The Evolution of Aeronautical Research - from Principles to Operations

Prof. Dr.-Ing. Volker Gollnick

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Outline

- Development of aeronautical research

- The step towards operations
  - **Impact of technologies** on operational performance
  - **Boundaries** for Future Developments
  - A **Change of focus**
  - Trade Off between **Mobility and Green Transportation**
  - A Customer in the Air Transportation System – Who is it?
  - A **Customer Perspective** – The Airline
  - Overall **Operations Oriented** Integrated Aircraft **Design**
  - **Efficient Production** – a key for future prosperous air transportation
  - **Integrated Information** Systems
  - **Climate** Optimized Air Transportation
  - **Laminar Flow** Technologies in Operations

- **Future Objectives** of Aeronautical Research
Development of Aeronautical Research

Aeronautical disciplinary research on aircraft has reached a very high level of maturity during the past decades.

- Junkers F13, 1919
  From first full metallic aircraft to more than 50% composite aircraft

- Focke-Wulf Fw 200, 1937
  From 26 pax, 1700km range to 550 pax, 15000km range

- Airbus A380, 2003
  Boeing B787, 2012
Development of Aeronautical Research

Aeronautical disciplinary research on aircraft has reached a very high level of maturity during the past decades.

De Havilland Ghost Mk1

From zero bypass to high bypass (12:1) engines

Pratt & Whitney, PW1400

From turbulent flow profiles to laminar flow profiles
Development of Aeronautical Research

Aeronautical disciplinary research on aircraft has reached a very high level of maturity during the past decades.

- Focke-Wulf Fw 200, 1937
- Concorde, 1969
- Boeing B787, 2012

From low L/D ratio (~9) to **high L/D ratio** (21, CL=0.508, CD=0.0459) aerodynamic performance.

From single analogue to **highly integrated avionics** systems to reduce pilot information load.
The Step towards Operations

Impact of technologies on operational performance

- Increase in fuel consumption and CO₂
- Less fuel consumption and CO₂
- Alternative Fuels (reduces CO₂ emissions, not fuel consumption)
- Engine Thermal and propulsive efficiency
- Oswald factor
- Profile drag (C₀₀)
- Design Point

OWE/MTOW

Reduction of Spec. parameter
Increase of spec. parameter
The Step towards Operations
Boundaries for future developments

Oil Price Development

Developing energy cost and saturating demand for mobility will limit quantitative growth
The Step towards Operations
Boundaries for future developments

Average age of aircraft is continuously increasing towards 40 years of individual A/C operation

Thus money can only be made with short life time components like cabin, avionics, software, cabin electronics which are to be replaced every few years
The Step towards Operations
Boundaries for future developments

No new aircraft within the next 25 years!!!
The Step towards Operations
Boundaries for future developments

The „Rebound“ Effect:

- **Weight savings are consumed** by additional equipment

- **Individual** of aircraft fuel consumption **savings** through aerodynamics, propulsion and weight are **consumed by massive increase in world aircraft fleet**
The Step towards Operations
A change of focus

- Most **physical principles** of aircraft design disciplines are **well understood**
- Only **minor incremental improvements** are further achievable with significant effort
- During the next at least 20 years **no new aircraft** are to be expected due to the great success of the current products like A320NEO, B737Max, A350, B787
- Aviation is facing **more competition** with other transportation systems
- Stakeholder expectations (passenger, are more and more addressing **quality**, **efficiency** and **environmental compatibility of the entire transportation chain**
- Due to high economic and ecological pressure **efficient operation** of aircraft is a key for success of aviation

The aircraft is no longer in the main focus

**Overall chains** from production to operation become more relevant and **key success factor**
The Step towards Operations
Trade Off between Mobility and Green Transportation

- An increasing demand for **Mobility as a major pillar** of prosperity
- Increasing energy/oil cost and ecological responsibility **argue against** quantitative traffic growth
- Ensure **mobility with less energy effort**, emissions and noise, **requests for** less traffic ➔ less aircraft, less airport, airspace capacity
- **Passenger mobility** can be achieved with **less aircraft movements**
- **Cost and emissions** per flight are **to be shared** by more people per trip

➤ **Paradigm shift from quantitative air transport growth to qualitative air transport growth**

Source: U. Becker, TU Dresden, V. Gollnick, DLR
Optimization and Quality are mainly addressing partial areas of the entire transportation chain.

VISION2020 and FLIGHTPATH2050 are setting extreme and holistic challenges.

Air Transportation faces increasing social concerns.

Stakeholder/customer are more demanding.

Are passengers the only customer?
The Step forward to Operations
A Customer in the Air Transportation System – Who is it?

<table>
<thead>
<tr>
<th>Customer</th>
<th>Service Provider</th>
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<tbody>
<tr>
<td>Aircraft Manufacturer</td>
<td>System Supplier</td>
</tr>
<tr>
<td>Airline</td>
<td>Aircraft Manufacturer</td>
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<tr>
<td>Airline</td>
<td>MRO</td>
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<td>Retail</td>
<td>Airport</td>
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</tbody>
</table>

- Many provider are customer as well
- Each service provider is optimizing himself to fulfil specific customer expectations in his area...
The Step forward to Operations
A Customer Perspective – The Airline

Overall travel Expectation :
- Connectivity
- Travel times
- Comfort
- Predictability
- Fluency

Efficient aircraft (low SFC, low emissions, low MRO)
- Low acquisition costs
- Available as required

Low costs
- High reliability
- High utilization
- High availability

Process improvements increase customer satisfaction!
The Step towards Operations
Overall Operations Oriented Integrated Aircraft Design

Source: DLR, Institute for Air Transportation Systems
The Step towards Operations
Efficient Production – a key for future prosperous air transportation

Production and assembly of high quality large integrated components

Automated production and assembly of fuselage and cabin
The Step towards Operations
Integrated information exchange

Communication and Software Technologies are key for efficient production and operations.
The Step towards Operations
Climate Optimized ATS – Trade Off between DOC and climate impact

- Trade-off for exemplary mission depicted
  (→ Pareto frontier)
- Mission: DTW-FRA
- Climate impact reduction of 59 % requires 40 % DOC increase wrt. minimum DOC operations!
- Identification of ideal trade-off for whole route network allows for the derivation of a new design point for a more climate-friendly aircraft
The Step towards Operations
Laminar Flow Technologies in Operations

Single Mission Operation vs. Fleet Operation

Fuel saving on operational level

-6.5%  -5.7%
-4.0%  -1.9%
-2.8%  -2.0%  -1.6%

% of flights substituted with NLF aircraft
Introduction of NLF first on long routes

Share of flights with NLF aircraft [%]

Optimum laminar flow
Reduced laminar flow

Available seat kilometers [%]

Number of flights [\textit{]}]

avg. distance
75% of flights
95% of flights
The Step towards Operations
Laminar Flow Technologies in Operations – Life Cycle Cost Analysis

Airline Life Cycle Cost-Benefit Model **AirTOBS**
Modeling all cost, revenues, and utilization of aircraft operations
Superior to standard DOC-methods

(a) **Cash flow results**
   Main assumptions:
   Fuel price at 80 $/barrel, same aircraft list price and maintenance cost.

(b) **Fuel price variation** for \( \Delta \text{NPV} \)
   For design range and representative range distribution
   Assumptions:
   - **Best case**: +20$/FC maint.; same A/C list price
   - **Worst case**: +500$/FC maint.; +5% A/C list price

![Graph](chart23.png)
The Step towards Operations
Future Objectives for Aeronautical Research

Operational Issues of Future Aeronautical Research:

- Comfort
- Travel time
- Capacity
- Maintenance
- Security
- Emissions
- Noise
- Production
- Recycling

In a world of growing energy cost, increasing A/C life time, saturating mobility:

It’s **operations** rather than physical technologies, which drives the success of future qualitative growth of air transportation!
Thank you for your interest!

Univ. Prof. Dr.-Ing. Volker Gollnick
E-Mail: volker.gollnick@dlr.de

Address: German Aerospace Center (DLR)
Institute for Air Transportation Systems of DLR at TUHH
Blohmstraße 18
D-21079 Hamburg
Germany
www.dlr.de/ly