Flying Testbeds
A Need for Validation and Demonstration

C.-C. Rossow

Motivation & Physics (I)
Flight Testing
Motivation & Physics (II)
Perspectives
Conclusion

DLR

Motivation I

Why
Flight
Testing
?
Because
Aviation
Is
Special

Flight Envelope
Physics I

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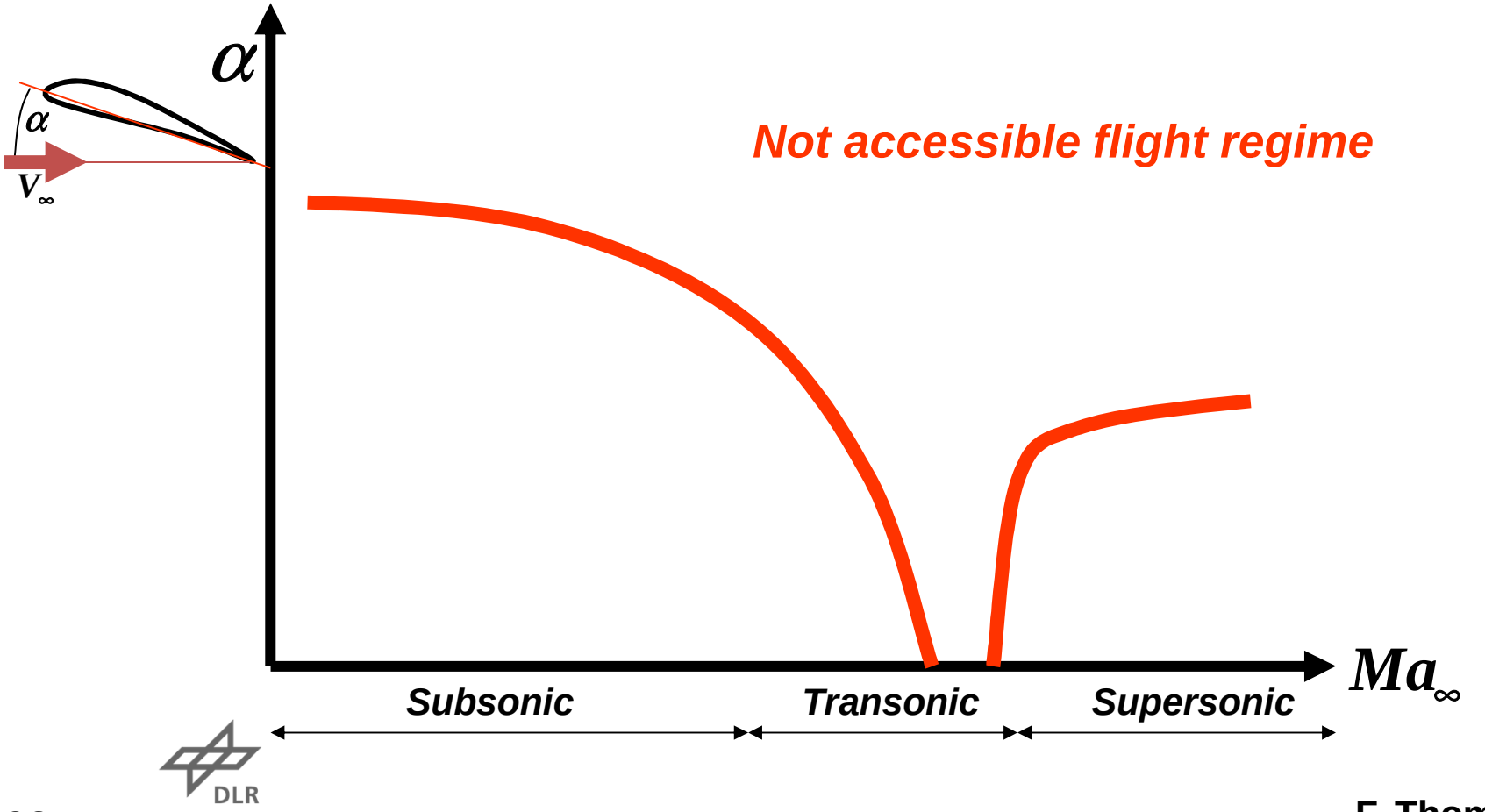
F. Thomas, 1966

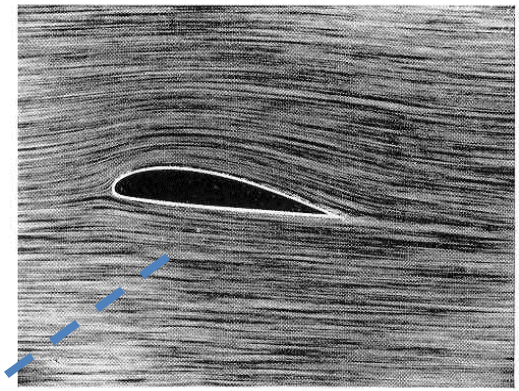
Flight Envelope
Physics I

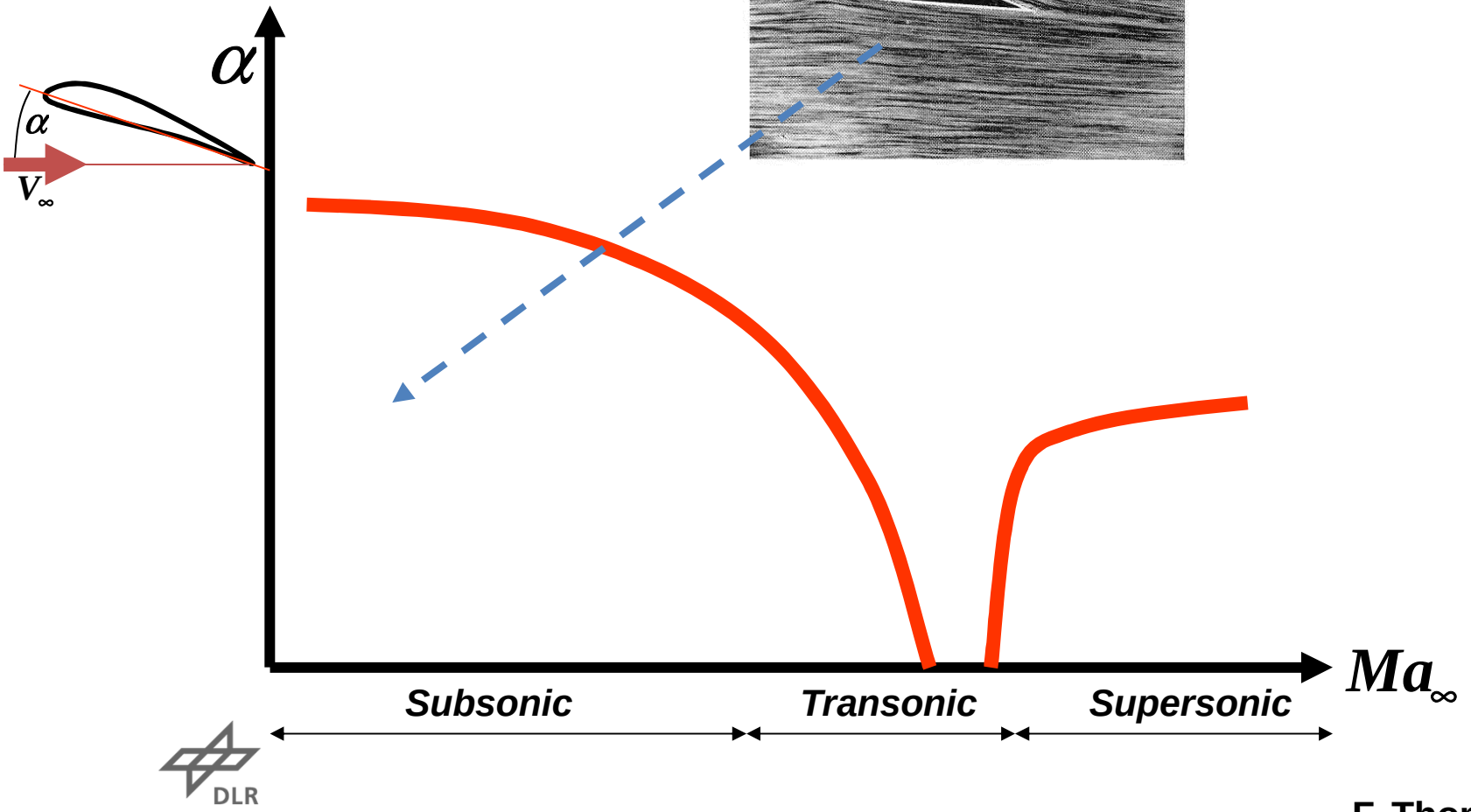


F. Thomas, 1966

Flight Envelope
Physics I

- **Subsonic**

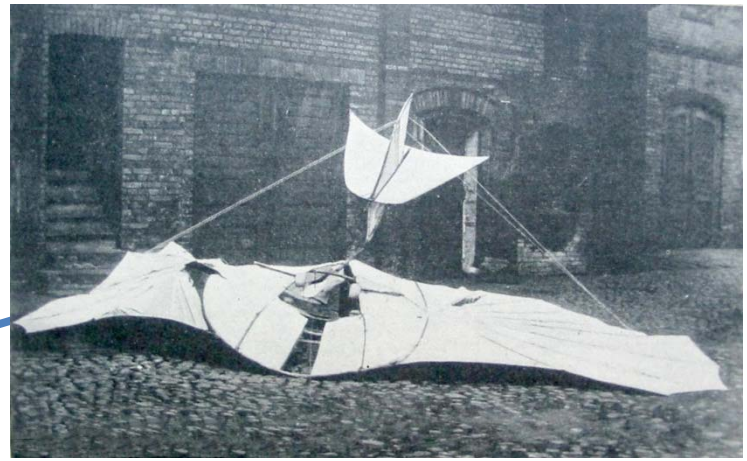




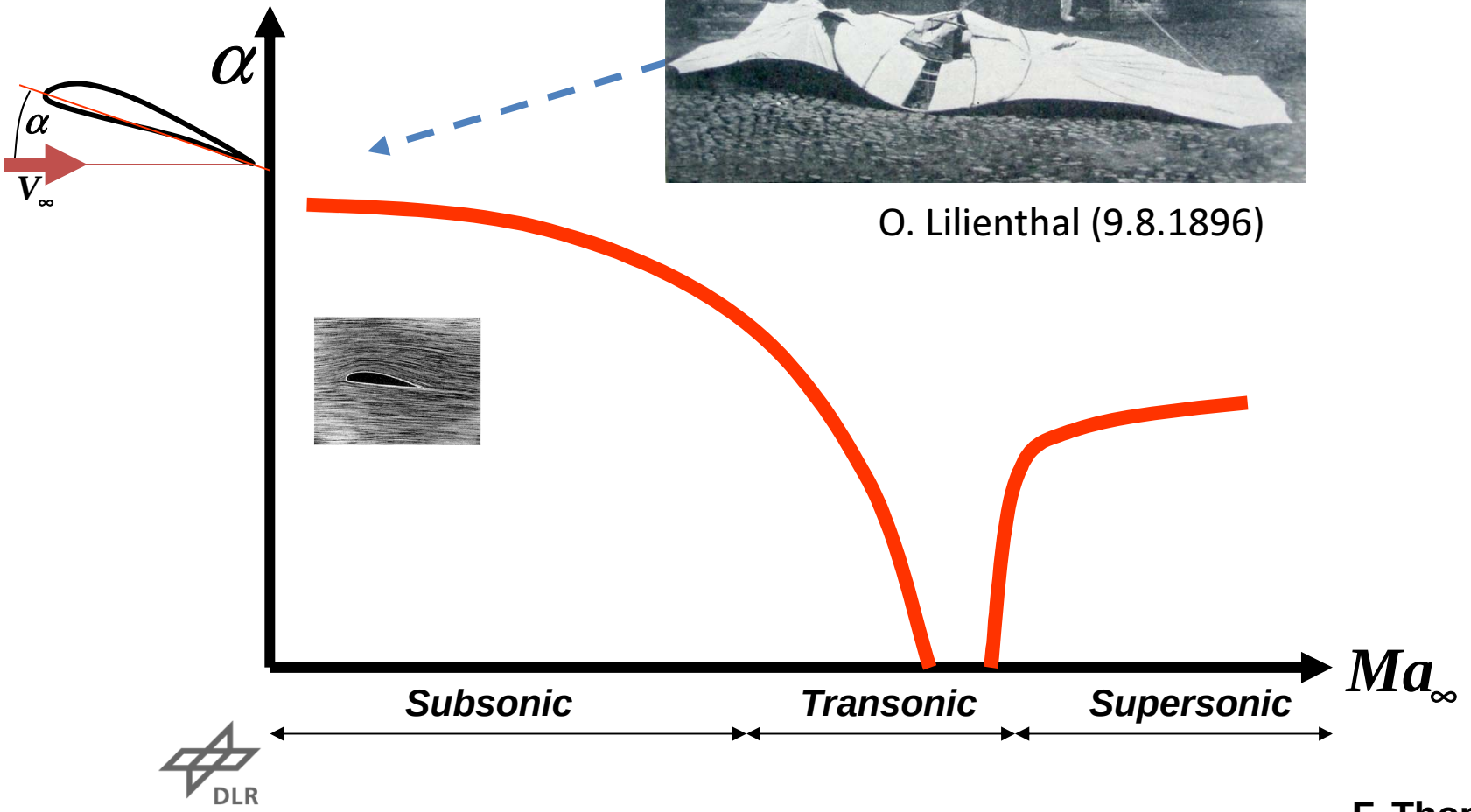
F. Thomas, 1966

Flight Envelope
Physics I

- **Subsonic, separation**



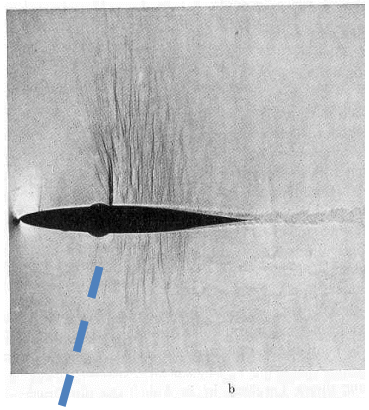
O. Lilienthal (9.8.1896)

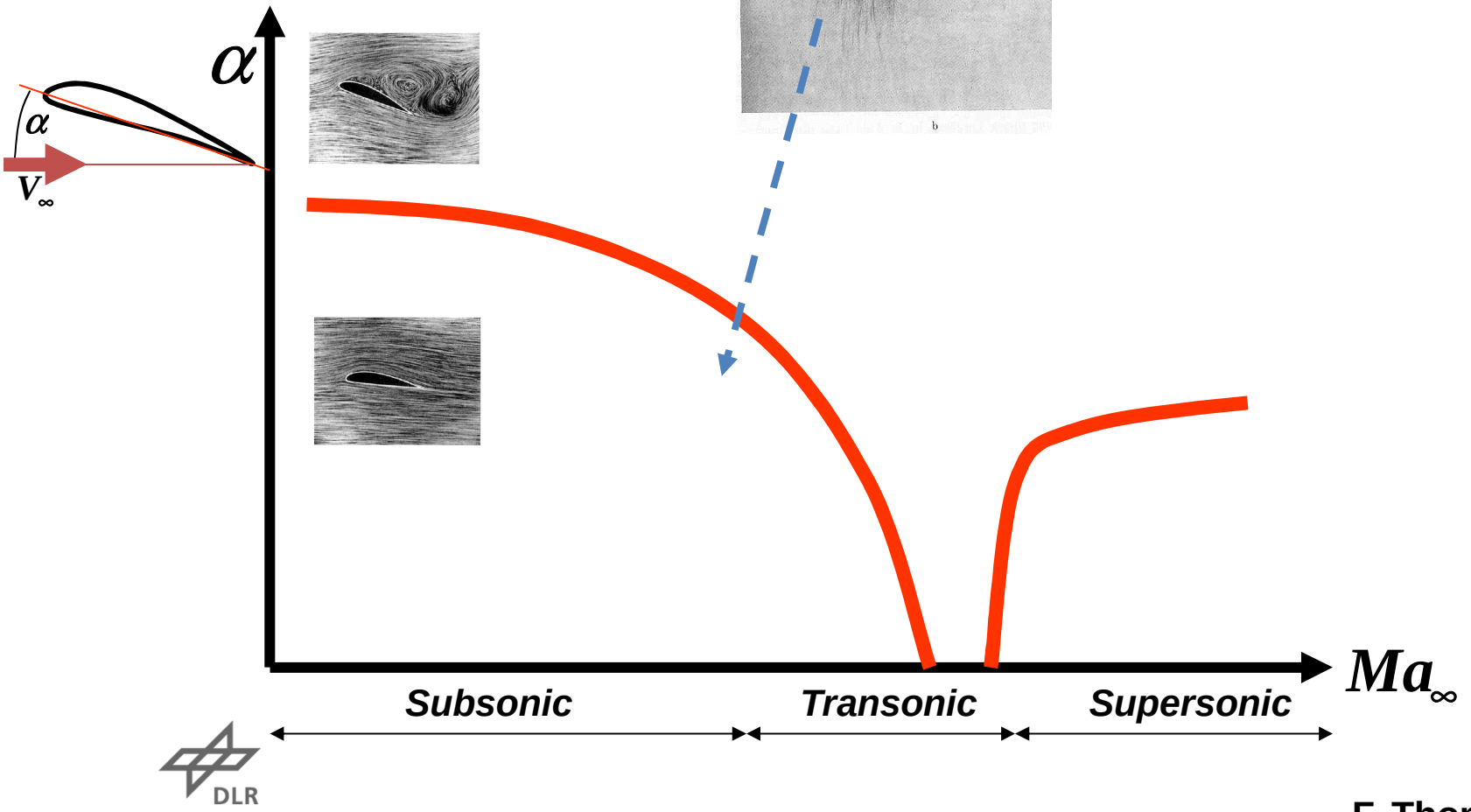


F. Thomas, 1966

Flight Envelope
Physics I

- **Transonic, shock**

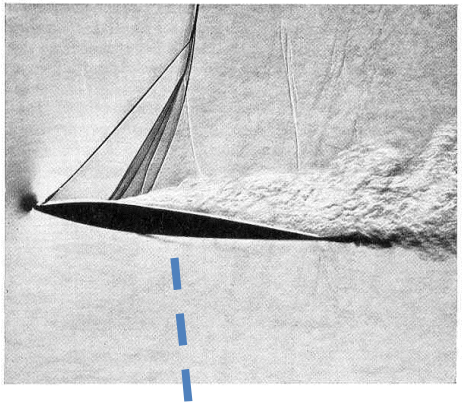


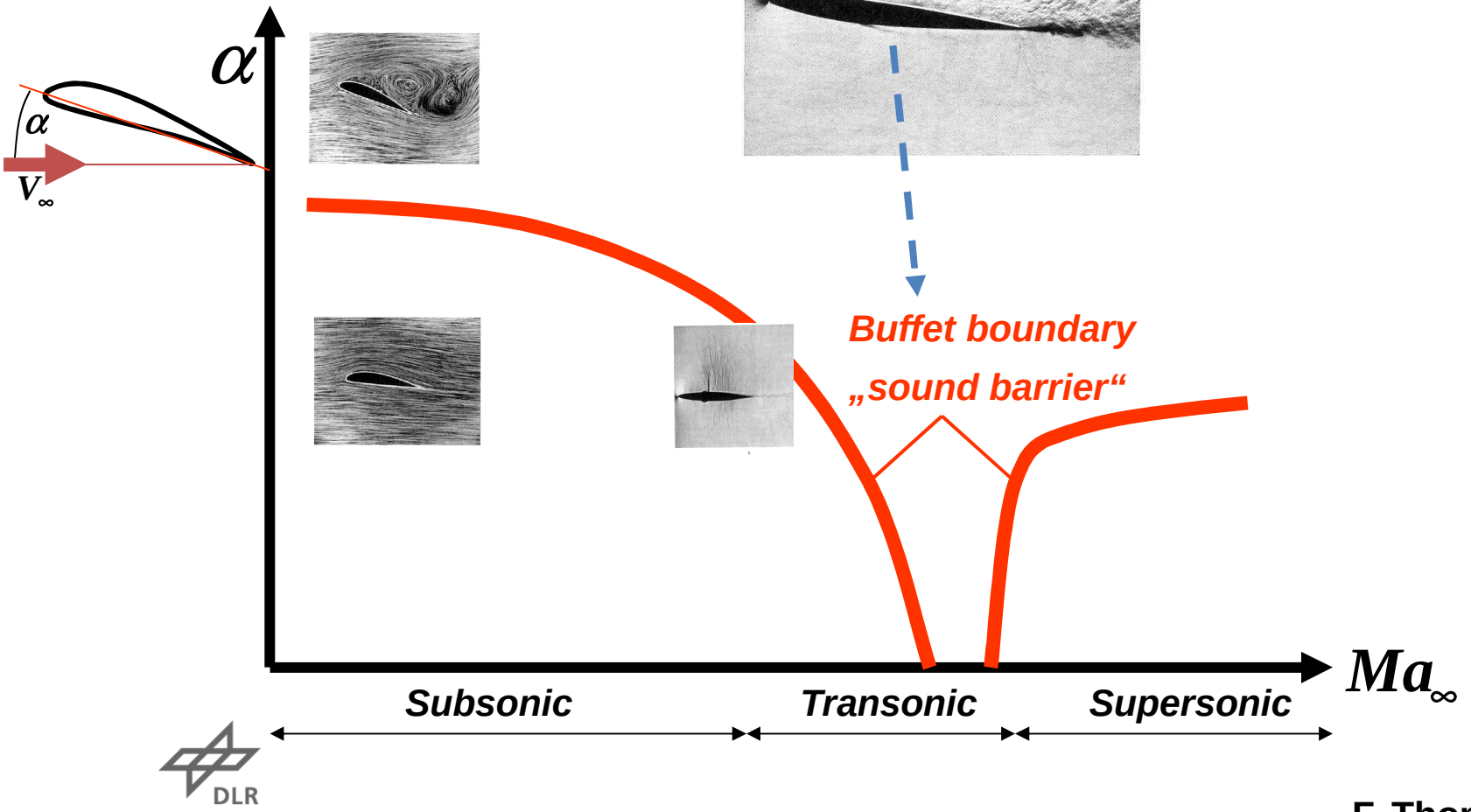


F. Thomas, 1966

Flight Envelope
Physics I

- **Transonic, shock + separation**





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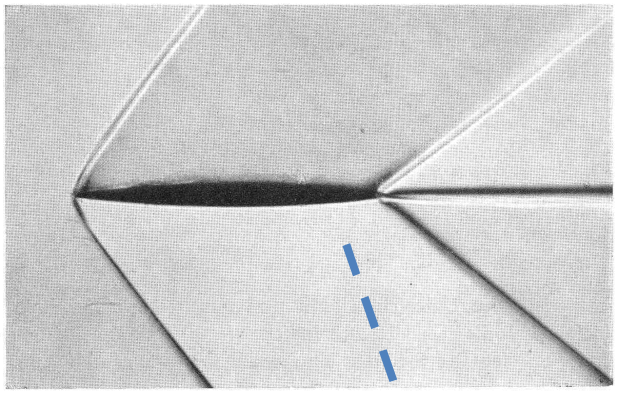
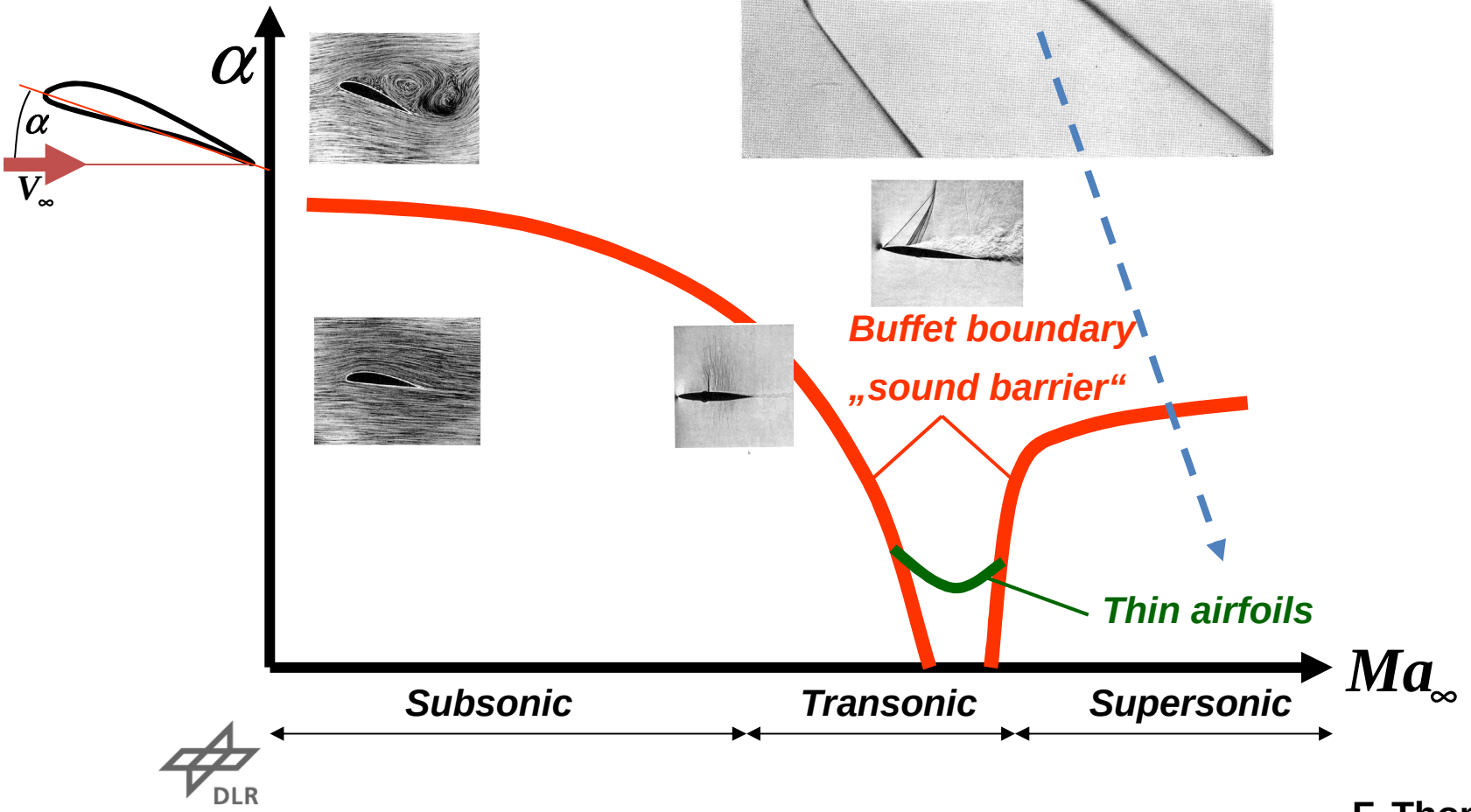
F. Thomas, 1966

Flight Envelope
Physics I

- **Supersonic, attached shocks**





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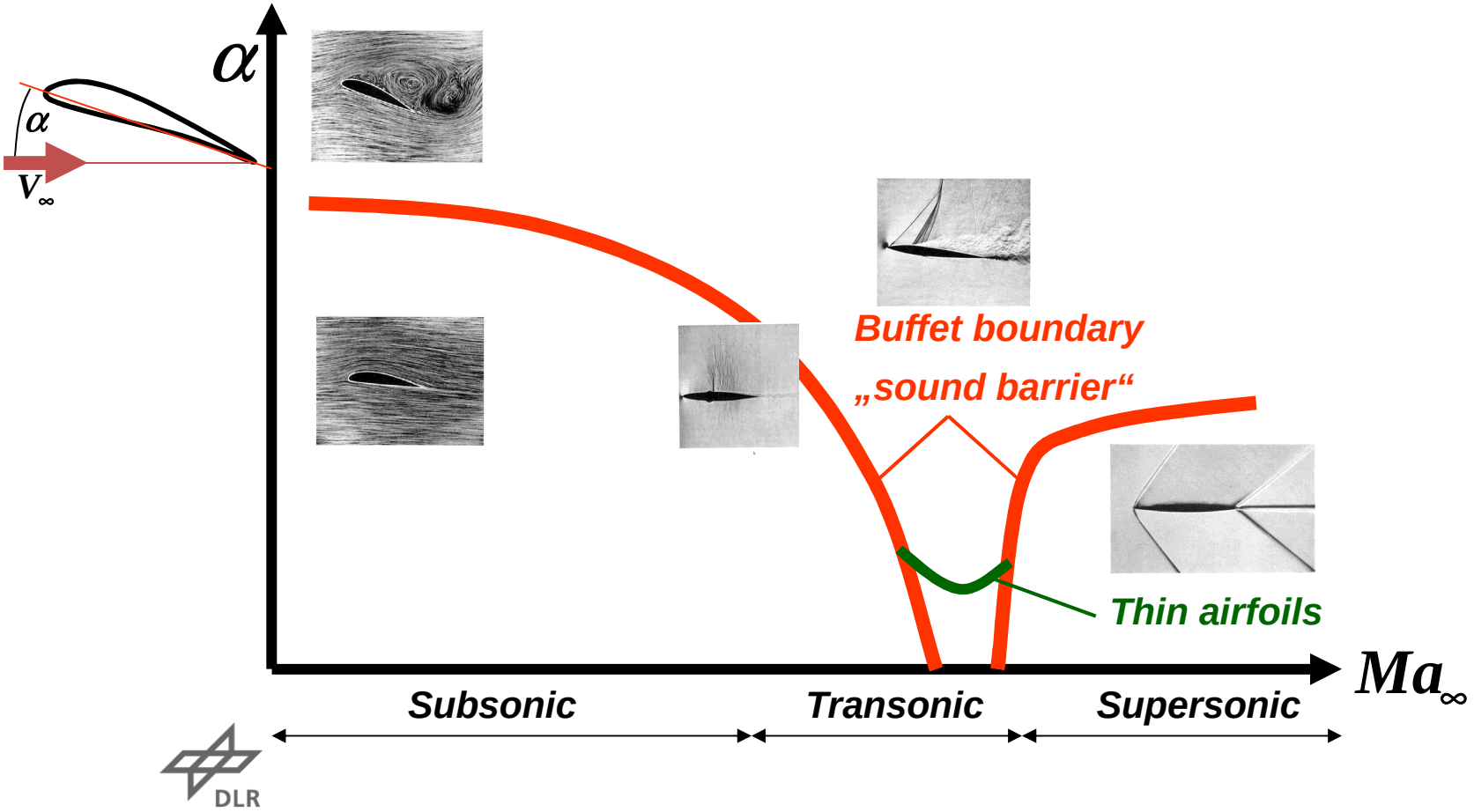
F. Thomas, 1966

Flight Envelope

Aircraft Design and Operation

- **Transonic Civil Transport A/C**

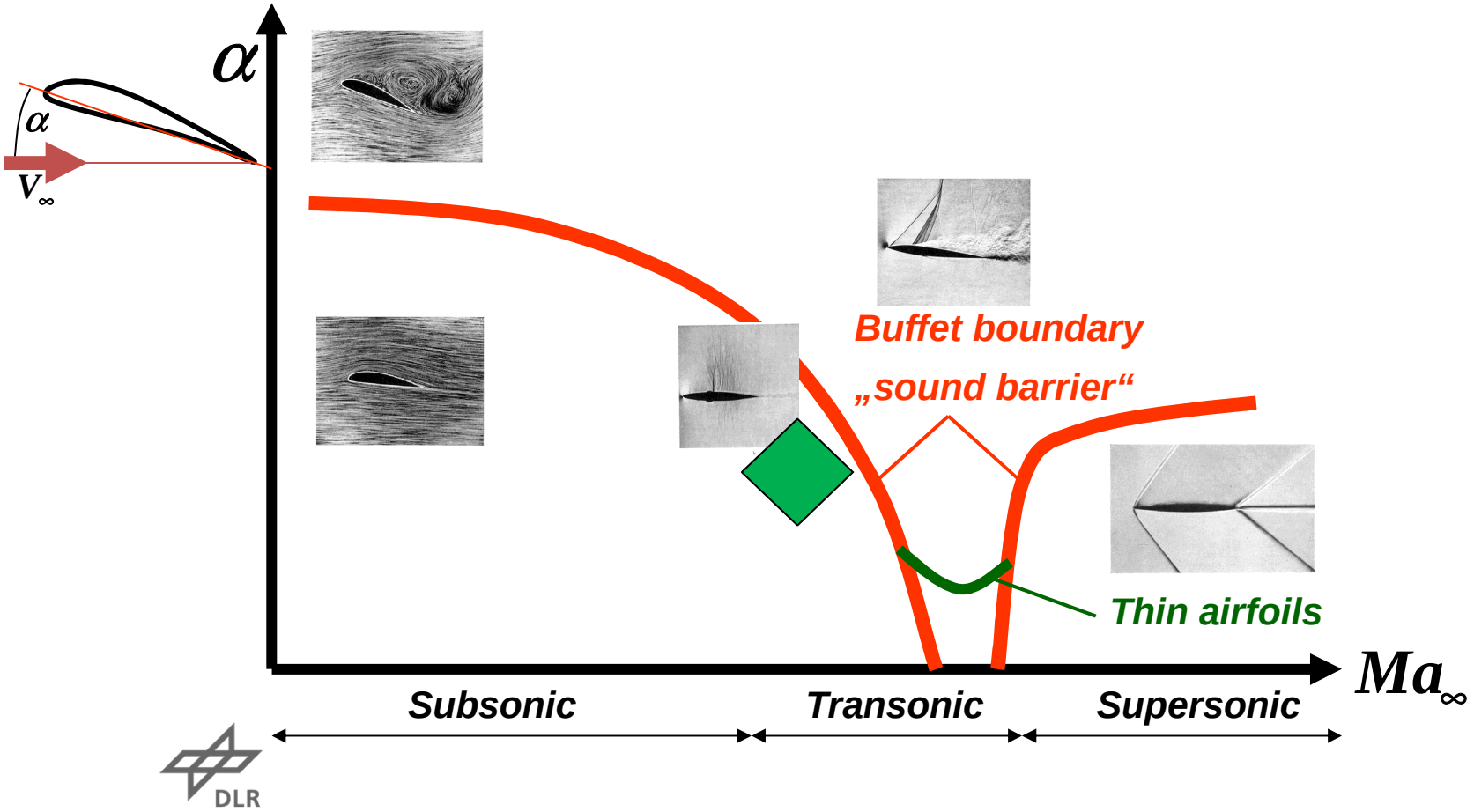


Flight Envelope

Aircraft Design and Operation

- **Transonic Civil Transport A/C: Cruise Design Point**

  High Mach number at low drag (close to drag rise)

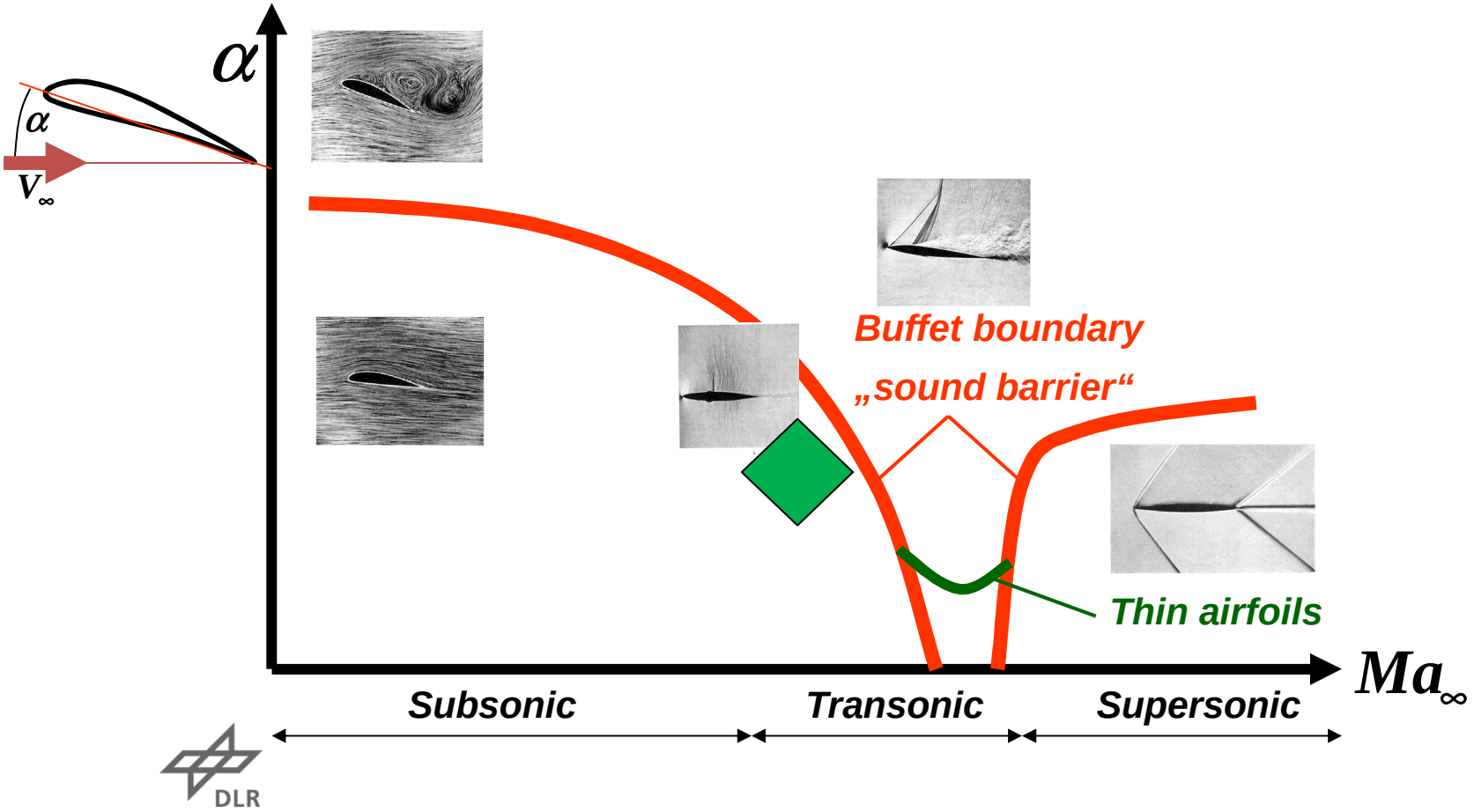


Flight Envelope

Aircraft Design and Operation

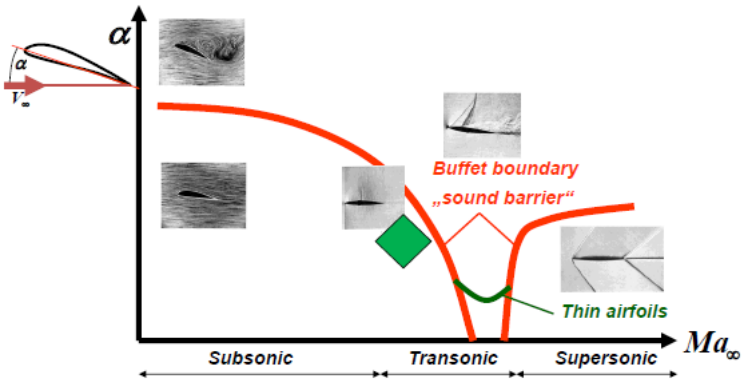
- **Increase in performance only by precise knowledge of envelope**

  Exact a/c characteristics required for drag, weight, noise reduction



Flight Envelope
Aircraft Design Data

- **Means for Assessment**



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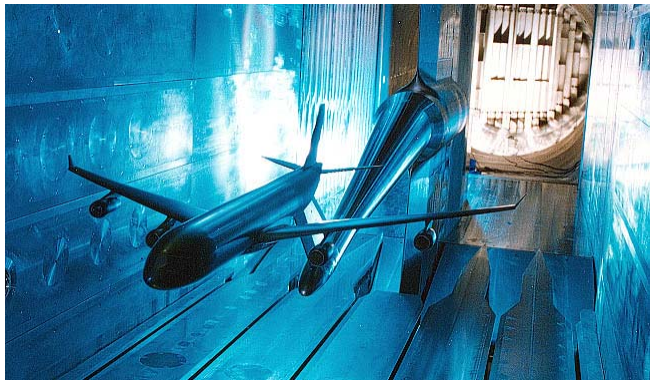
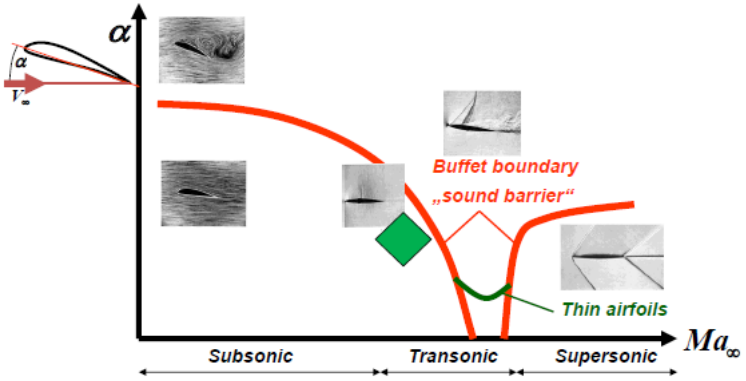
Flight Envelope
Aircraft Design Data

- **Means for Assessment** **Windtunnel**





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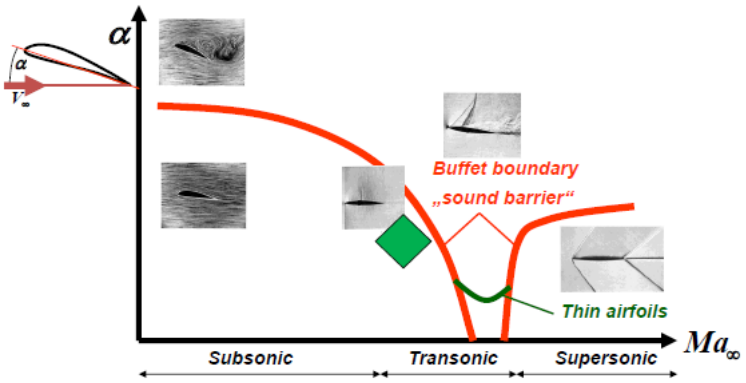
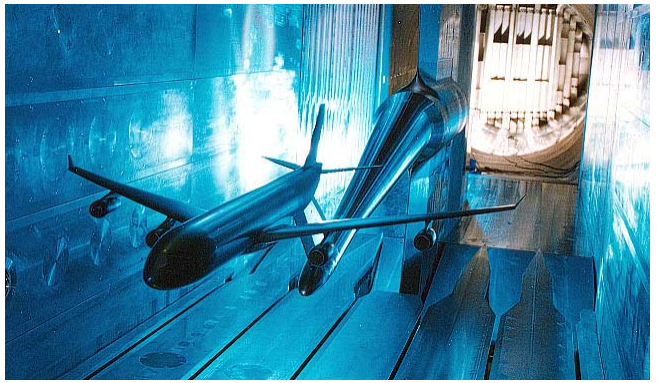
Flight Envelope
Aircraft Design Data

- **Means for Assessment**



Windtunnel



Flight Test

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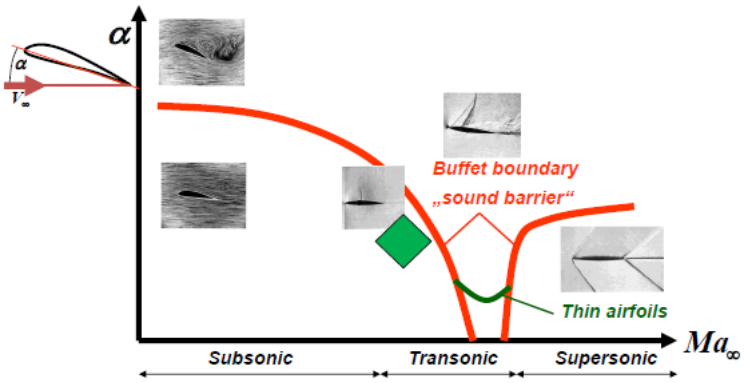
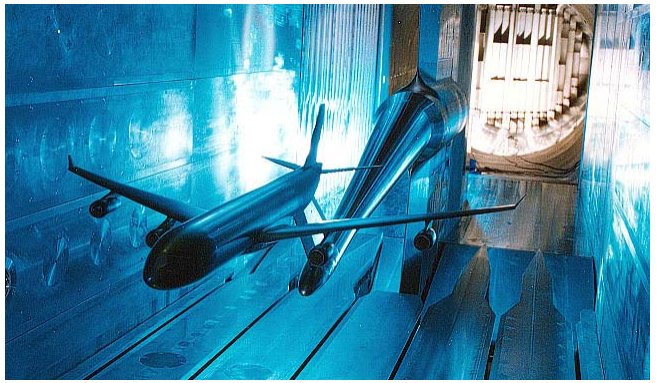
Flight Envelope
Aircraft Design Data

- **Means for Assessment**

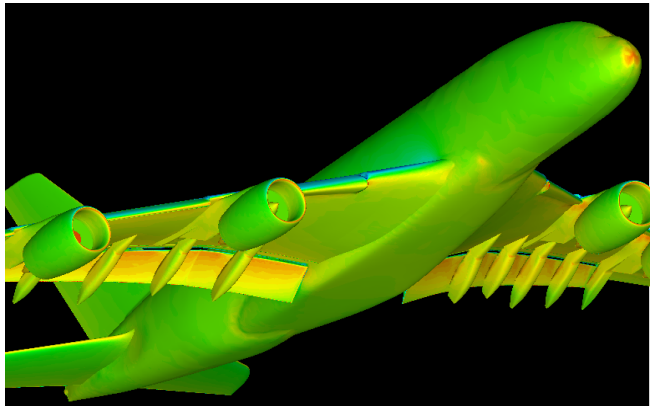


Windtunnel



Flight Test

Simulation



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Flight Testing: Relevance

- **Objectives**

  Technological concepts: **Demonstration (feasibility & benefit)**

  Physical information: **Knowledge & Validation**

- **Significance: Mastering of Challenges**

  Human flight: **Lilienthal**

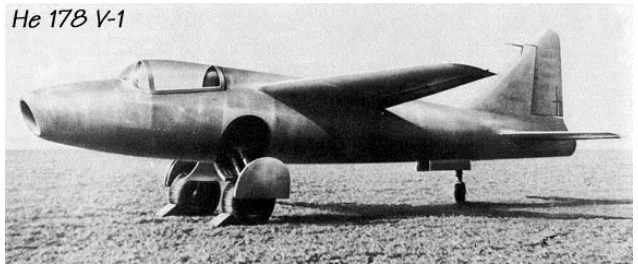
  Powered flight: **Wright et al.**

  Jet propulsion: **Heinkel, He 178**

  Swept wing: **Junkers, Boeing**

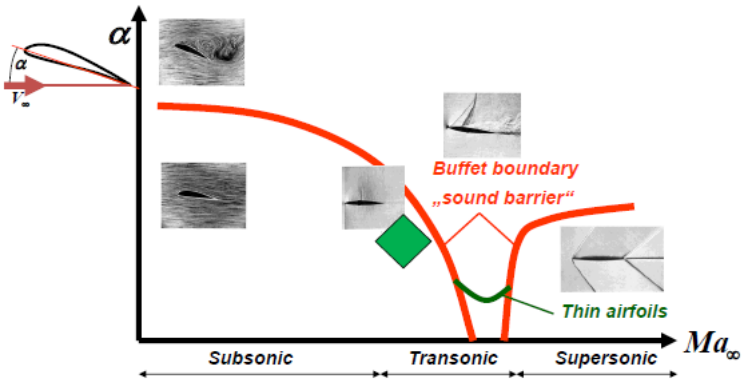
  Supersonic flight: **Yeager, Bell X-1**

  Supercritical Wing: **Whitcomb, F-8**



„The Right Stuff“

Flight Testing: Campaigns



Laminar Flow

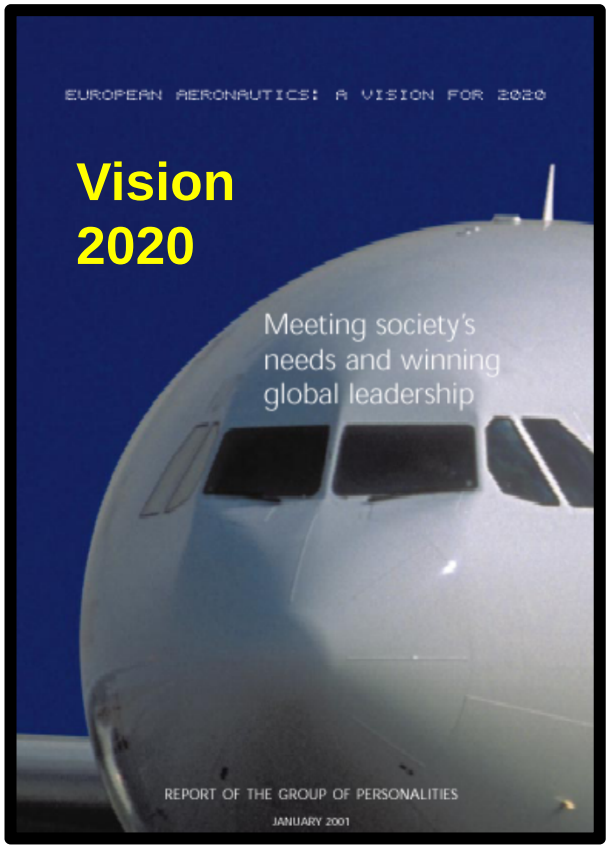
Load Control

Validation

Engines

Configurations

Motivation & Physics II



Why Future Flight Testing ?

- 50% CO_2
- 50% Perceived Noise

- 75% CO_2
- 65% Perceived Noise
- Industrial Competitiveness

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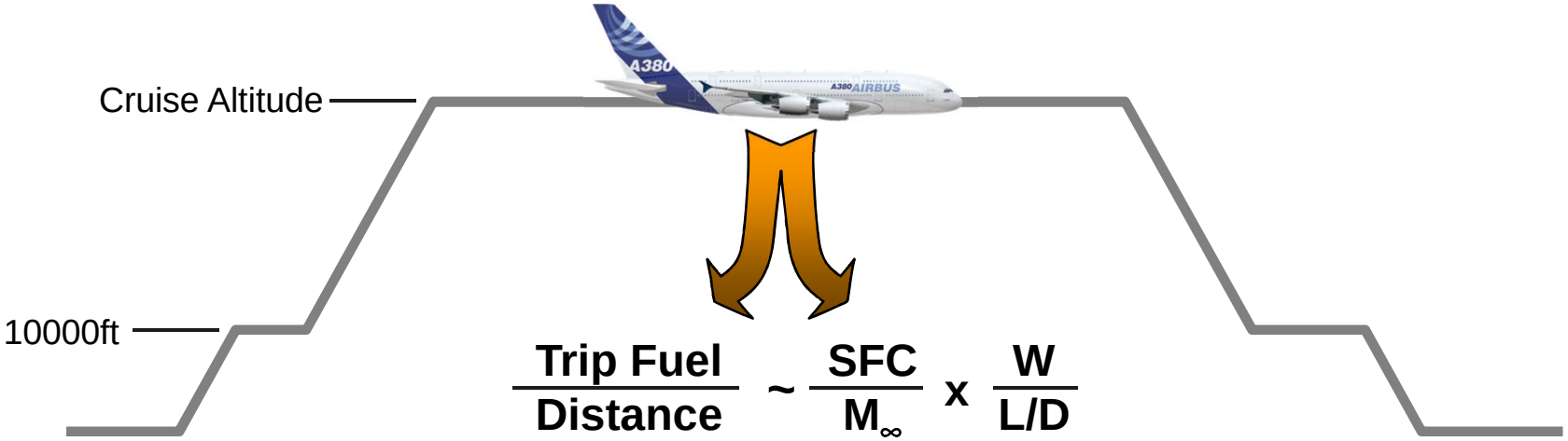
Motivation & Physics II

A/C Fuel Consumption: Main Parameters of Influence



$$\frac{\text{Trip Fuel}}{\text{Distance}} \sim \frac{\text{SFC}}{M_\infty} \times \frac{W}{L/D}$$

- **Breguet-Formula**
  - **SFC:** **Specific Fuel Consumption** **=> Propulsion**
  - **W:** **Weight** **=> Structures**
  - **L/D:** **Lift to Drag ratio** **=> Aerodynamics**
  - **M_∞ :** **Cruise Mach number** **=> Aerodynamics/Propulsion**

More of the same?

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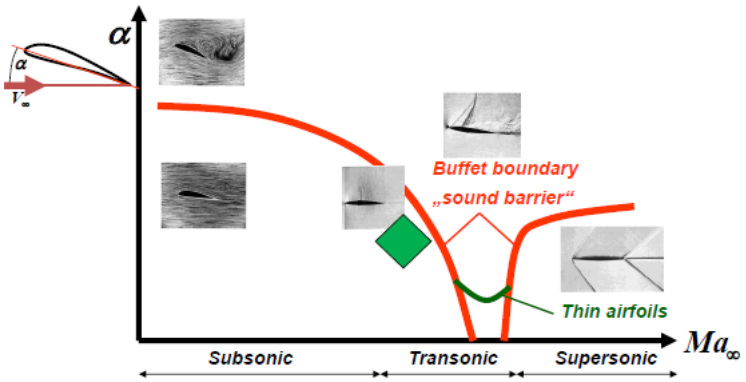
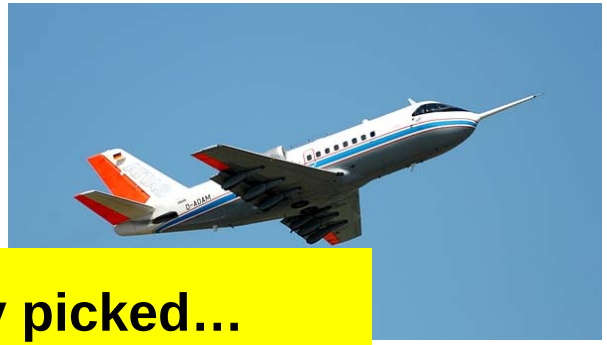
Technological Perspectives



Laminar Flow

Load Control



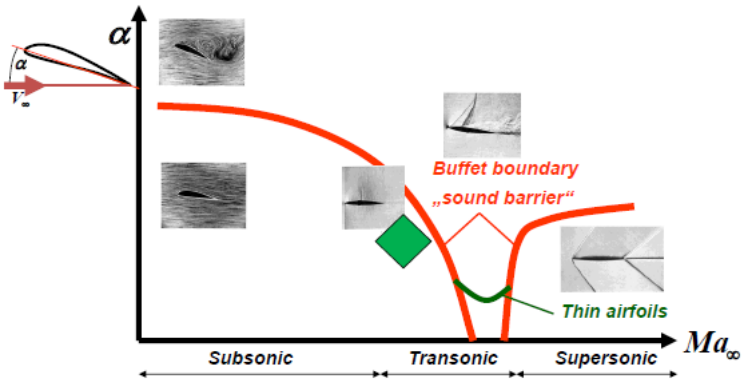
Yes, but the low-hanging fruits were already picked…

Validation

Engines

Configurations

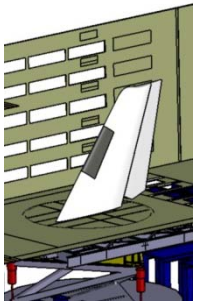
Technological Perspectives



Laminar Flow

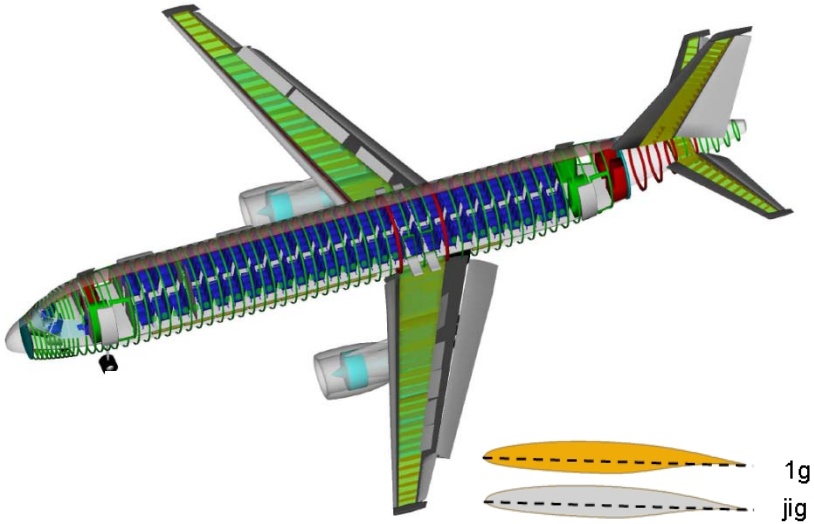
Hybrid Laminar Flow Control

From ground to flight test



Natural Laminar Flow Control

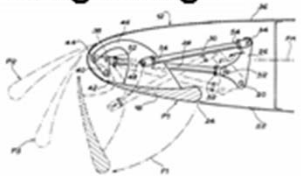
Unconventional Configuration

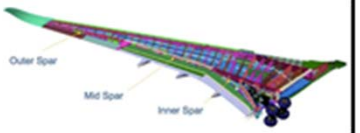


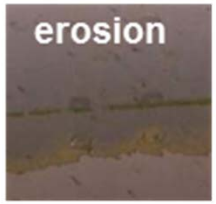
1g flight shape

jig shape

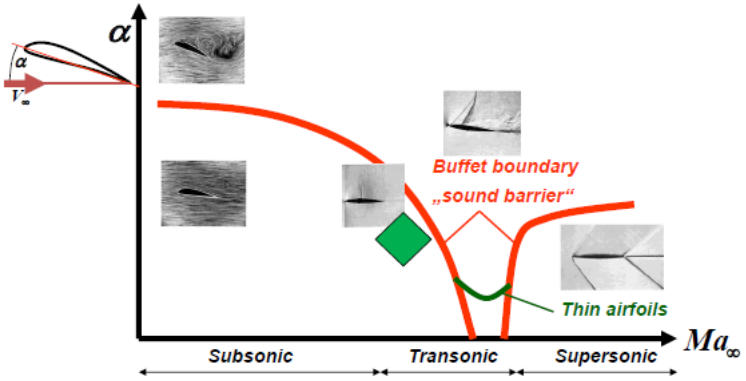
Function integrated Wing Design



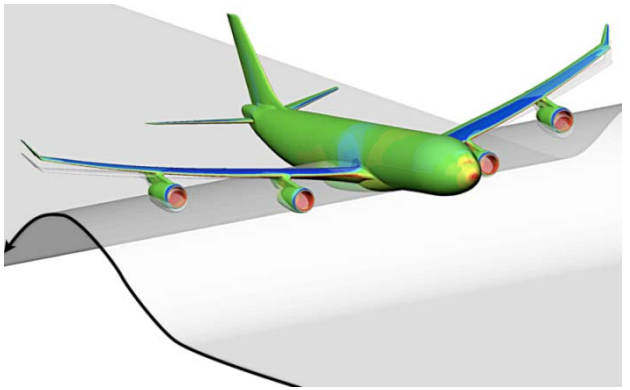


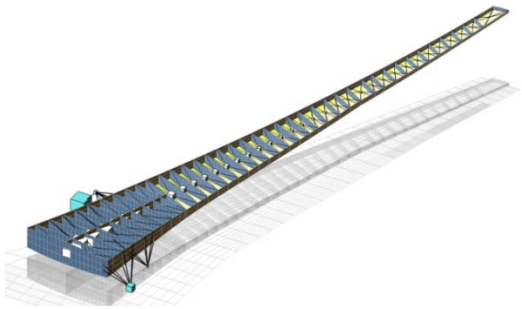


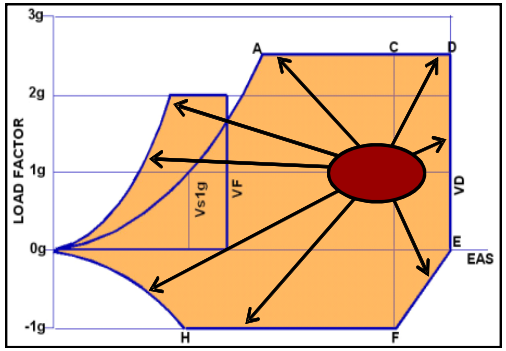
Technological Perspectives



Load Control

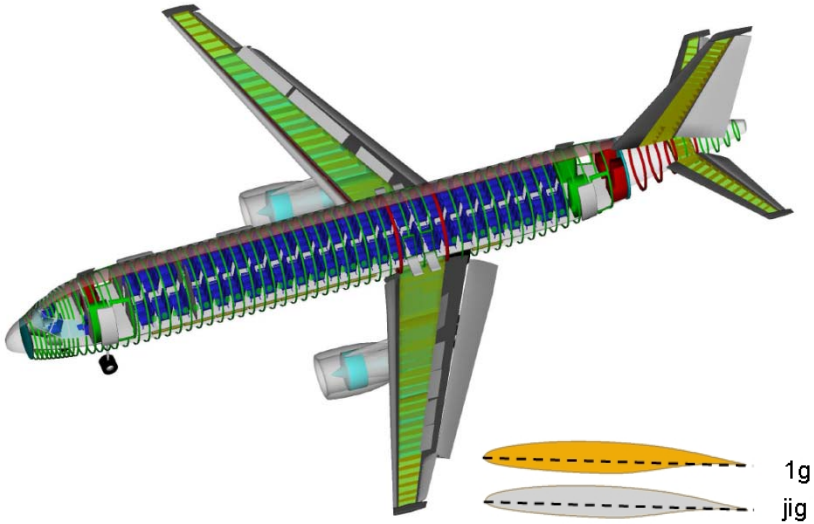






Natural Laminar Flow Control

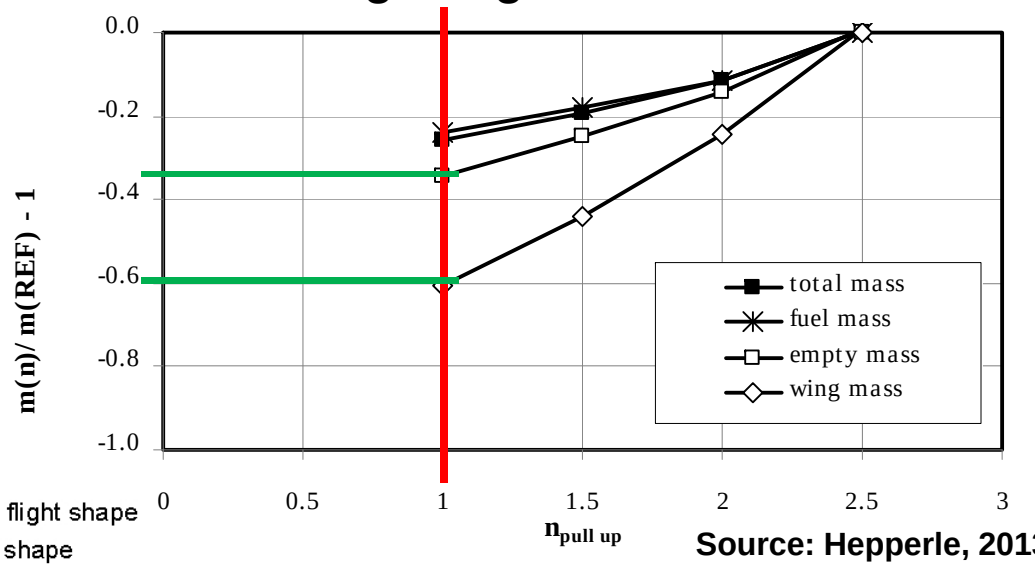
Unconventional Configuration



1g flight shape

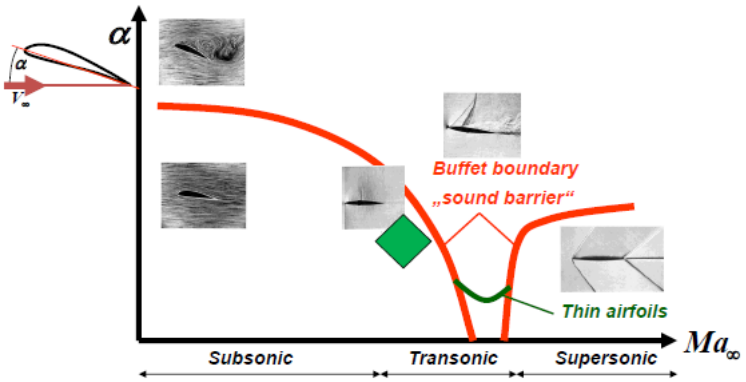
jig shape

1g Wing



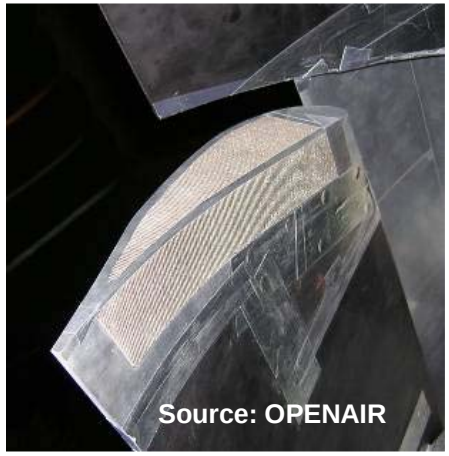
Source: Hepperle, 2013

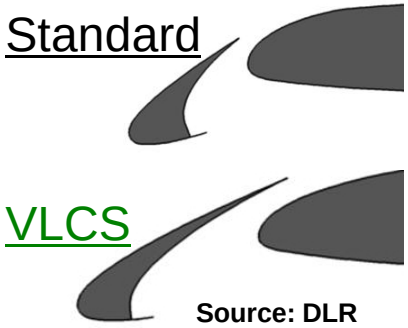
Technological Perspectives



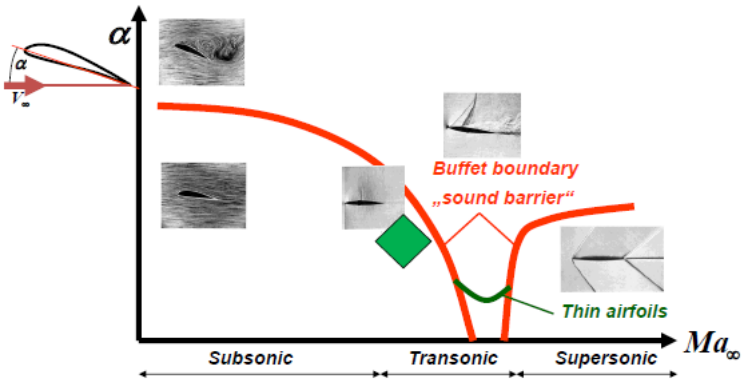
Noise Reduction

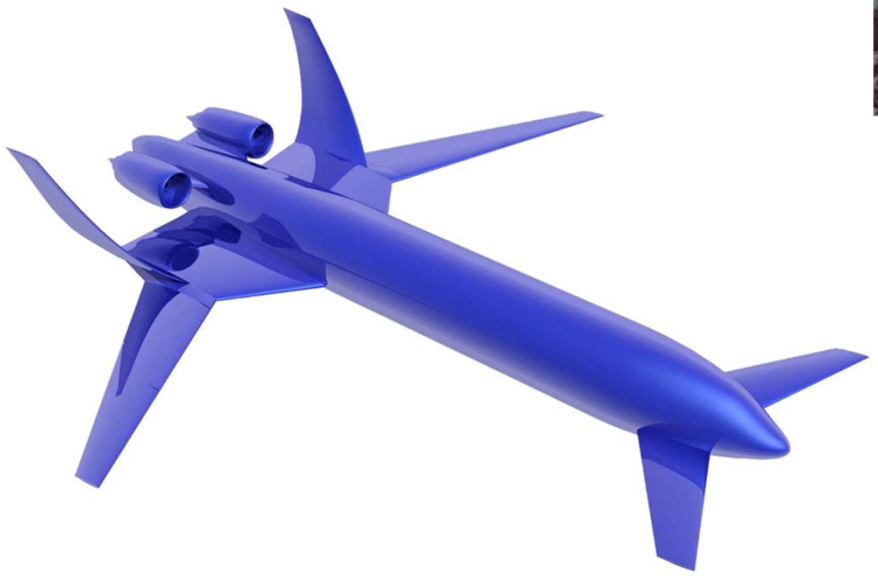
Low Noise Configuration I





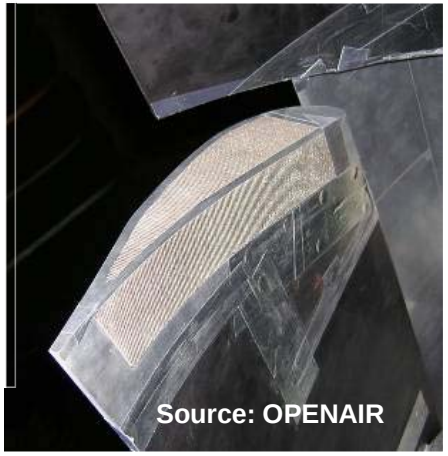
Technological Perspectives





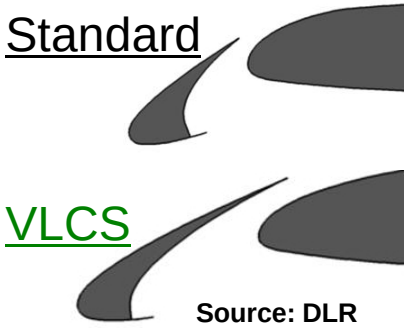
Noise Reduction

Low Noise Configuration II

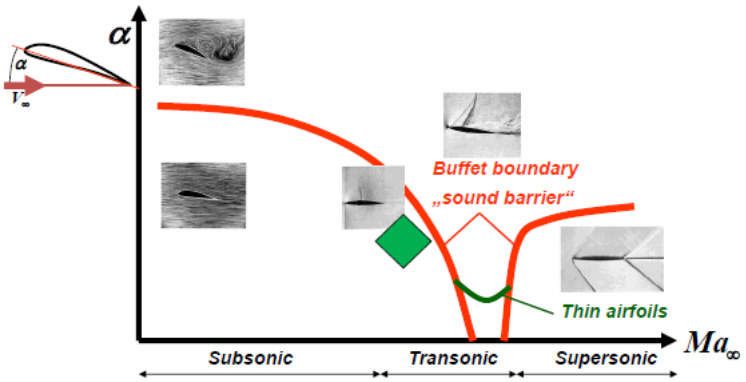


Standard

VLCS

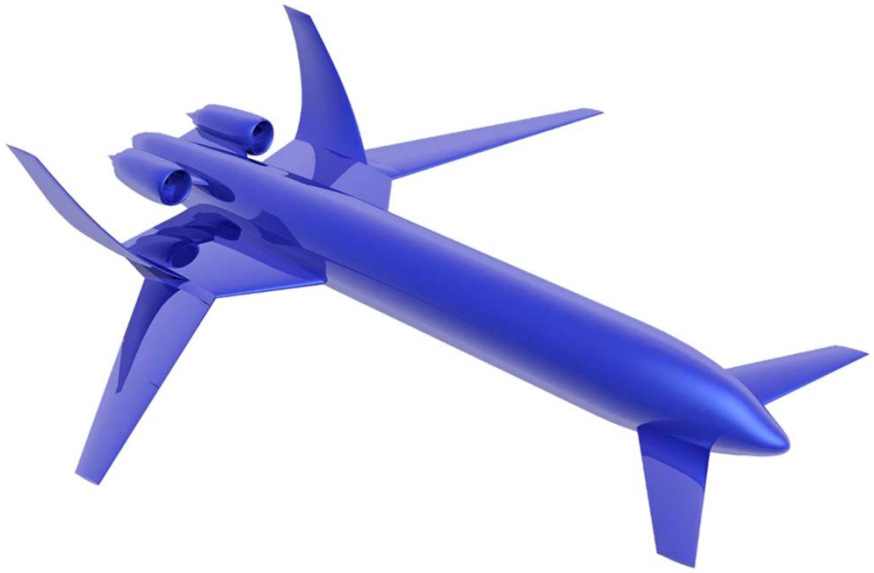


Technological Perspectives



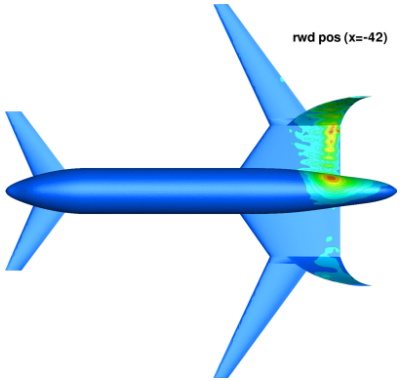
Noise Reduction

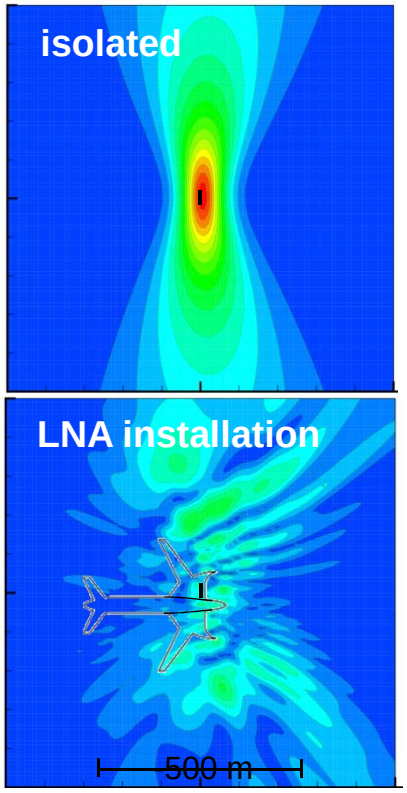
Low Noise Configuration II



DLR LNA

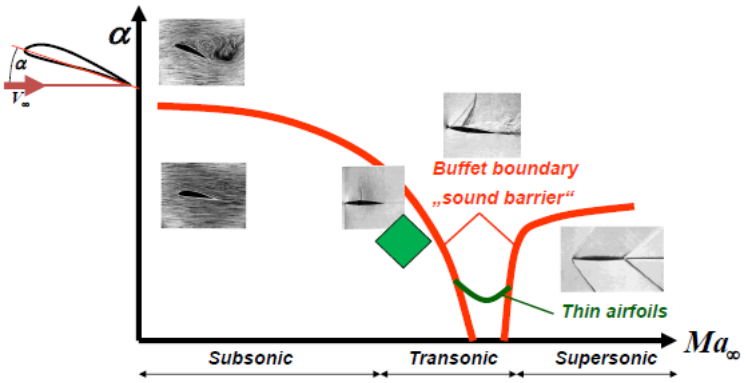
Shielding Concept



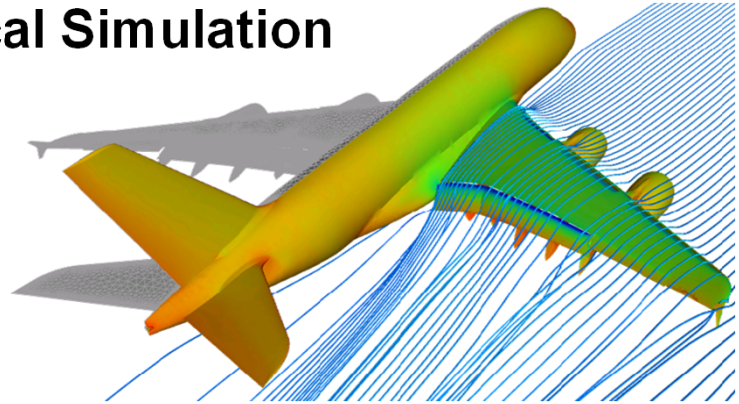


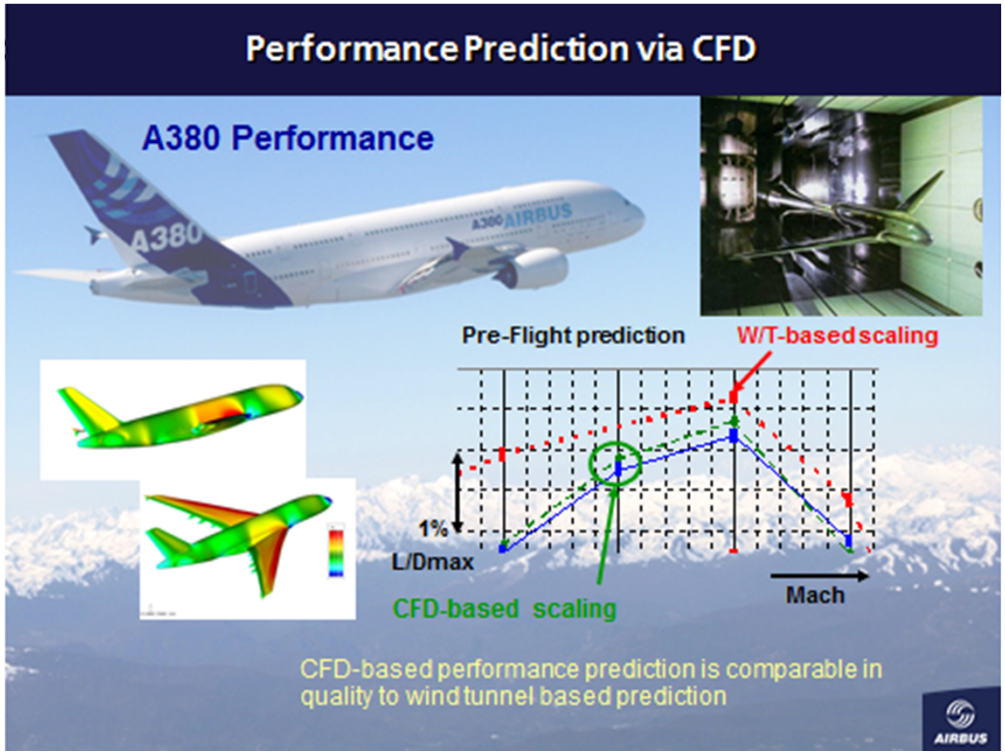
10-12 dB Noise Reduction

Technological Perspectives

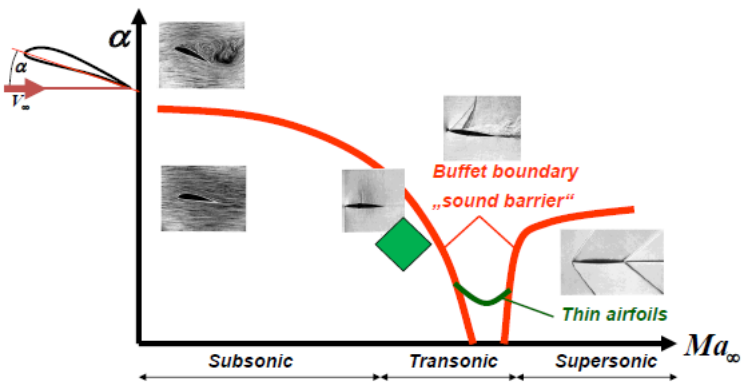


Numerical Simulation

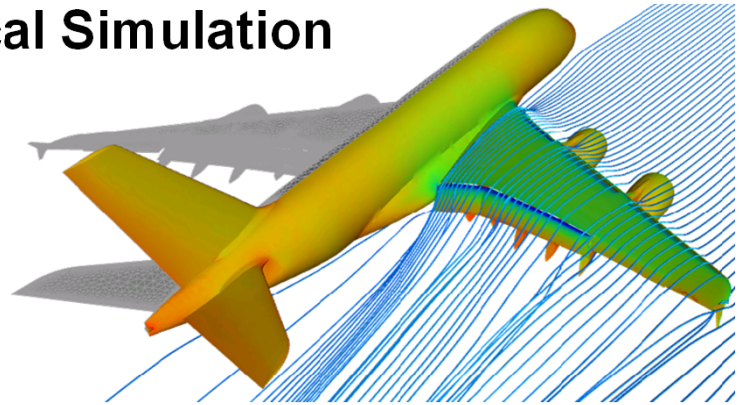




Technological Perspectives

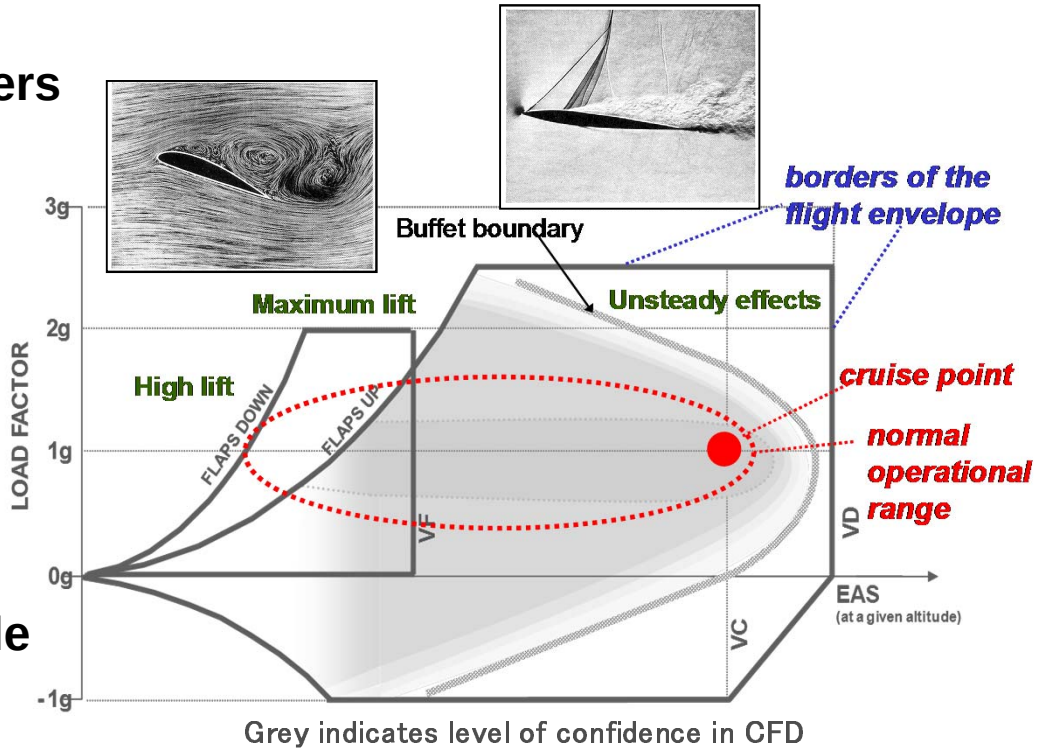


Numerical Simulation



Validation @ full envelope + maneuvers

Comprehensive data only achievable by dedicated flight testing



Characteristics of Flight Testing

Special requirements of flight testing

- **Very high cost: operation & maintenance of a/c, long idle periods**
- **Highly skilled personnel: certification of changes, experiments, etc.**
- **Limited access to physical information: observer is part of experiment**
- **Very specialized measurement technologies required**

➡ **F/T only, if no other test technique applicable**

DLR

Conclusion

- **Flight testing requires**
  - Careful planning and execution
  - High effort of time and cost
- **Flight testing provides**
  - Unique data for knowledge & validation
  - Sustainable technological demonstration
- **Flight testing stands for**
  - Ultimate proof in research & science
  - Decisive advantage in competitiveness
- **Flight testing is**

“The Right Stuff”