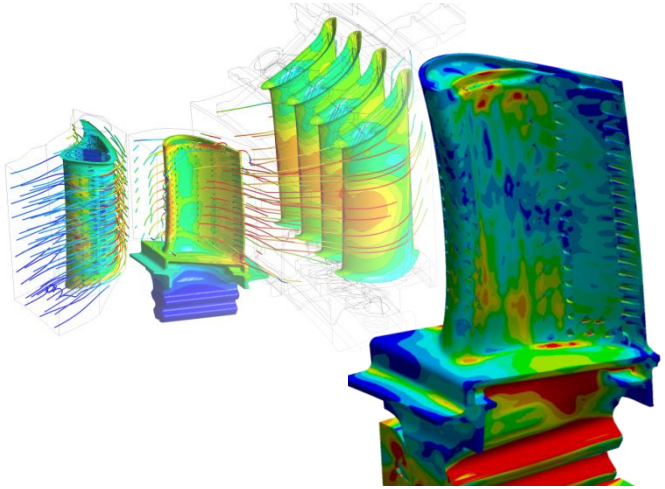

Predictive Maintenance of Aircraft Engines by use of a Digital Twin

LHT: *Motivation*

ITB: *Technical Solution*

vipo - Symposium 2020

Presented by Dr. Frank Brehmer – ITB

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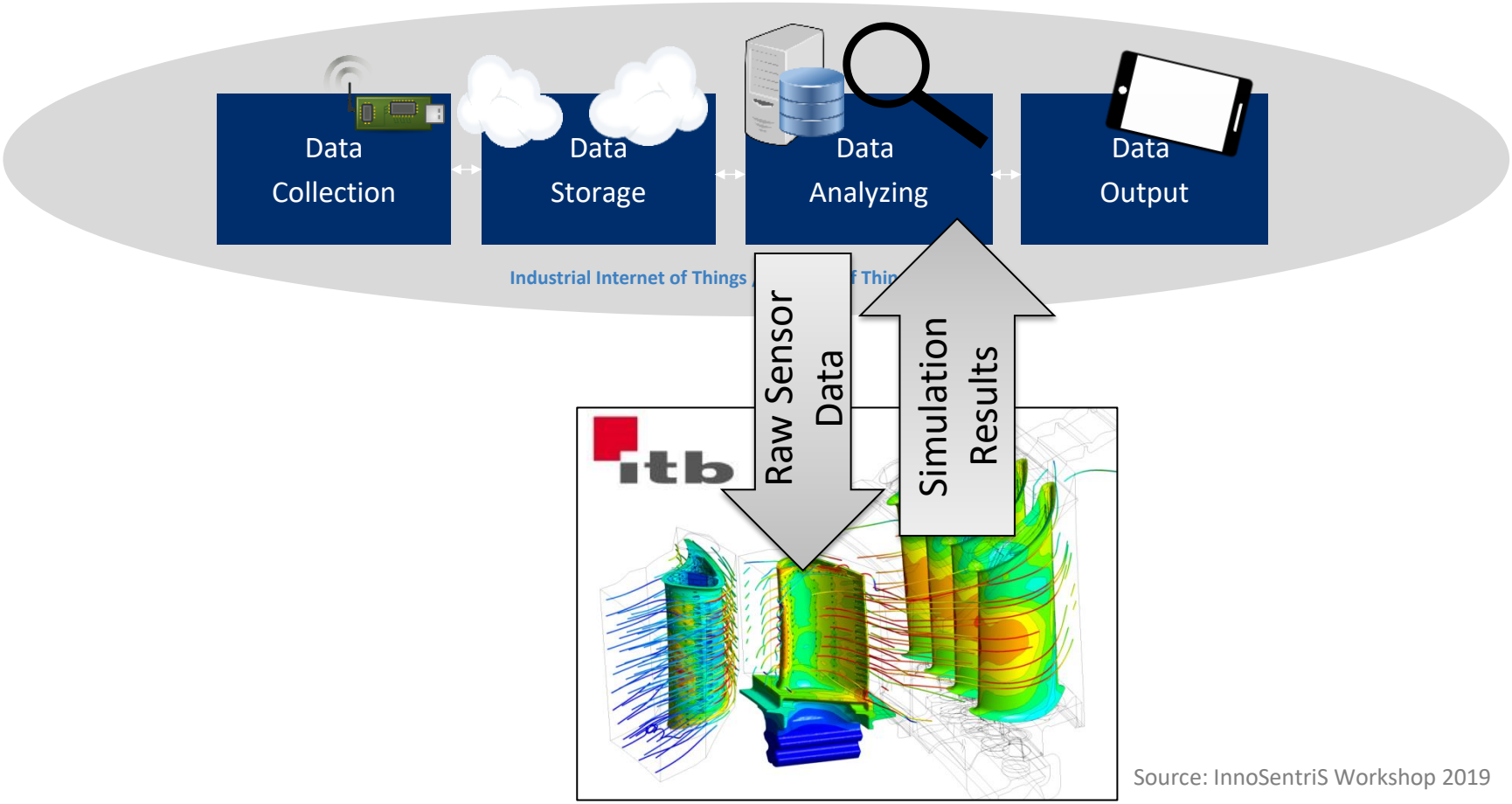
Digital Twin: The Four Fields of Innovation



Source: InnoSentriS Workshop 2019

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Predictive Maintenance

LHT Motivation

C. Werner-Spatz | HAM T/ES-Z
M. Zschieschank | HAM T/ES 21

22.03.2018

Lufthansa Technik

Lufthansa Group – The business segments

Passenger transportation

The Lufthansa Group airlines rank among the world's leading carriers.

Logistics

Lufthansa Cargo – one of the world's leading cargo carriers in international air traffic.

Lufthansa Technik
Maintenance, Repair, Overhaul

Lufthansa Technik – leading provider of MRO services in the world's airline business.

Catering

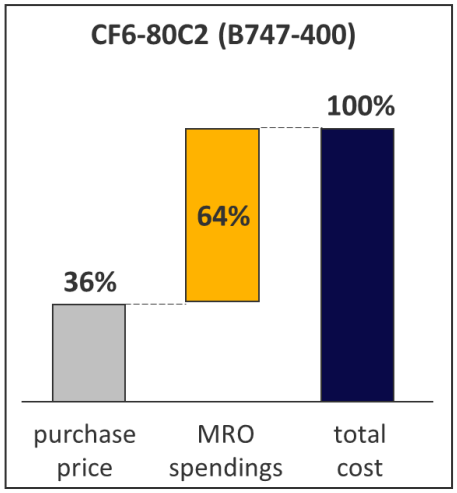
LSG Sky Chefs – leading provider of airline catering and integrated in-flight solutions.

Other activities

Lufthansa Aviation Training
Lufthansa AirPlus
Lufthansa Industry Solutions
(and many more)

Why do we need prognostic methods?

- Contracts covering maintenance for engine fleets increasingly complex. Often flat-rate contracts or fixed / not-to-exceed price elements included → MRO supplier shares technical and financial risks with operator



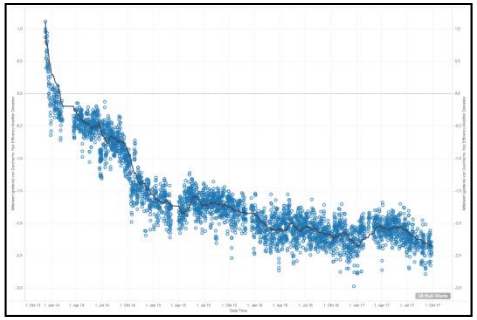
- Fleet management becomes increasingly important
  - Removal and maintenance planning
  - Monitoring: plan vs. actual performance

  → Manage risk through early detection of problems

  → Improve cost per flight-hour

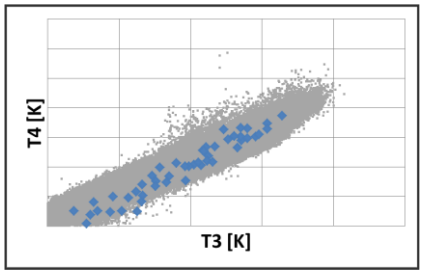
- Removal and maintenance planning requires prognosis: How will engines behave over several years under expected operating conditions?
  - Performance deterioration
  - **Damage to critical components**

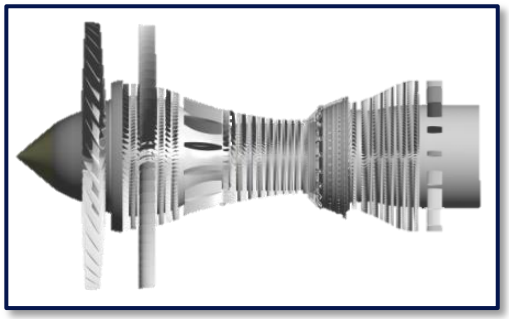
  → Expected removal reason; time on wing; required maintenance workscope

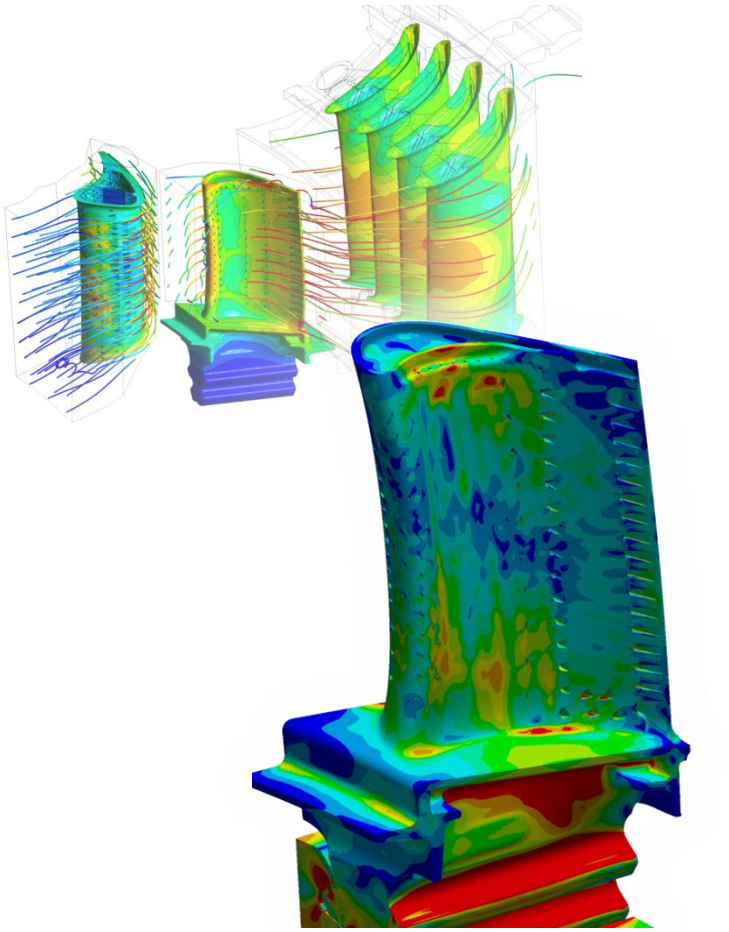


How do we approach the subject?

- Issue complex and highly non-linear; many parameters involved
- „Normal“ approach nowadays: Big data → statistical analysis as basis for identifying relevant sensitivities and for surrogate model
- But:
  - Available data from operation doesn‘t qualify as „big data“ if filtered properly
  - Statistical methods may solve the problem, but don‘t provide thorough understanding of the sensitivities → who supervises the model?
- LHT approach: physics-based model based on thermodynamic cycle and numerical simulation
  - Accurate representation of engine geometry and engine behaviour
  - Determine loads throughout actual operation
  - Determine damage / life consumption resulting from these loads for critical components of the engine
  - Efficient implementation for routine application requires use of high-quality surrogate models







ITB Ingenieurgesellschaft für technische Berechnungen mbH

„Digital Twin“
for Lufthansa Technik

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The Task

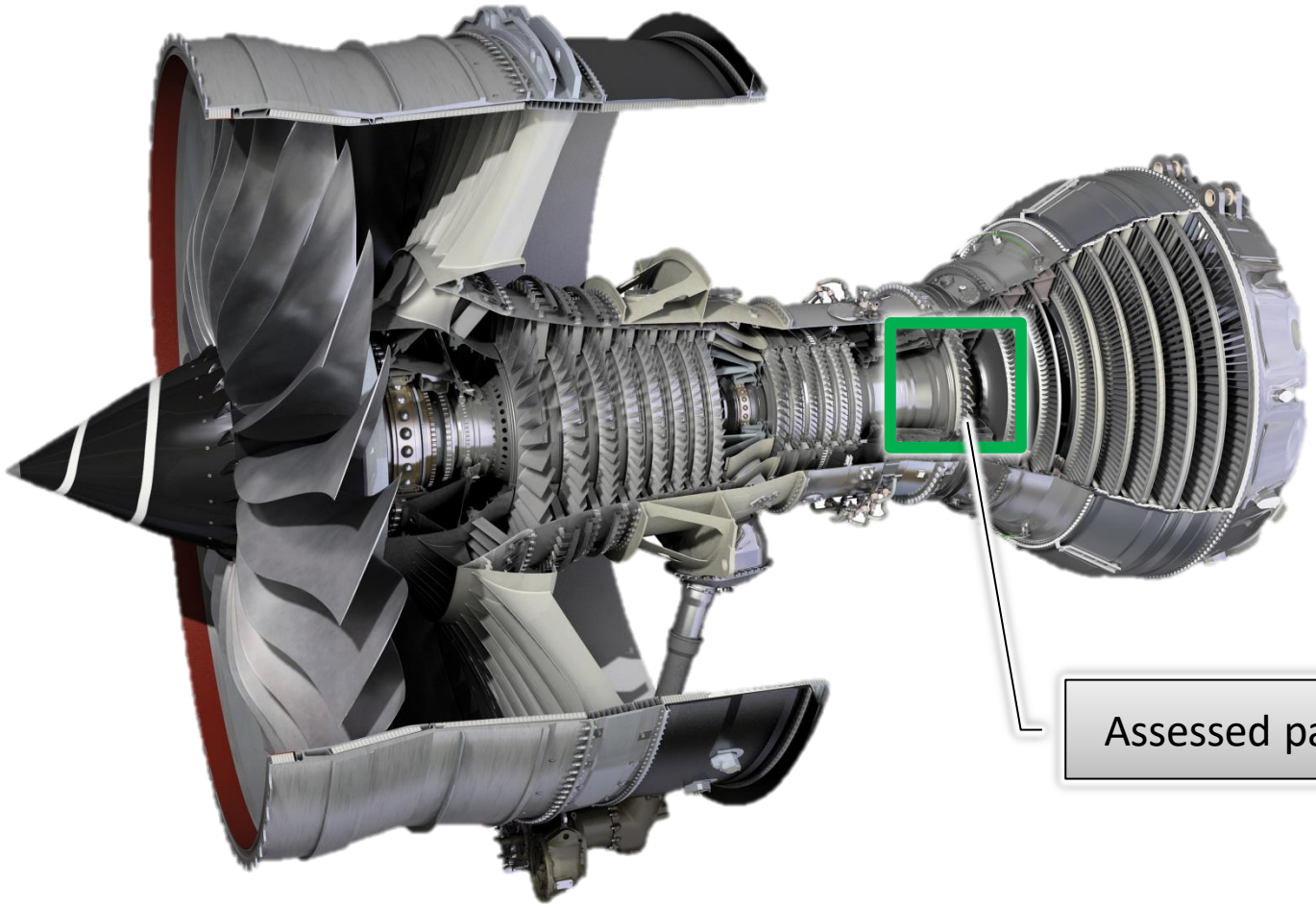
- ✓ Simulation of the turbine:
  CFX & FE 1-way FSI Simulation
- ✓ Actual operation parameters as input
- ✓ Evaluation of values that can't be measured !
- ✓ Simulation output fed into LHT fatigue assessment software

15 hours simulation time on 128 node cluster – unfeasible for daily use!

Solution: Meta Model / Digital Twin

Setting up the 1-way FSI simulation models

- Turbine cut away



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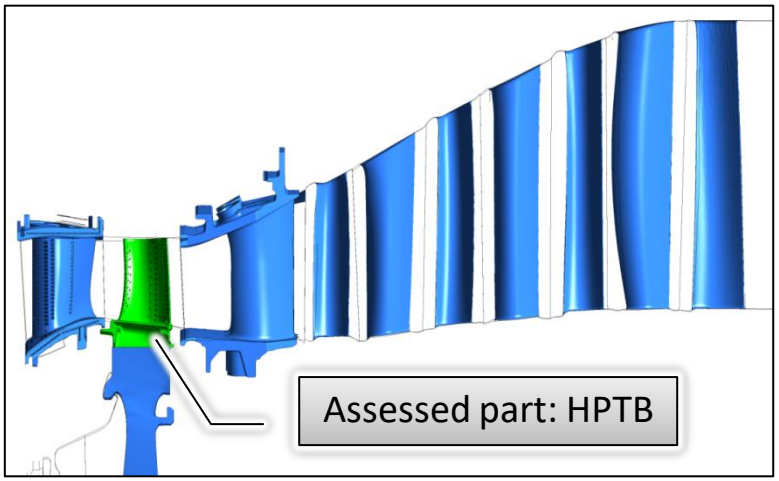
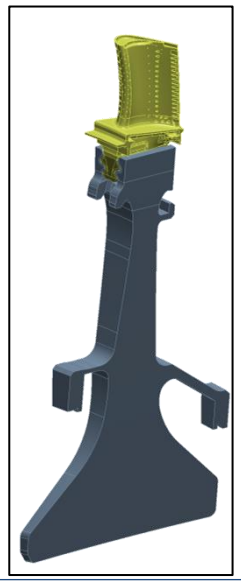
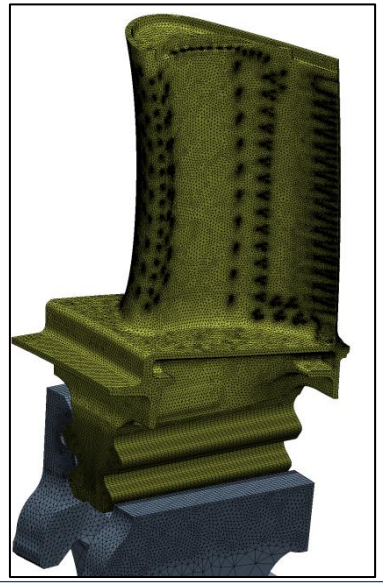
Setting up the 1-way FSI simulation models

- Parametrizing and optimizing the setup for fast processing







- Reduction of output to the required minimum (location & result)
- Definition of tight convergence values based on the remaining output values
- Automated selection of the best available initial solution, depending on the design-point parameters, for decrease of solution time
- Optimized mesh density & solver settings
- Scripting of data-transfer

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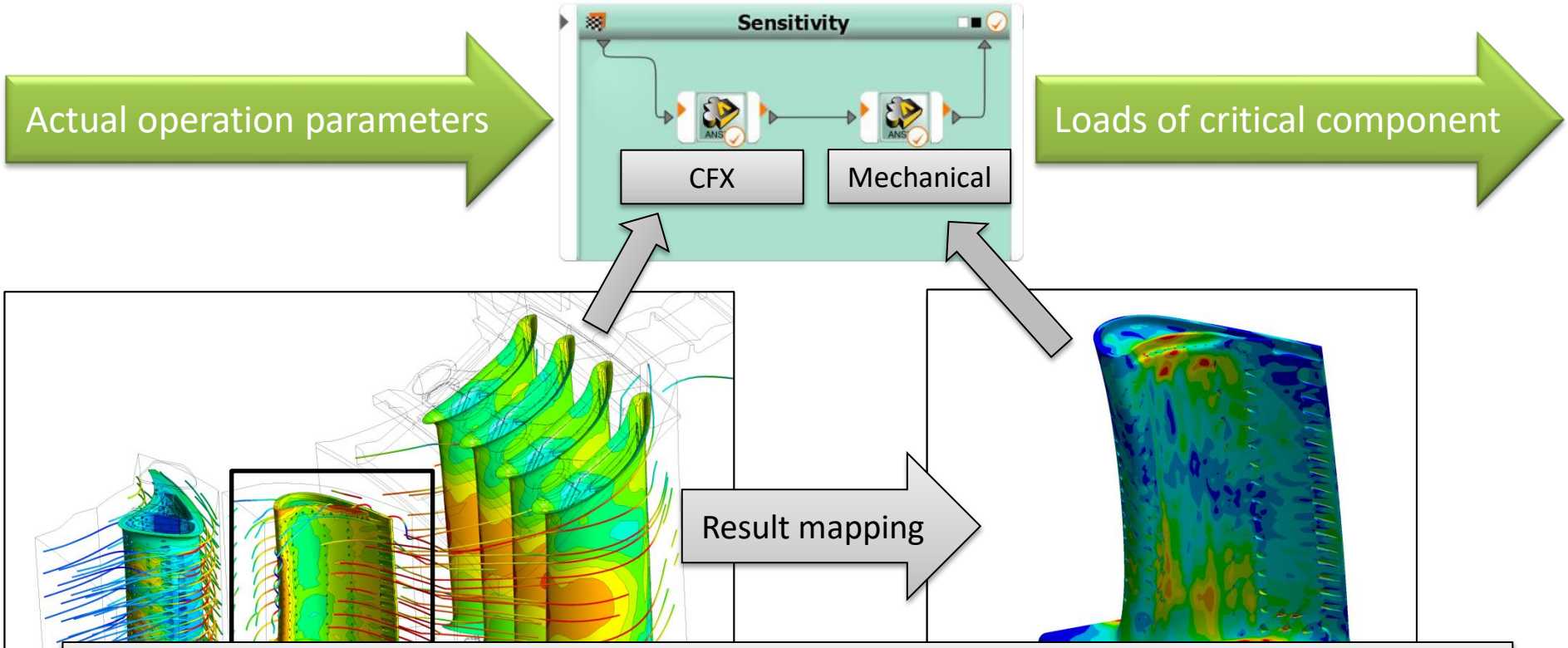
Implementing the simulation models in an optiSlang workflow

- Simulation loop in *optiSlang*



Run workflow!

- Simulate 50 different cases (~ 50 “virtual measurements”)
  → 15h for each simulation → 1 month process time !
- Generates Meta Model for turbine

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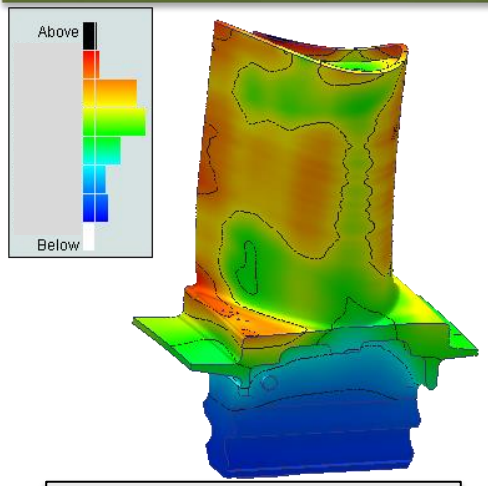
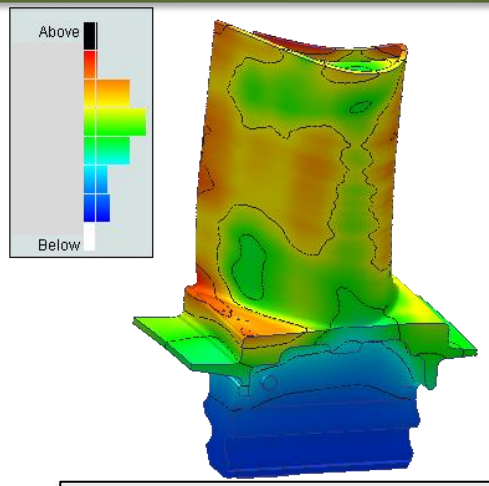
Results

- FMOP in *Statistics on Structures*

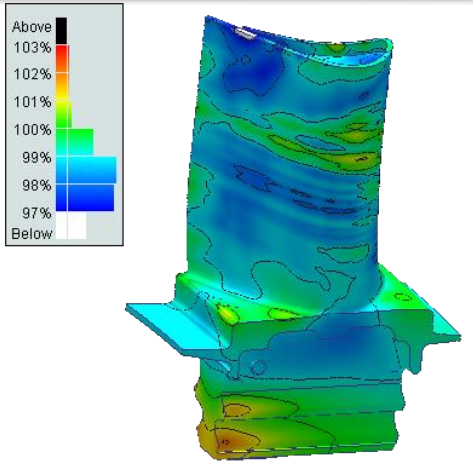
Temperatures [K] – Overall accuracy > 99 %



FE-Results



Meta Model
(FMOP)



Result accuracy
Perfect match = 100 %

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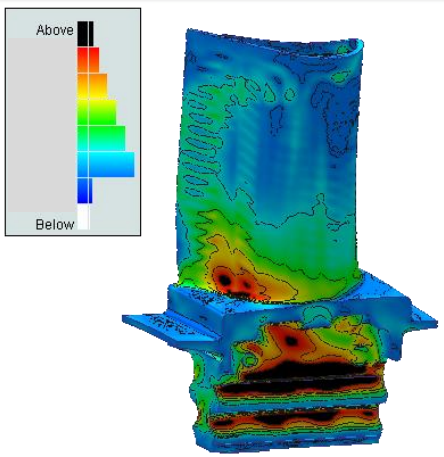
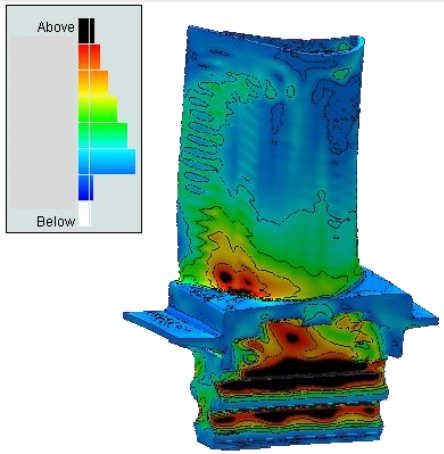
Results

- FMOP in *Statistics on Structures*

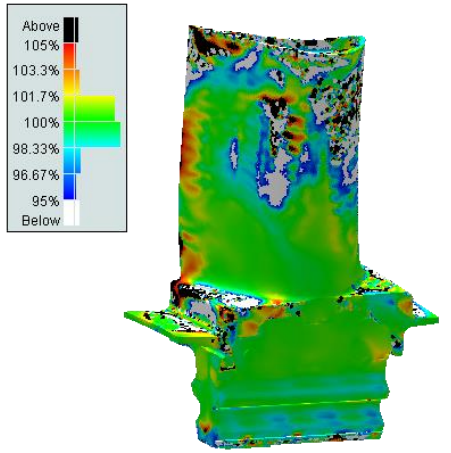
Maximum Principle Stress S1 [MPa] – Overall accuracy > 95 %



FE-Results



Meta Model
(FMOP)



Result accuracy
Perfect match = 100 %

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Application

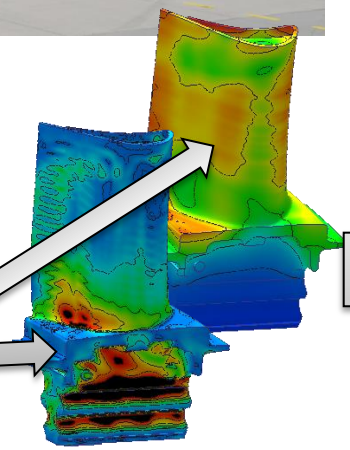
- Consumption of Life Time

Life Time Consumption Plane #52

100 %

Flight Data

Meta Model



Calculation of Life Time consumption of individual flight

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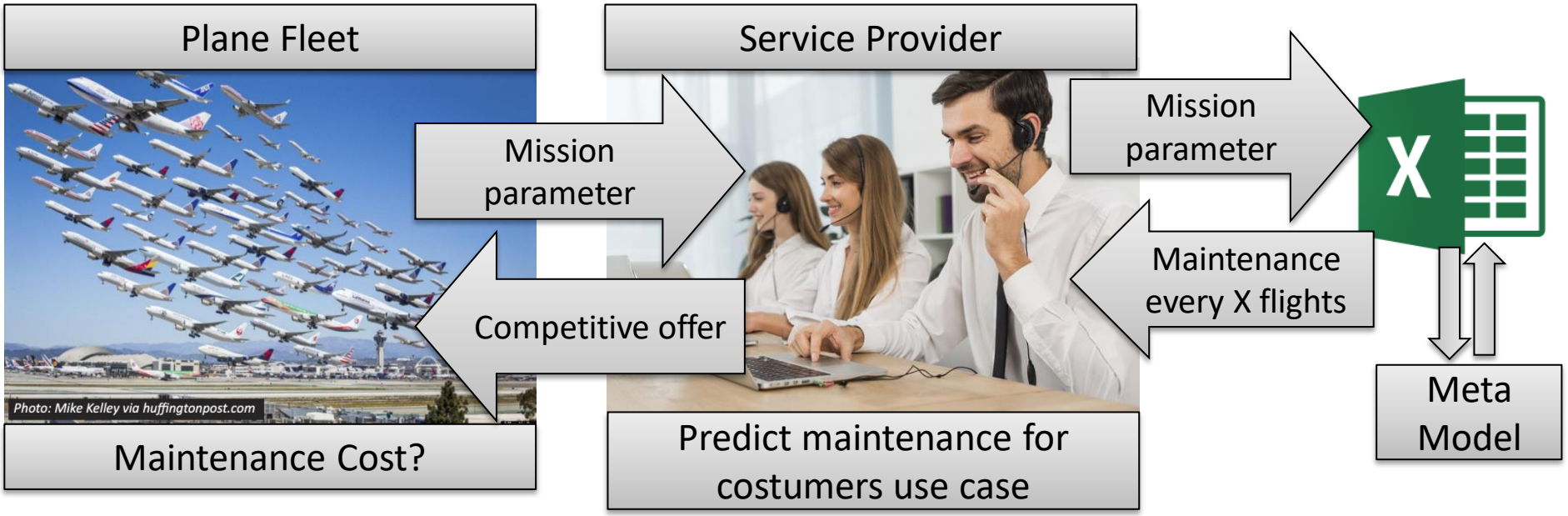
Application

- Maintenance cost prediction



Images: Freepik.com

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Summary

- The utilization of a turbine blade in a **highly complex setup** can be predicted with a Meta Model, **based** simply **on flight data**.
- Simulation allows to evaluate data that's **not directly measurable**!
- The structural responses from actual flight data can be **predicted within seconds**. Contrary, direct simulation of the setup takes half a day on a 128-Core HPC-cluster.
- Highly accurate results of Meta Model allows to **increase time between maintenance**.
- Democratized workflow enables sales to accurately **predict maintenance cost** based on costumers missions.

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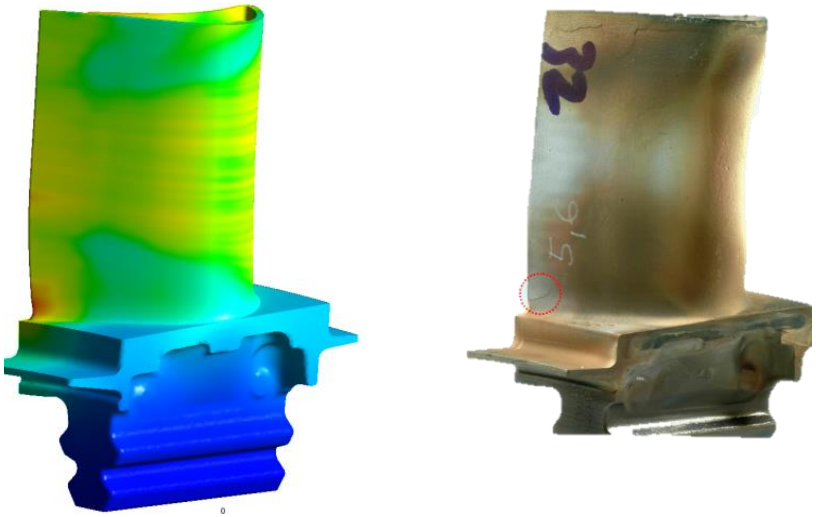
Thank you for your attention !

I‘m pleased to answer any further questions !



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