Advanced Genetic Algorithm based Engine Condition Monitoring

KLM Engine Services

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KLM

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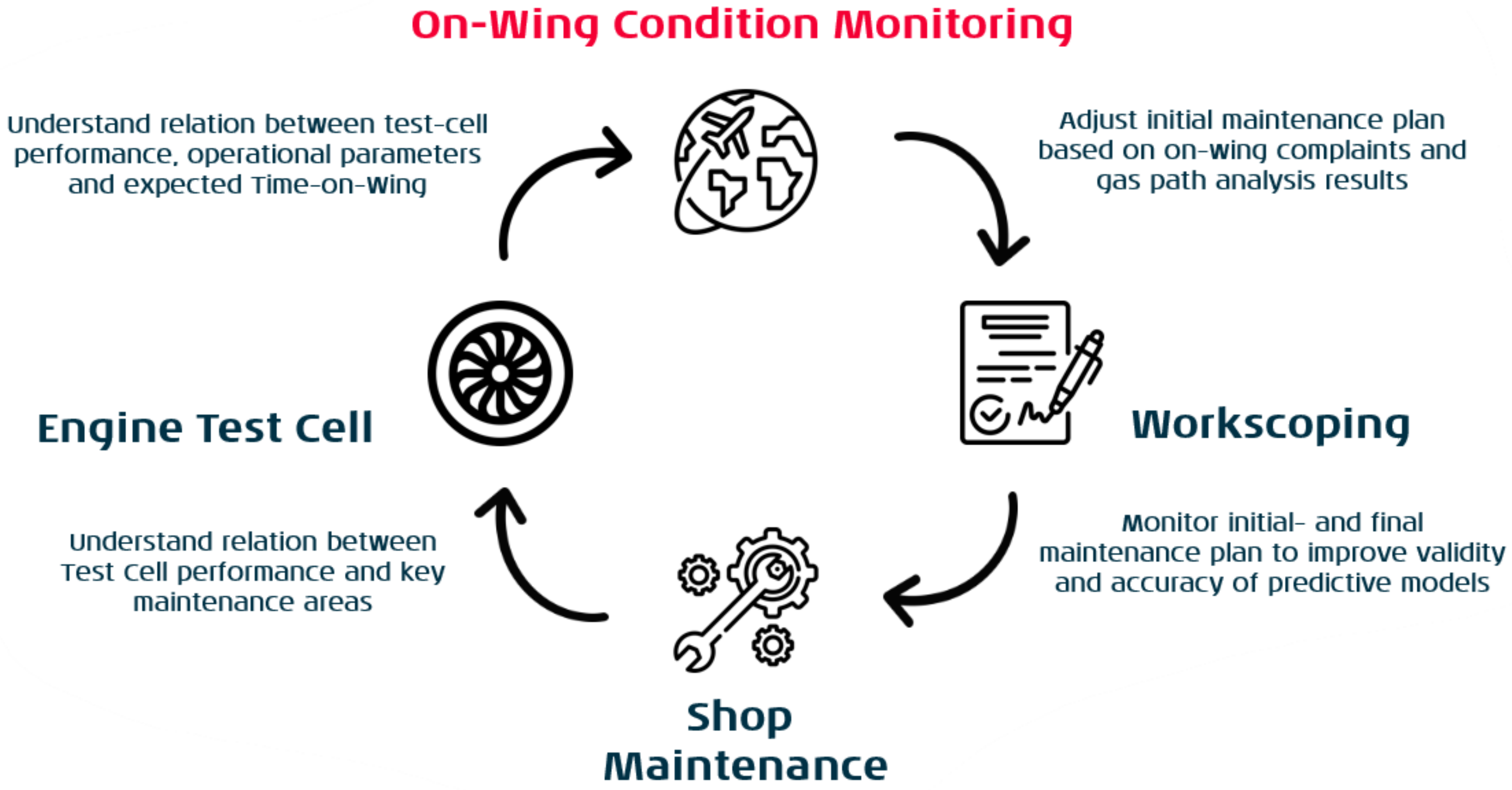
KLM ES Maintenance Strategy



Research Goal

Future-proofing Gas Path Analysis techniques at KLM Engine Services by developing accurate on-wing component condition monitoring software for next-gen turbofan engines

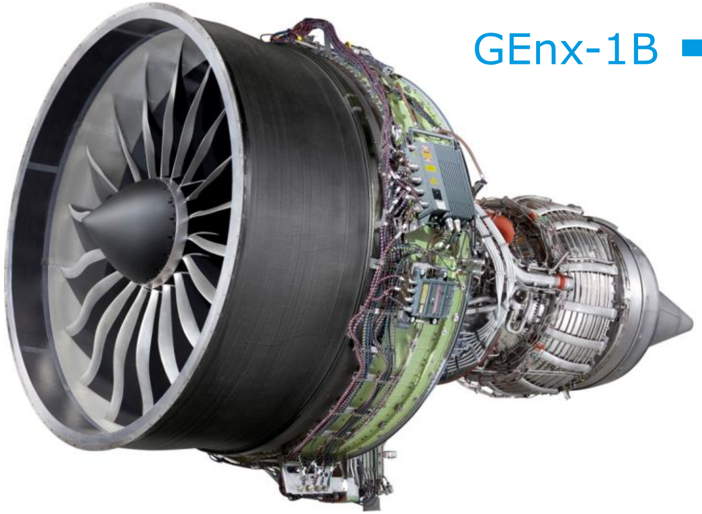
- *GEnx-1B*
- *LEAP-1A/B*

Key research areas:

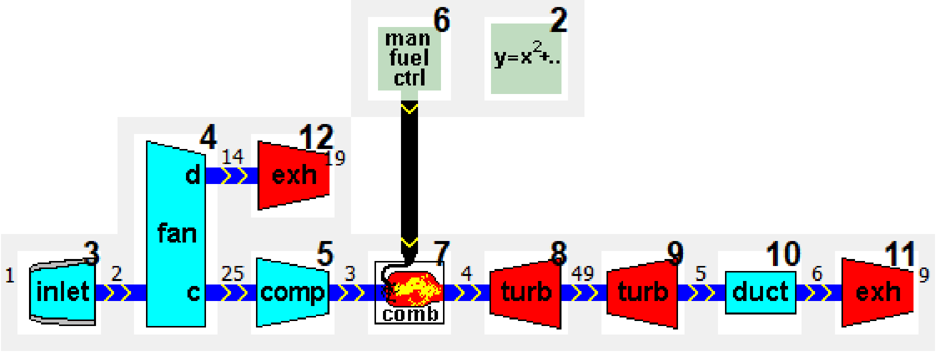
- Gas Path Analysis with Gas Turbine Simulation Program (GSP)
- Genetic Algorithm optimizing routine
- Multiple Operating Point Analysis (MOPA)
- Continuous Engine Operating Data (CEOD)

Gas Path Analysis with GSP

Gas turbine simulation on a component level



GEnx-1B → GSP model



Deterioration effects analysis

- Change in component efficiency
- Change in component mass flow capacity

Genetic Algorithm Optimization

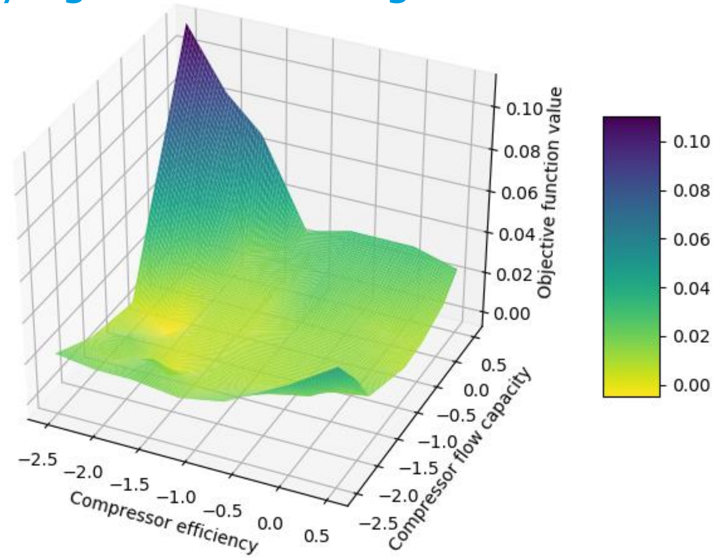
mimics evolutionary race of a population

- **Selection** – individuals for next generation chosen based on fitness
- **Crossover** – creates new individuals
- **Mutation** – introduces new information by applying random changes

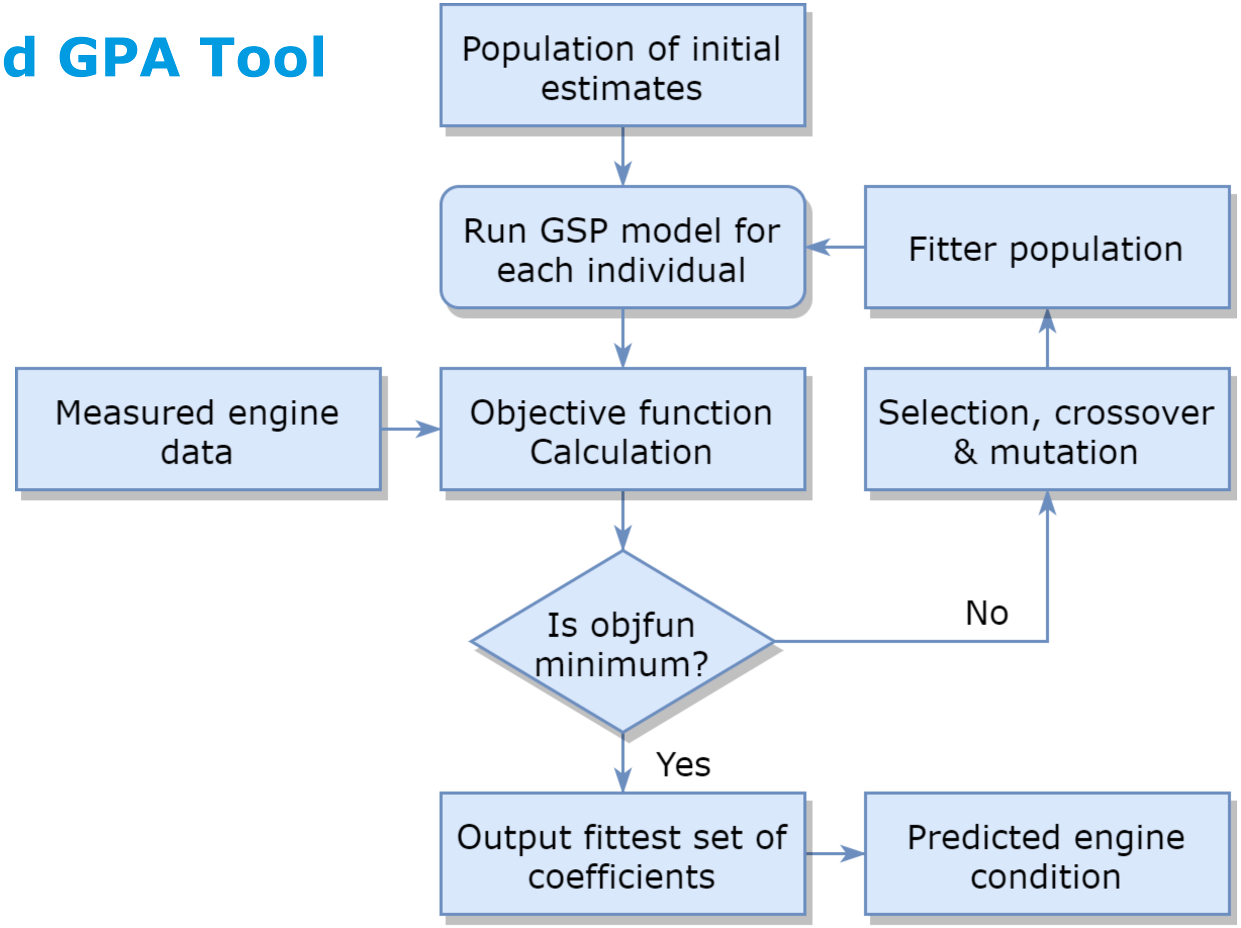
Advantages:

- Escape local minima in complex search space
- Find solution despite presence of noise & bias

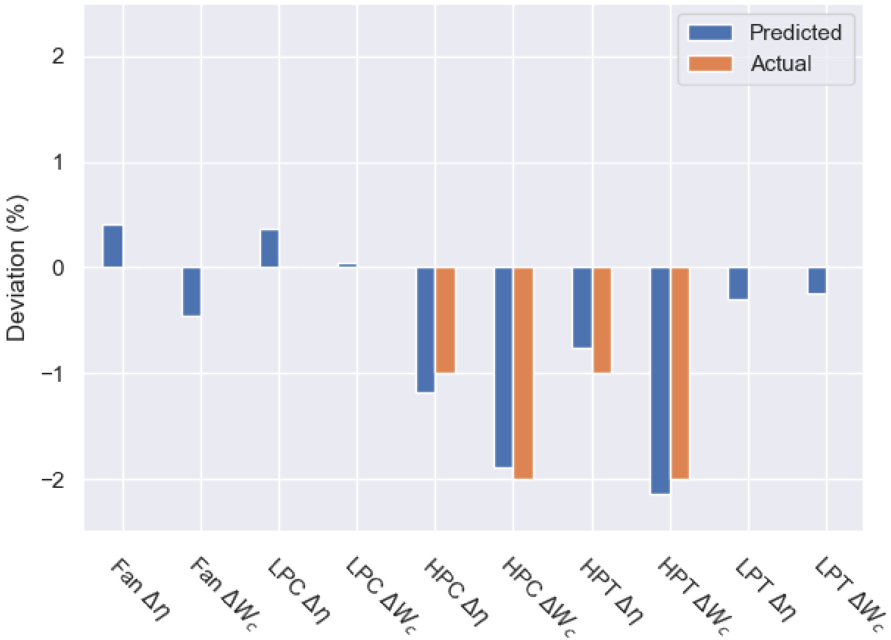
Population will cluster around optimal solution



- **Hybrid GPA Tool**

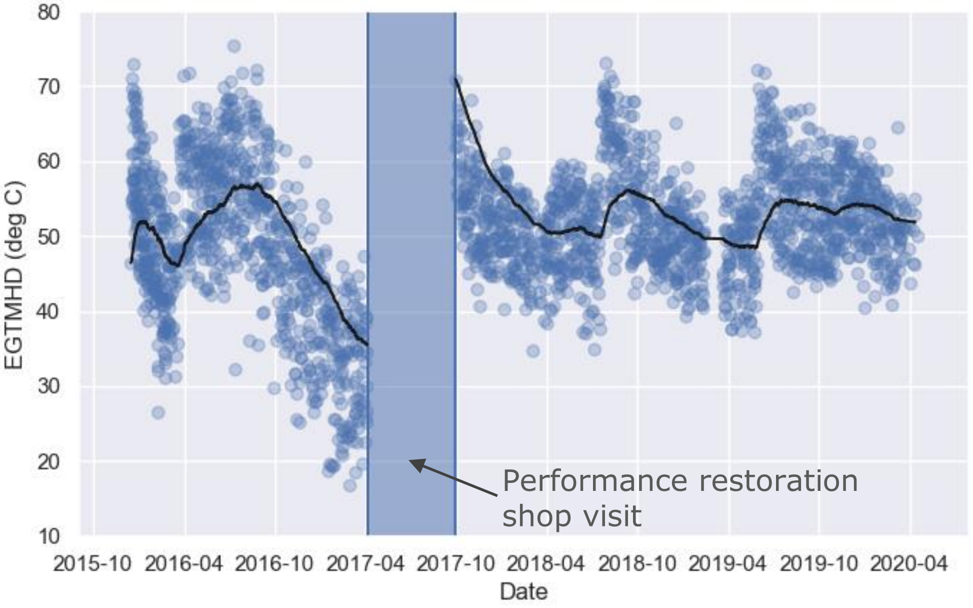


Results



Component deterioration prediction by analysing multiple operating points

Engine performance trending



Conclusions

- The combined GSP - Genetic Algorithm (GA) approach offers a leap forward in condition monitoring at KLM
  - Accurate monitoring of engines during on-wing operation
  - Increased accuracy of test cell engine diagnostics at KLM ES
  - Next-gen engines with fewer gas path sensors can also be monitored accurately
- Integrating the method in the maintenance process will
  - increase safety, reliability and availability
  - help reduce CO_2 and other emissions (cleaner engines)
  - save $
  - increase customer added value
- Further work includes
  - Decreasing GA computational time
  - Preparing the method for routine usage on KLM aircraft and engine fleets