Engine Fleet Management

A future perspective and where innovations are needed

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ISABE Conference Manchester
September 2017

Agenda

- Lufthansa Technik Engine Services: An overview
- Learnings from customers – Operating Cost & Engine MRO Requirements
- Technical Engine Fleet Management using a digital shadow of fleet and engine
- Aviatar – a new platform for various services
- Where we need innovations …

Lufthansa Group – Facts & figures

Deutsche Lufthansa AG is an aviation group with global operations and a total of more than 550 subsidiaries and equity investments.

Corporate headquarters:

Cologne

Passengers carried in 2016:

109,670 thousands

Number of employees:

124,307*

Lufthansa Group hubs:

Frankfurt, Munich, Dusseldorf, Zurich, Vienna

Lufthansa Group is active in four business segments.

*as of 31.12.2016

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

Lufthansa Technik Group – Facts & figures

800+ customers worldwide

20,839 employees worldwide*

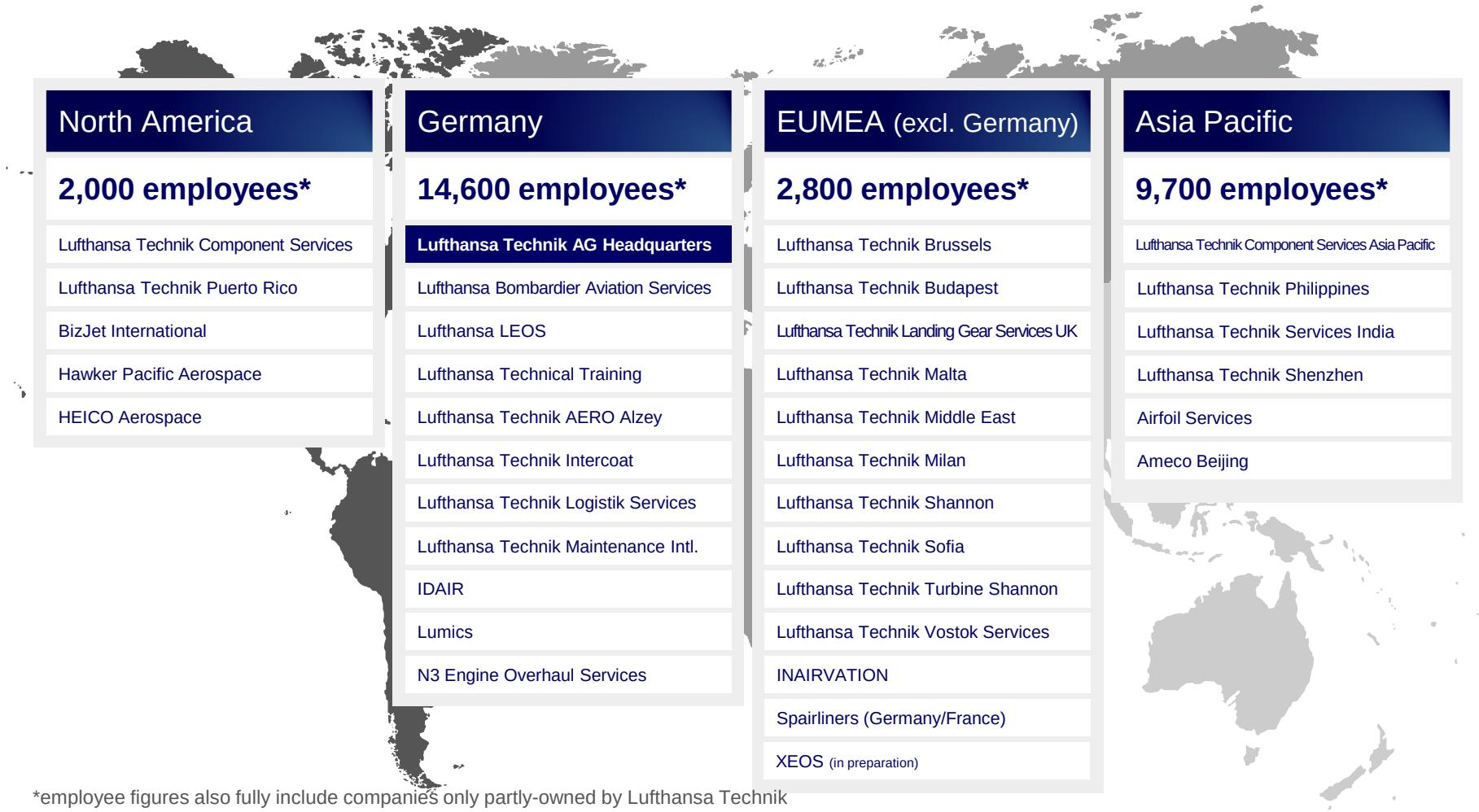
4,132 aircraft under exclusive contracts

5.144 billion € in revenue*

35 subsidiaries and affiliates worldwide

* Lufthansa Technik AG Germany and 23 consolidated companies of Lufthansa Technik Group in 2016; employees as of 31.12.2016

Lufthansa Technik Group worldwide



North America

2,000 employees*

- Lufthansa Technik Component Services
- Lufthansa Technik Puerto Rico
- BizJet International
- Hawker Pacific Aerospace
- HEICO Aerospace

Germany

14,600 employees*

- **Lufthansa Technik AG Headquarters**
- Lufthansa Bombardier Aviation Services
- Lufthansa LEOS
- Lufthansa Technical Training
- Lufthansa Technik AERO Alzey
- Lufthansa Technik Intercoat
- Lufthansa Technik Logistik Services
- Lufthansa Technik Maintenance Intl.
- IDAIR
- Lumics
- N3 Engine Overhaul Services

EUMEA (excl. Germany)

2,800 employees*

- Lufthansa Technik Brussels
- Lufthansa Technik Budapest
- Lufthansa Technik Landing Gear Services UK
- Lufthansa Technik Malta
- Lufthansa Technik Middle East
- Lufthansa Technik Milan
- Lufthansa Technik Shannon
- Lufthansa Technik Sofia
- Lufthansa Technik Turbine Shannon
- Lufthansa Technik Vostok Services
- INAIRVATION
- Spairliners (Germany/France)
- XEOS (in preparation)

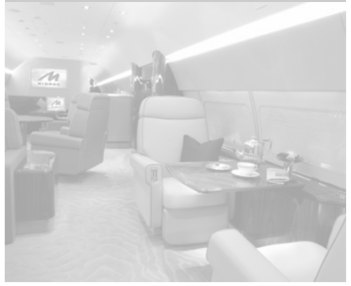
Asia Pacific

9,700 employees*

- Lufthansa Technik Component Services Asia Pacific
- Lufthansa Technik Philippines
- Lufthansa Technik Services India
- Lufthansa Technik Shenzhen
- Airfoil Services
- Ameco Beijing

*employee figures also fully include companies only partly-owned by Lufthansa Technik

Lufthansa Technik Group – Engine Services

Aircraft Services (Maintenance, Overhaul)	**Engine Services**	Component Services	Landing Gear Services	VIP & Special Mission Aircraft Services
				

General Electric: CF6-80C2, CF34-3, -8, -10

CFMI: CFM56-5, -7B

Pratt & Whitney: JT9D, -7A, -7F, -7J, -7Q, -7R, JT9D-59A, -70A, PW4000-94, PW100, PW150

Rolls-Royce: RB211-535, Trent 500, 700, 900, Spey, Tay 611

Honeywell: LF507, ALF502

IAE: V2500-A5, -D5

APUs: APS2000/3200, 2300, PW901A, -C, GTCP36-300, GTCP131-9A, GTCP131-9B, GTCP331-200, 331-250, 331-350, 331-500, 331-600, TSCP700-4E

Lufthansa Technik Group Headquarter in Hamburg

Lufthansa Technik Engine Services – Leading independent provider for engine repair & overhaul

Turnover of Engine Services:

2,500 million

31.000 Engine and APUs overhauls in over **60 years**

More than **1.100** overhauls in **2016**

Material stock in 2016:

445 m € and

~100 spare engines

Number of employees:

3,800*

11 Engine Services **facilities** and **7 test cells** around the world for **~40 engine** and **APU types**

Parts manufacturing approval and **design agency**

Repair station certificates from **35 countries**

Certified by **FAA** and **EASA**

* as of 31.12.2016

Lufthansa Technik is the only independent MRO with access to all new engine types

GE	**GEnx-2B** **GE9X**	✓	XEOS (JV with GE) in operation Q2/19 Location is Wroclaw Quick turns at FRA since 06/15 Dedicated Engine area in HAM (QT, PRSV) GEnX-1B AST services started
CFM The Power Of Flight	**LEAP-1A** **(Planned -1B)**	✓	LHT to build up PRSV capability in HAM Readiness for Quick turns in 2018/19
Pratt & Whitney A United Technologies Company	**PW1100** **PW1500**	✓	PW1100 Lufthansa “First To Fly” (A320neo) PW1500 Swiss “First To Fly” (CSeries) FRA is ready for ETR Dedicated Engine area in HAM JV with MTU planned, ETR 10/2019
Rolls-Royce	**Trent XWB**	✓	EIS at Lufthansa 2016 XWB at N3 EOS (JV with RR)

Lufthansa Technik Engine Services – Our locations

Lufthansa Technik
Turbine Shannon

Components for HPT & LPT, turbine blades and vanes, and shrouds

Lufthansa Technik
HAM, FRA, BER

CFM56-all, CF6-80C2, PW4000, V2500, GEnx-2B (QT), GTF (QT)

xeos
Wroclaw

In preparation: GEnx-2B

Ameco Beijing

PW4000, RB211, V2500

Lufthansa Technik
Shenzhen

AST, Lessor Services/ Engine Storage, Common Nozzle, Tail Cone, Engine Mount

BIZJET

Spey/Tay, Mobile Engine Services (build-up), Teardown

Lufthansa Technik
AERO Alzey

CF34-3, -8, -10, PW100, PW150

N3 Engine Overhaul Services

Trent 500, 700, 900, XWB

AIRFOIL services

HPC blades and vanes and LPT blades

When serving many customers we continously listen to specific requirements …

Numerous regional customers

EUMEA

AMERICAS

Numerous regional customers

ASIA PACIFIC

Numerous regional customers

Customized contract types

More and more PbH contracts requested

Time and Material	Consumed man-hour and material will be charged ➔ Best determination of workscope and costs
Fixed price package	For defined work packages a fixed price will be charged ➔ High cost predictability for single engine event
Power by the Hour	A rate per flight hour covers all agreed services ➔ Minimized financial risk and peace of mind for your entire engine maintenance

➡ **Drastic change for MRO!**

➡ **The best engine shop visit is the one avoided …**

What to think about when preparing an MRO offer for a fleet?

Owned or leased?

Lease return conditions?

Engine interchangability within fleet?

Fleet size?

Engine and aircraft type?

Age?

Life history of each engine and current status?

Which environment – polluted, hot&sandy?

Spare Engine situation?

Route structure and Fh/FC ratio?

Operator`s planning horizon and key optimization objective?

„One size fits all“ does not work!

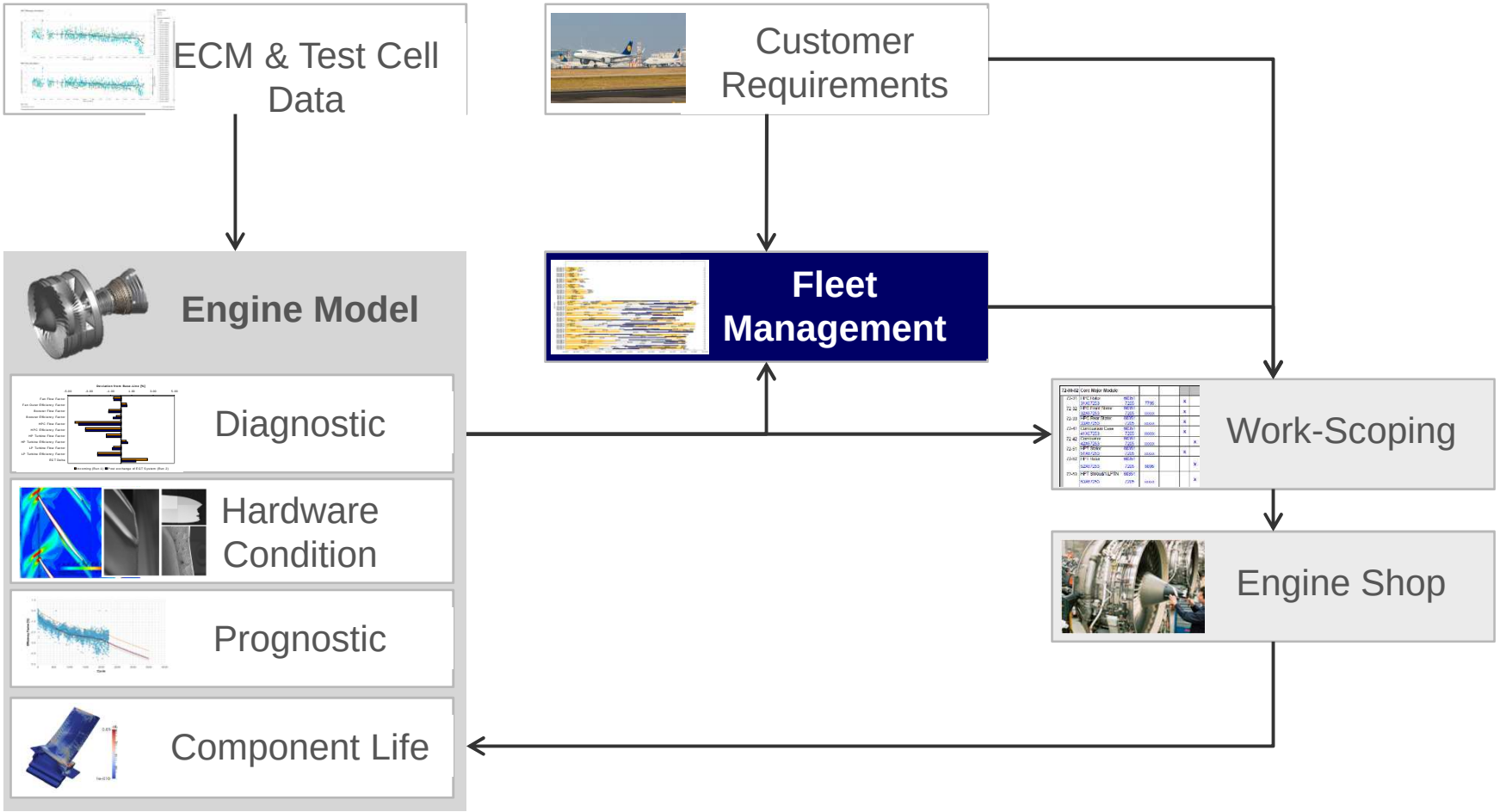
Lack of understanding and conservative margin mark-up …….. → **No business!**

Too agressive or optimistic assumptions …. → **Win business but lose money!**

Need for comprehensive Engine Fleet Management Approach!

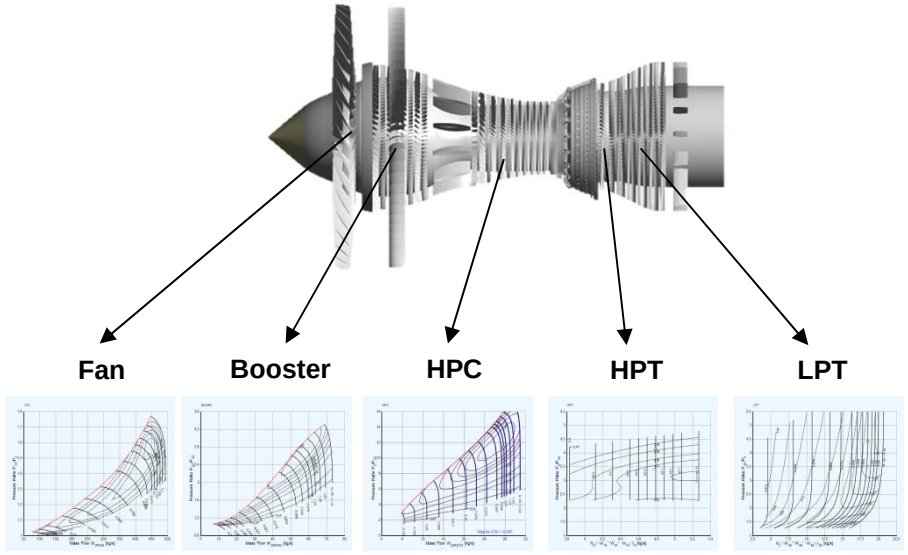
Key Elements of Fleet Management

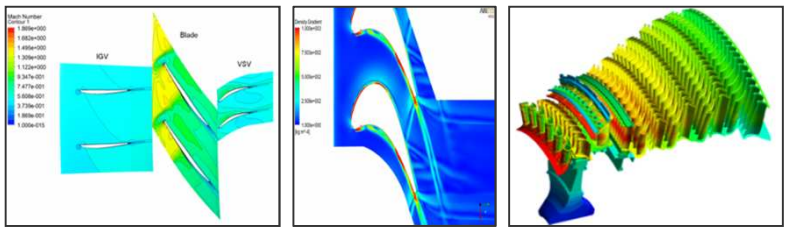
Multilevel model using numeric optimization algorithms



Digital Zooming Model to shadow specific engines

The heart of the Concept





Engine level:

Thermodynamic cycle model of engine

Module level:

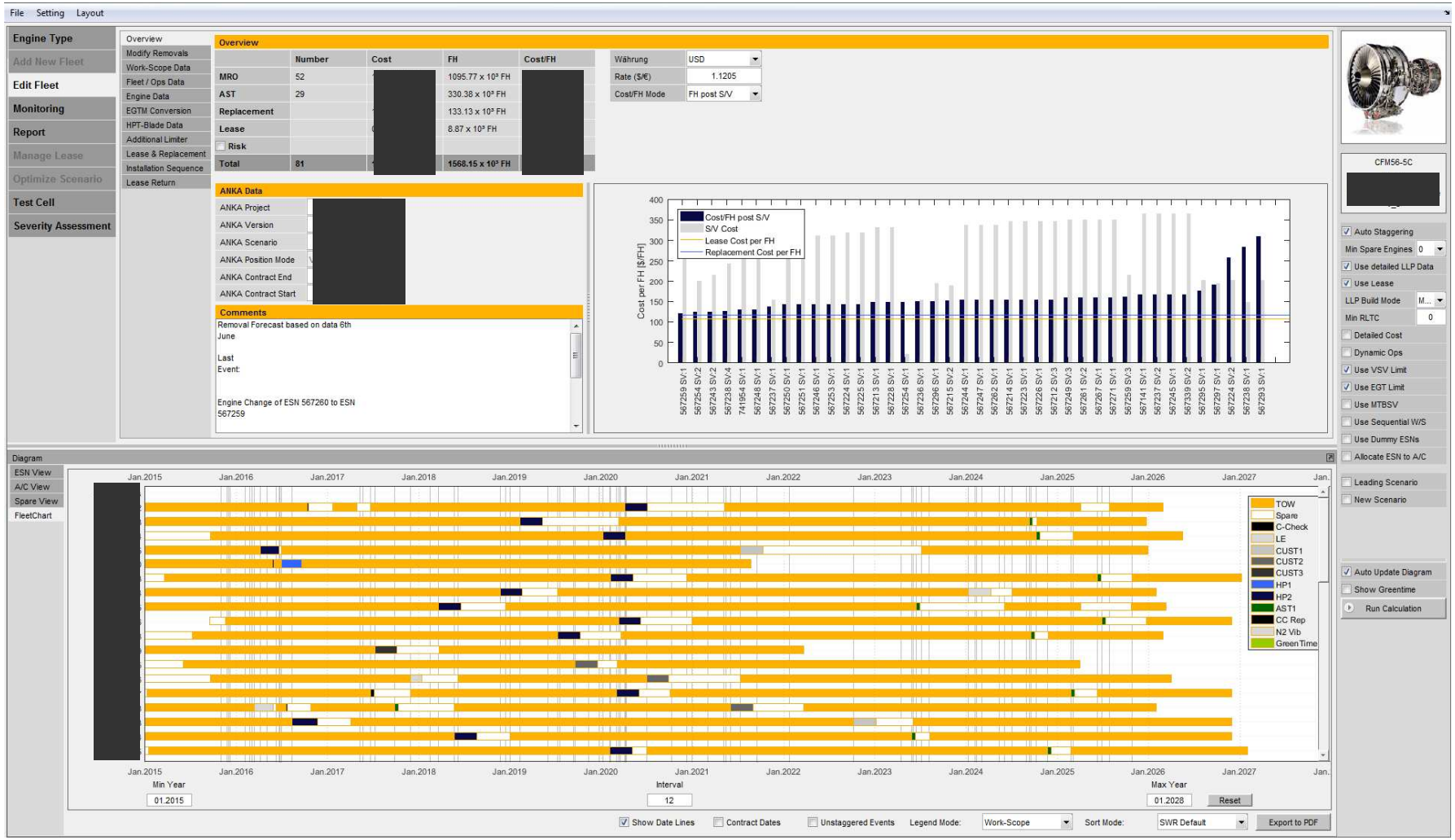
Engine operating map and Mean-Line models to describe module characteristics

Piece part level:

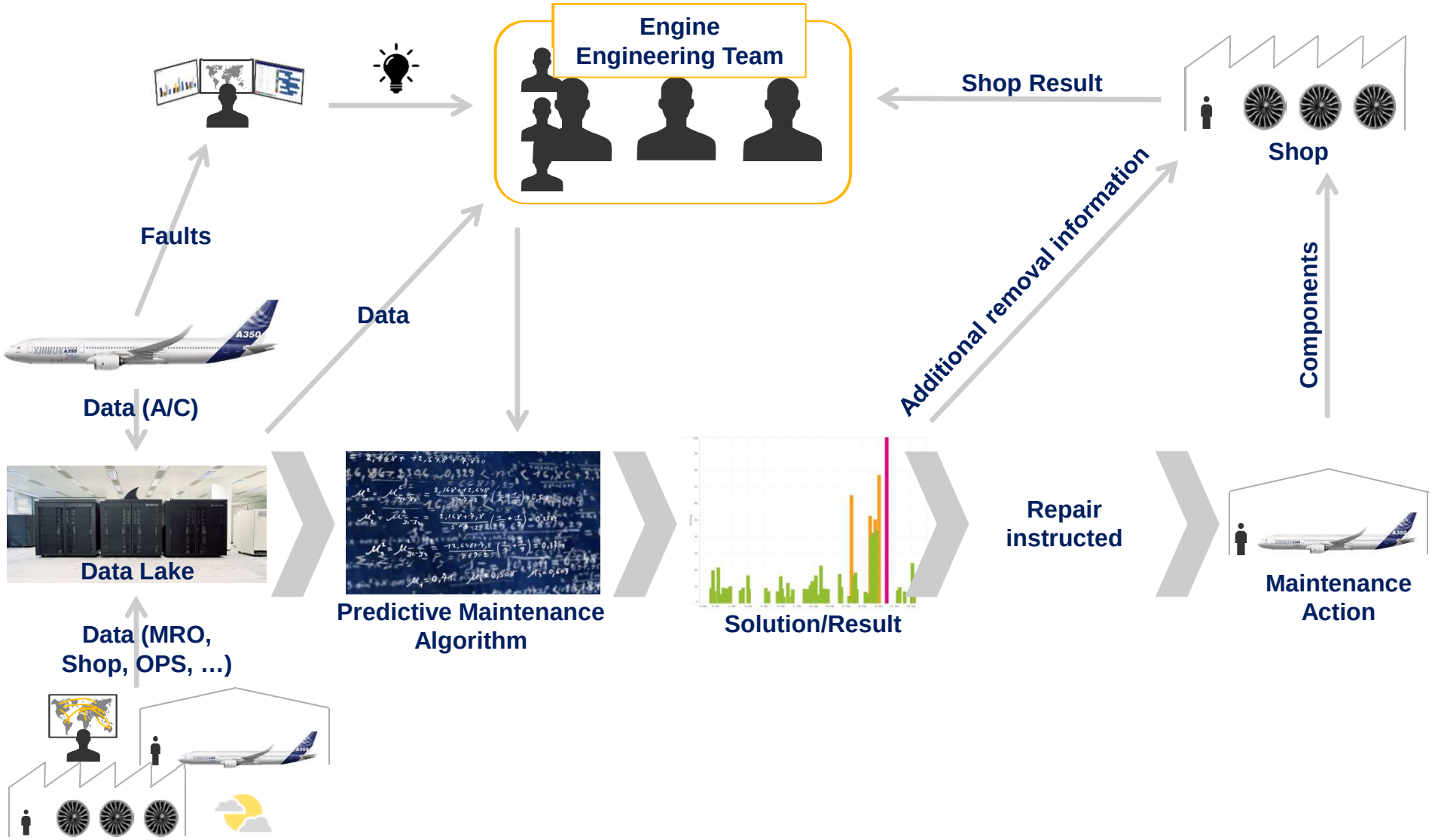
Detailed analysis of aerodynamic, mechanical and thermal properties

Engine Fleet-Management Tool Cockpit

From analysis to action with full cost prediction



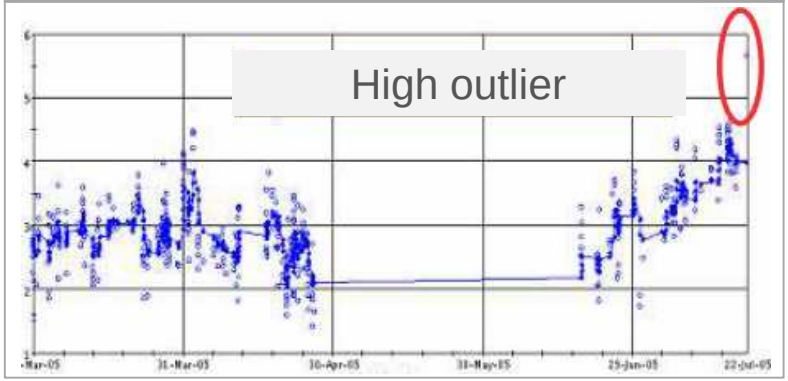
From data to maintenance action



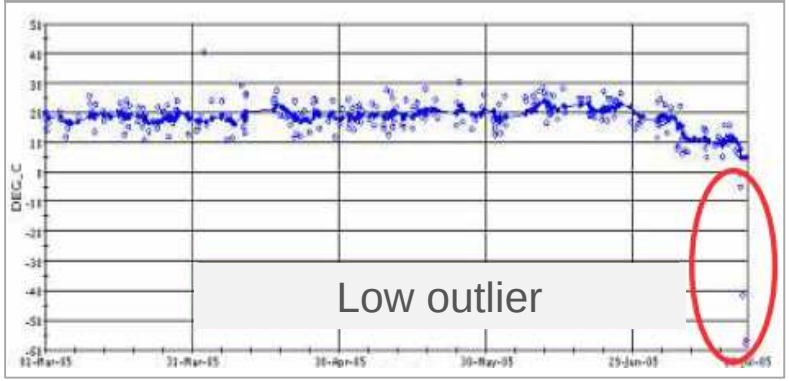
Example: Data analysis reveals defective hardware

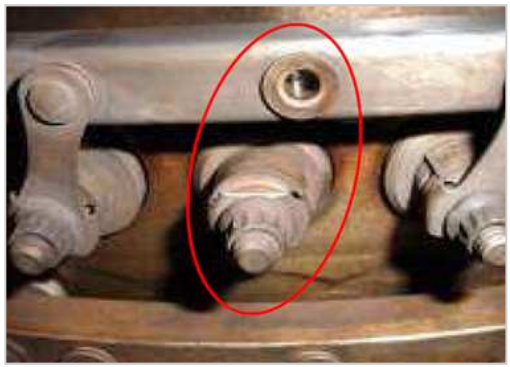
Broken VSV Lever Arm

Increasing EGT & Fuel Flow & N2



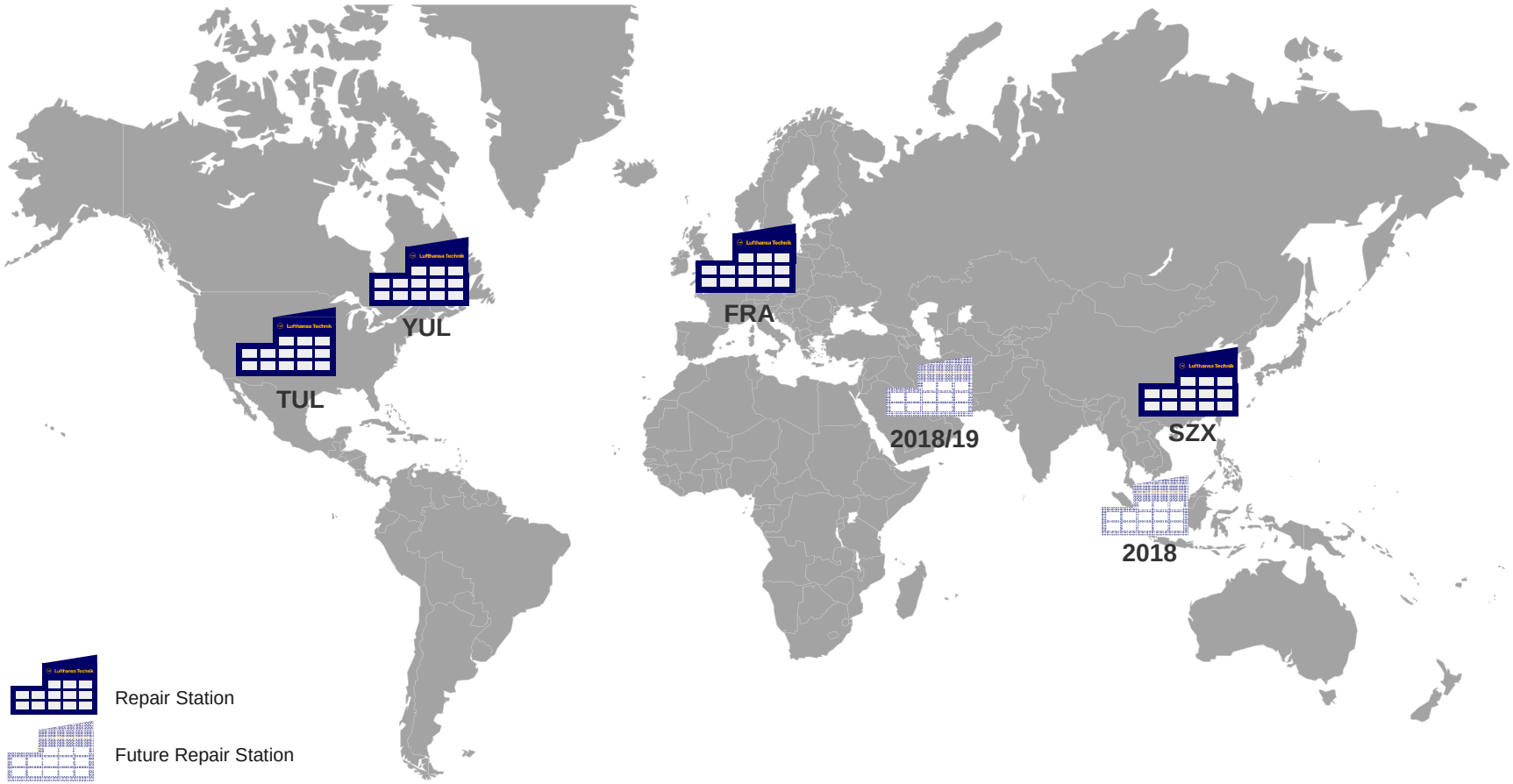
Decreasing EGT Margin



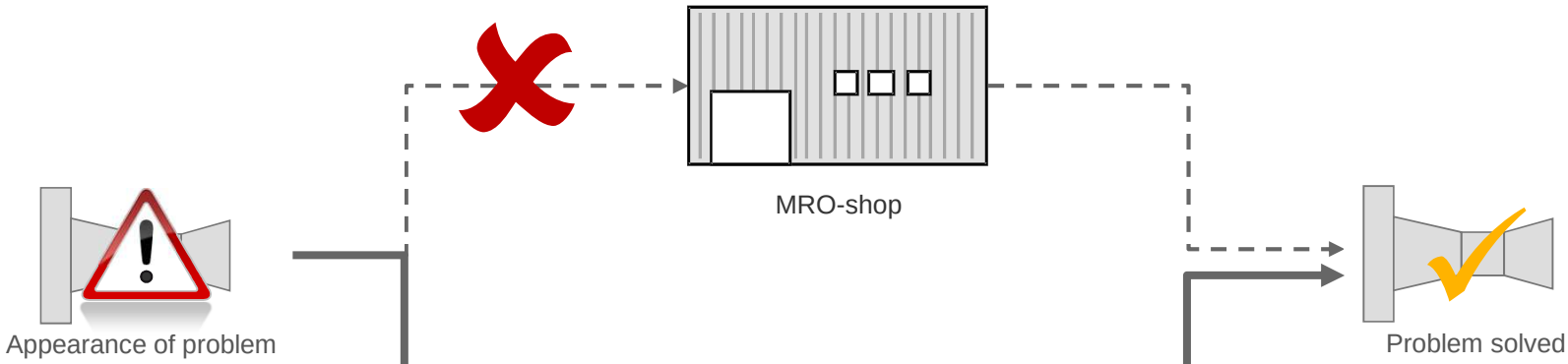


Early detection avoids EGT Exceedance and HPT distress

Our worldwide Mobile Engine Services network ramp-up is on-going and guarantees short response times



With Mobile Engine Services regular shop visits can be avoided



Mobile Engine Services

On-wing | On-site | Repair Station

- Tailor made repairs
- Risk of workscope extension is mitigated
- All-round carefree package (incl. tooling, material and workforce)

LHT created the brandnew open AVIATAR platform

The film …

www.aviatar.com

Food for thought …

Future fields of innovation with significant customer value

Improve numerical fleet optimization strategies and data availability

New algorithms identifying specific hardware failures from data

Development of new surgical strike mobile repairs

Virtual repair guidance technologies bridge parts hardware and manuals

Future LEAN production

engine shop technologies

