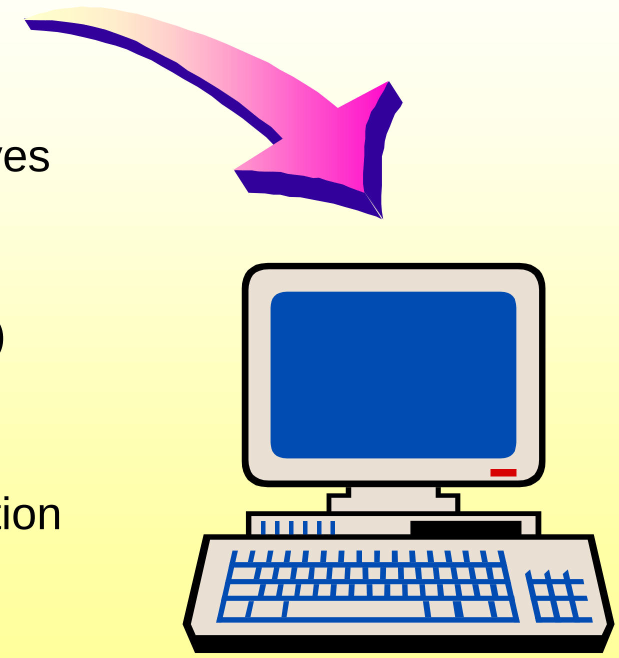


MTU has developed a computer-based LCC simulation model for maintenance, repair and operation.

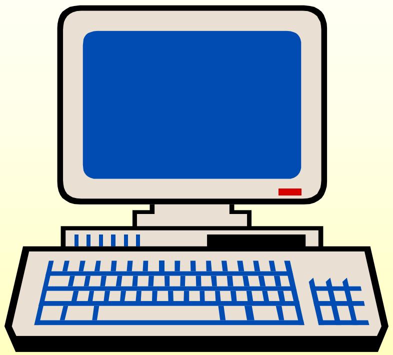
- ❑ Simulation of fleet operation with no restrictions as to the number of A/C
- ❑ Real-time simulation with a statistical daily failure ascertainment
- ❑ Consideration of time-dependent input data (like monthly flight hours or removal rates)
- ❑ Input of various module/component replacement strategies
  - investigation of the optimum strategy, depending on the failure combination
- ❑ Information about the optimum number of spare engines/modules
- ❑ Module maintenance actions split into various levels as a function of determined maintenance concept
- ❑ Analysis of Direct Operating Cost (DOC)

The required input parameters vary for technical and service-related modifications.

- ❑ **Engine delivery rate - squadron/fleet**
- ❑ **Flight hours/years of operation**
- ❑ **Component life characteristics**
  - o Failure mode distribution function
  - o Probability of secondary damage
  - o Life limitations - remaining issue service lives
- ❑ **Maintenance strategies (concepts)**
  - o Various maintenance concepts
  - o Inspection intervals (borescope inspection)
  - o Preventive maintenance
  - o Maintenance levels
  - o Maintenance turnaround times, transportation
  - o Maintenance capacities
  - o Man hours per event
- ❑ **Engine, module and component prices**



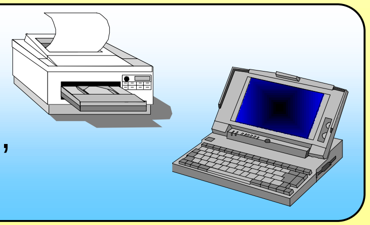
The output parameters can be selected individually and the output can be used for further processing.



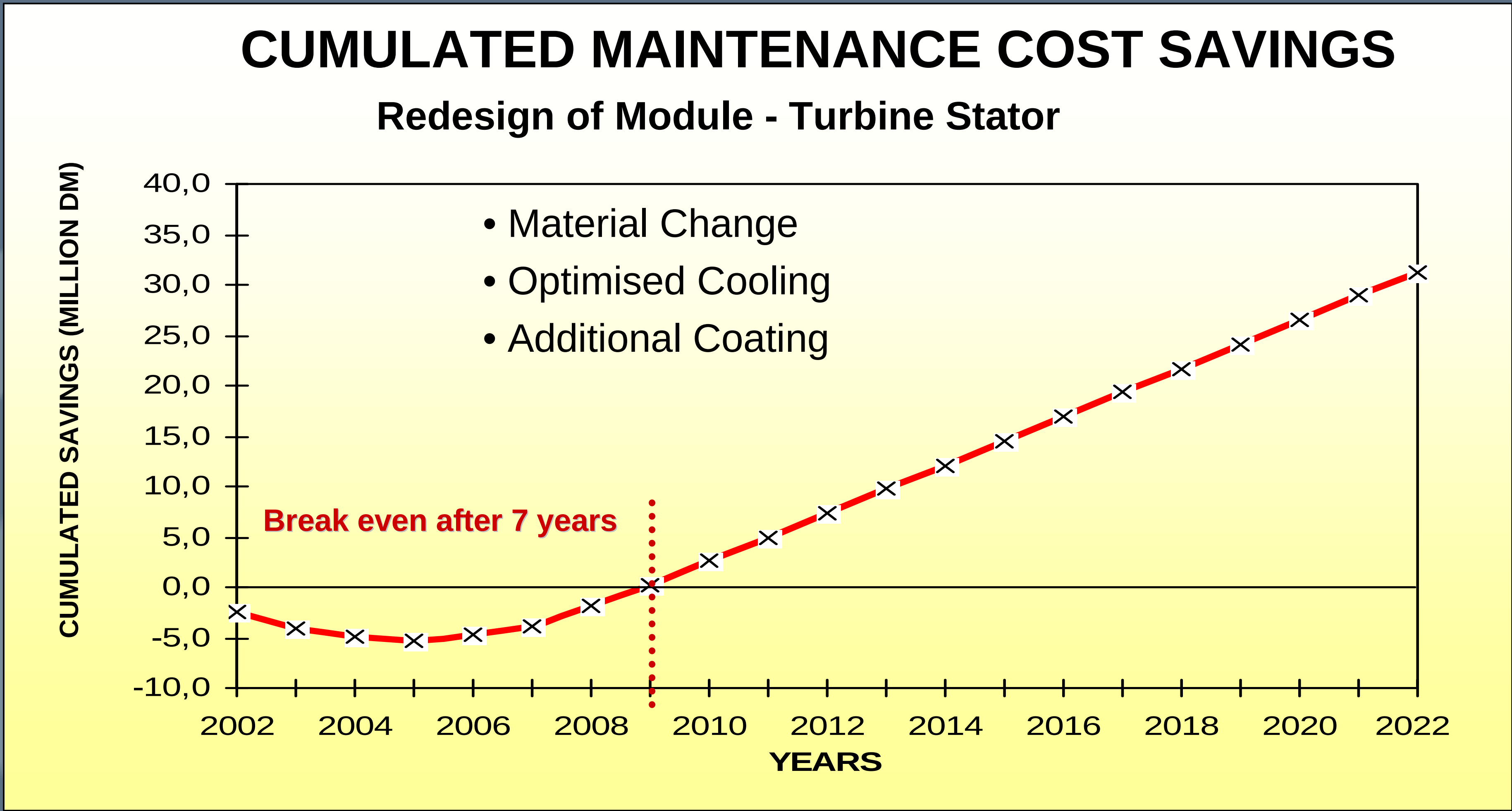
- ❑ **Engine, module, component and accessory arisings**
- ❑ **Failure rates depicted by removal reason**
  - o scheduled/unscheduled
  - o secondary damage
  - o random or time-dependent failure
- ❑ **Repairs shown by maintenance level and reasons for removal**
- ❑ **Maintenance/repair man hours**
  - o by maintenance level
  - o by scheduled/unscheduled maintenance action
- ❑ **Material costs of major components (quantity and DM/EFH)**
- ❑ **Spares requirements (engines/modules(components))**

Data printout per month, per year, average.

Output data can be used for further processing, e.g. for derivation of AGE requirements.



The results are shown in diagrams for comparison of various options.



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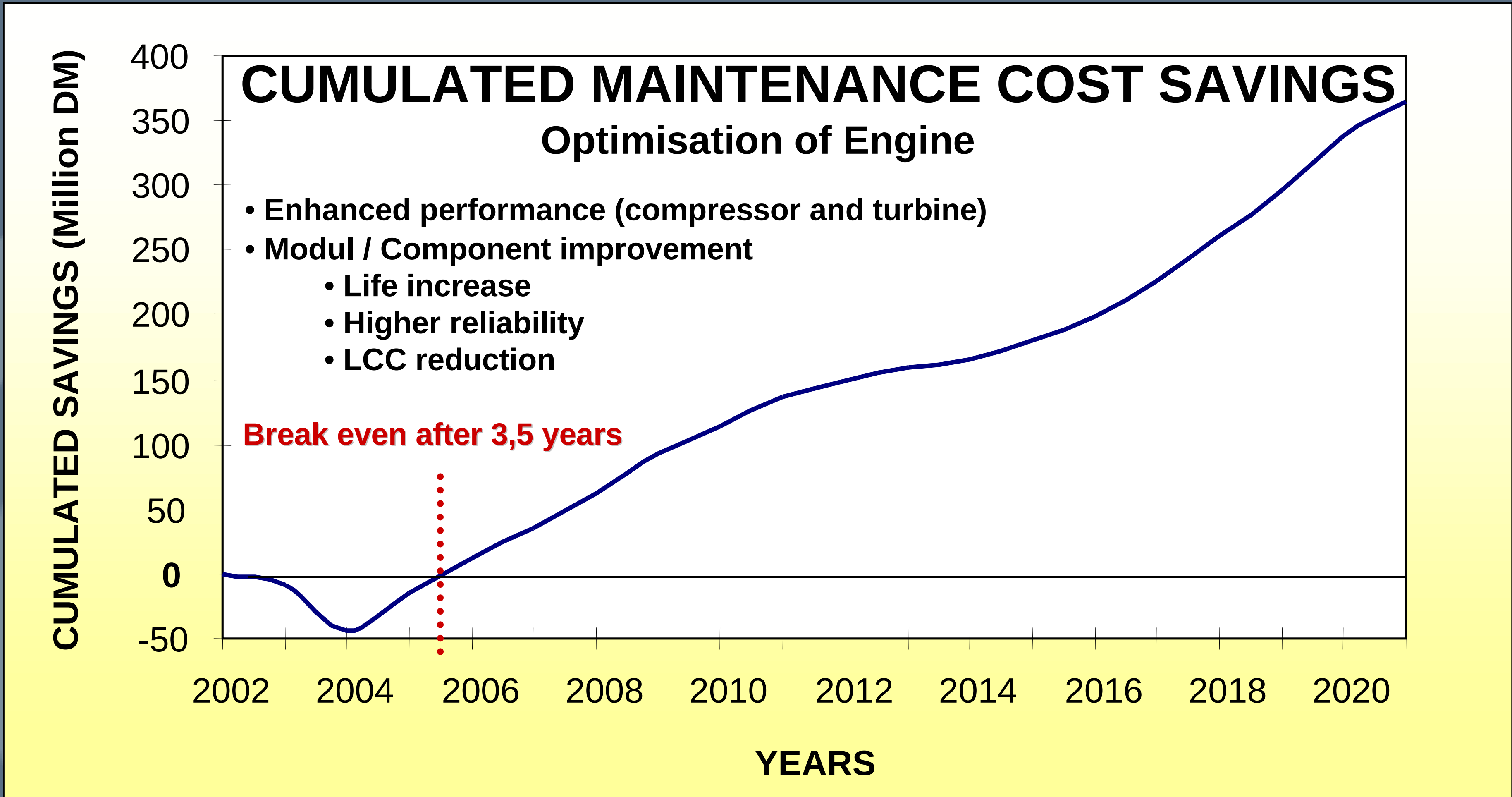

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- Classification of modifications.
- Life Cycle Cost (LCC) analyses of modifications result in high contributions to the Business Case.
- Life Cycle Cost cover all phases of an engine life.
- Of major importance for a LCC analysis is the operation phase.
- Three phases have to be considered during an embodiment of modification.
- Each phase has its specific relevant cost parameters.
- The various cost parameters are inter-dependent.
- MTU has developed a computer-based LCC simulation model for maintenance, repair and operation.
- The required input parameters vary for technical and service-related modifications.
- The output parameters can be selected individually and the output can be used for further processing.
- The results are shown in diagrams for comparison of various options (page 15 / 16)