



The European Transonic Windtunnel ETW

Unique Test Capabilities up to Flight Conditions

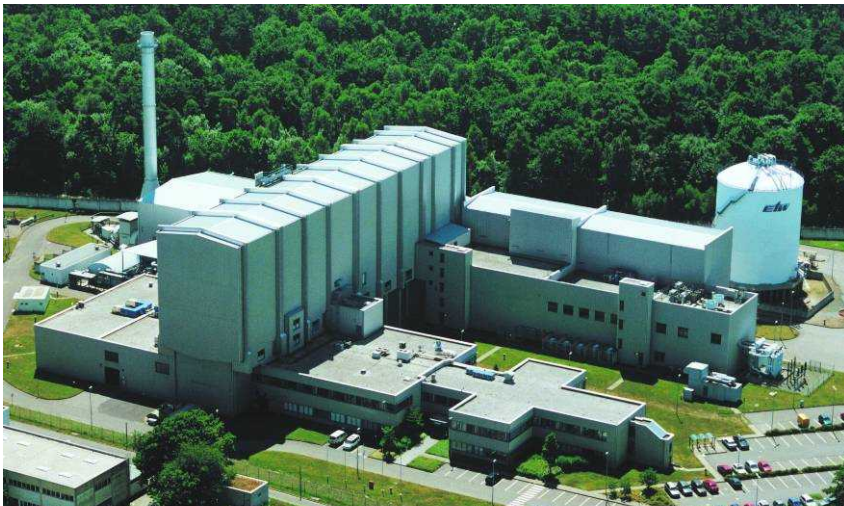
Konferencję Mechaniki Płynów
22 September 2008

Dieter SCHIMANSKI
Manager Tests and Operations

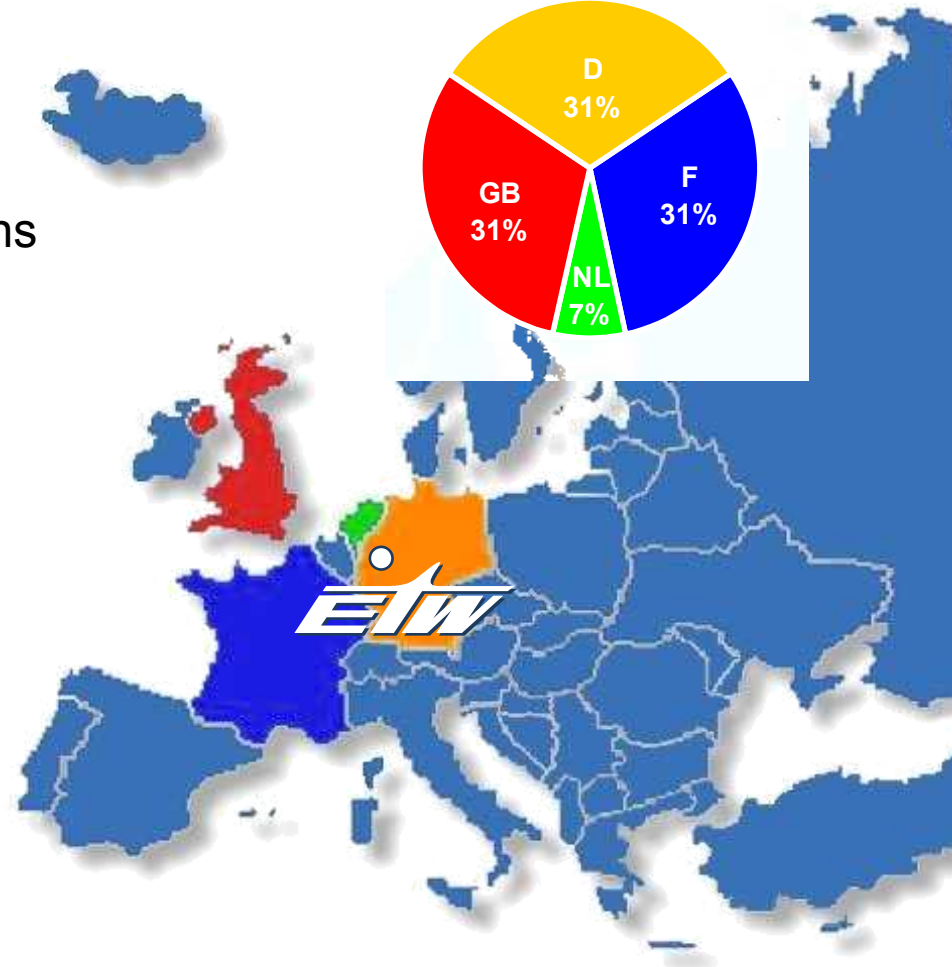
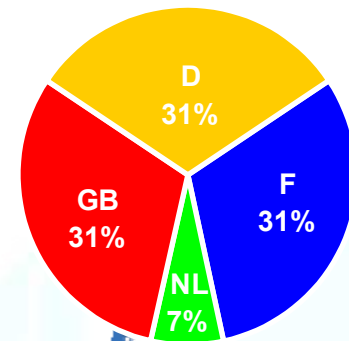


ETW Company at a glance

- > Limited-liability company
- > Self-supporting / non-profit policy
- > 35 employees in Cologne, Germany
- > Enclosed, secured site
- > Military-compliant security preservasions
- > Easy to reach by plane, train, and car



Shareholders



ETW History at a glance

1977 – 1985 Preliminary Design

1986 – 1988 Final Design

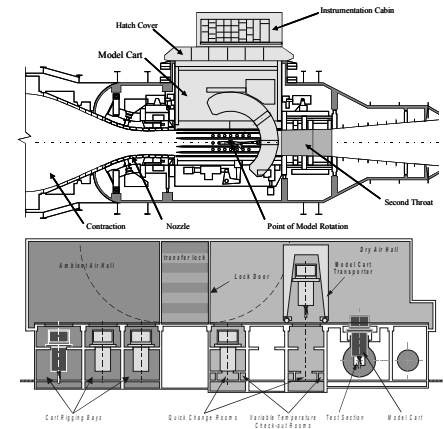
♦ 1988 ETW GmbH founded

1989 – 1993 Design and Construction

♦ 1993 Wind ON

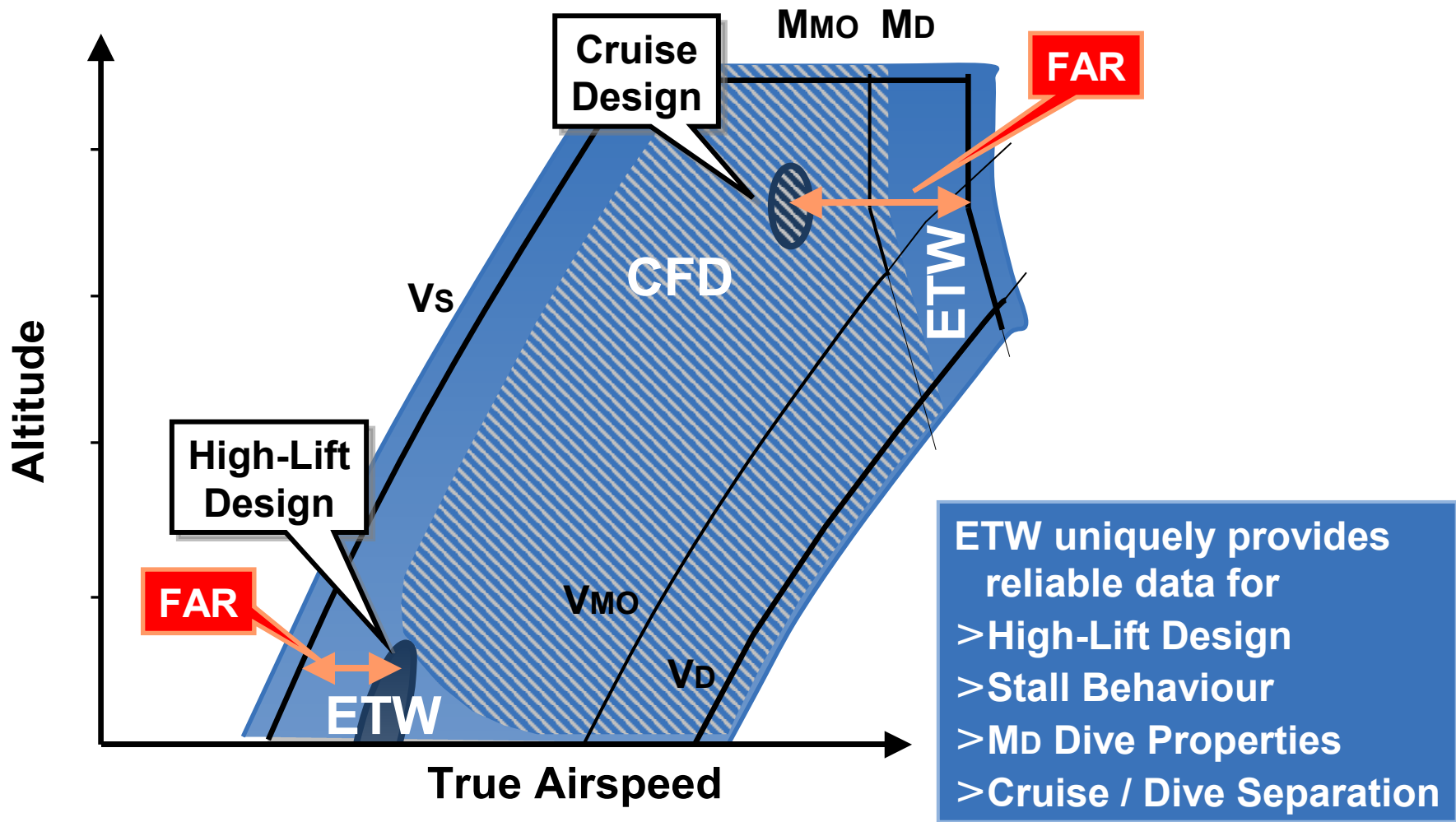
1994 – 2000 Initial Operation

Since 1995 Client Testing



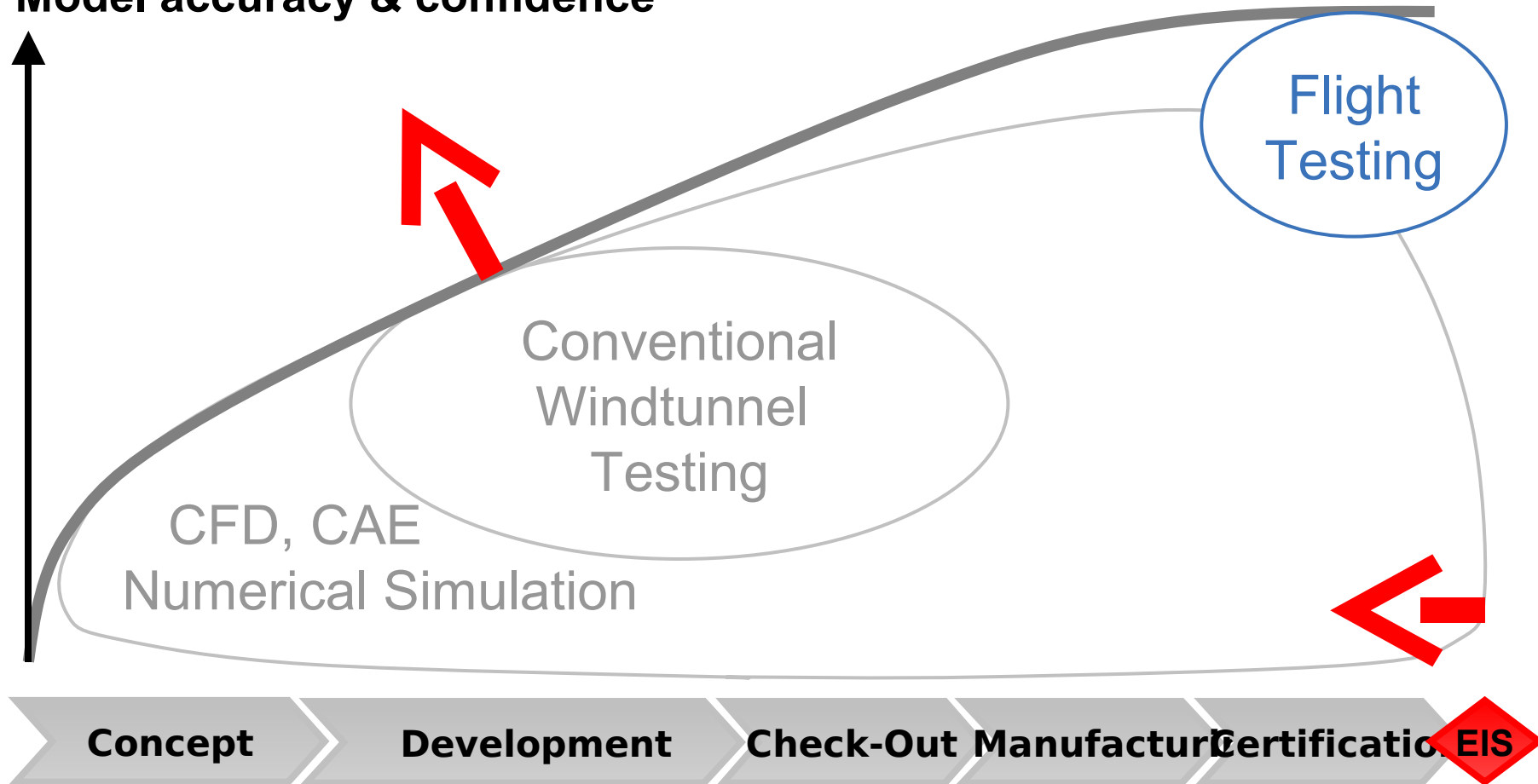
Full-scale-like Flight Reynolds Number Test Capability

Flight Envelope – Doghouse Plot



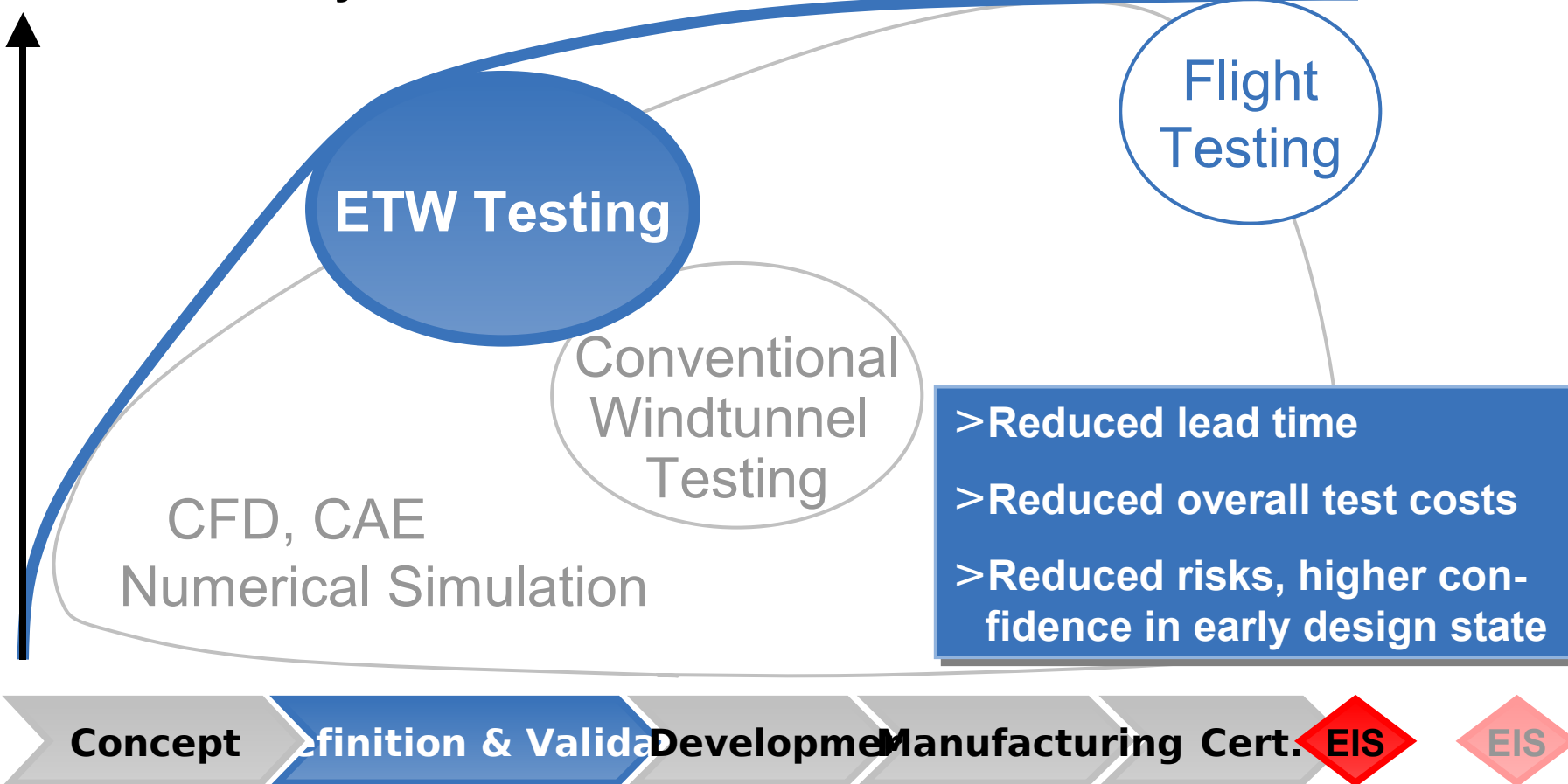
ETW Complements the Aircraft Development Process and enables better solutions faster at lower risks

Model accuracy & confidence

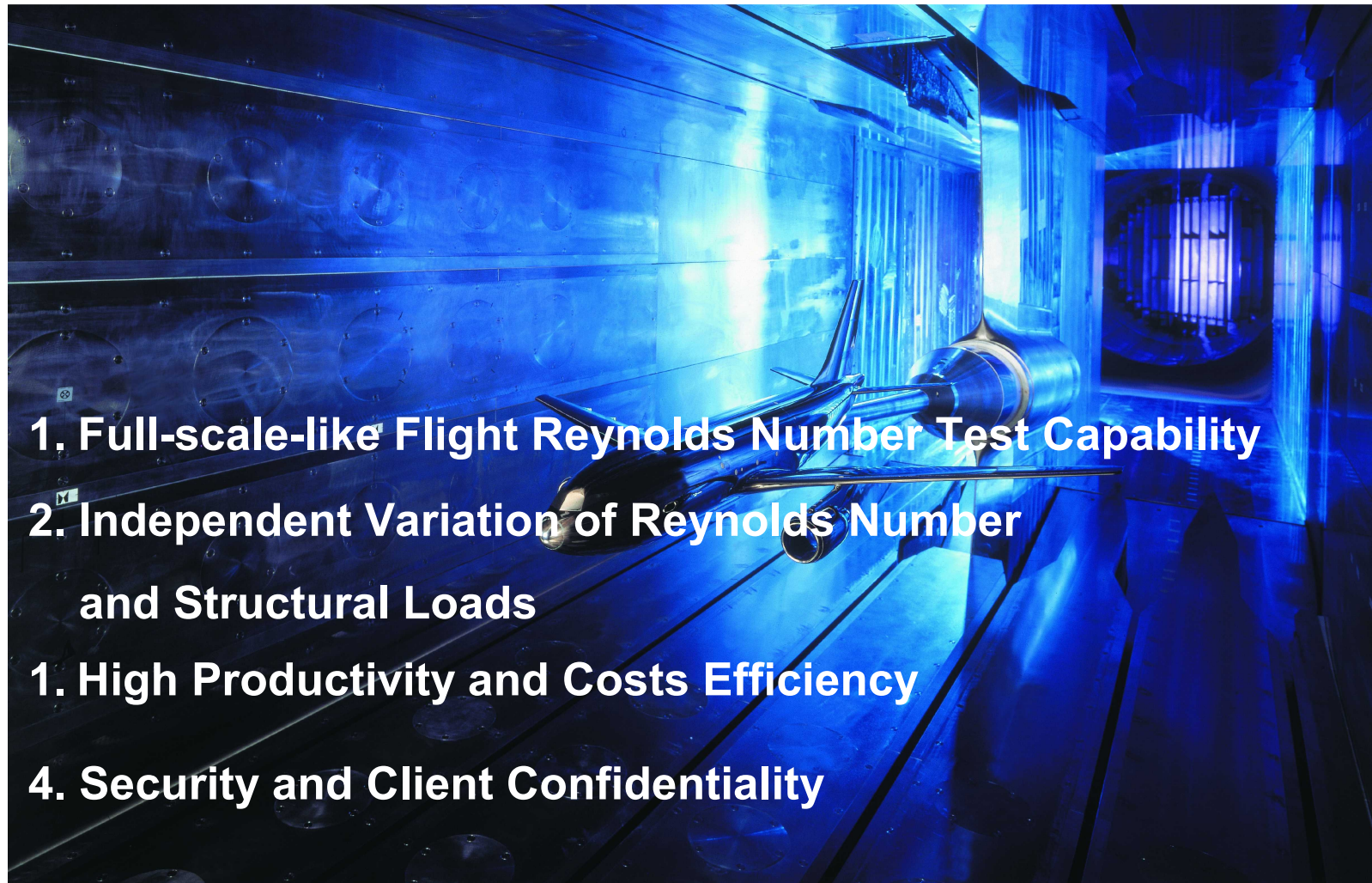


ETW Complements the Aircraft Development Process and enables better solutions faster at lower risks

Model accuracy & confidence



ETW is a Unique, Worldwide Leading Facility with respect to time-cost-quality



1. Full-scale-like Flight Reynolds Number Test Capability

**2. Independent Variation of Reynolds Number
and Structural Loads**

1. High Productivity and Costs Efficiency

4. Security and Client Confidentiality

ETW is a Unique, Worldwide Leading Facility with respect to time-cost-quality

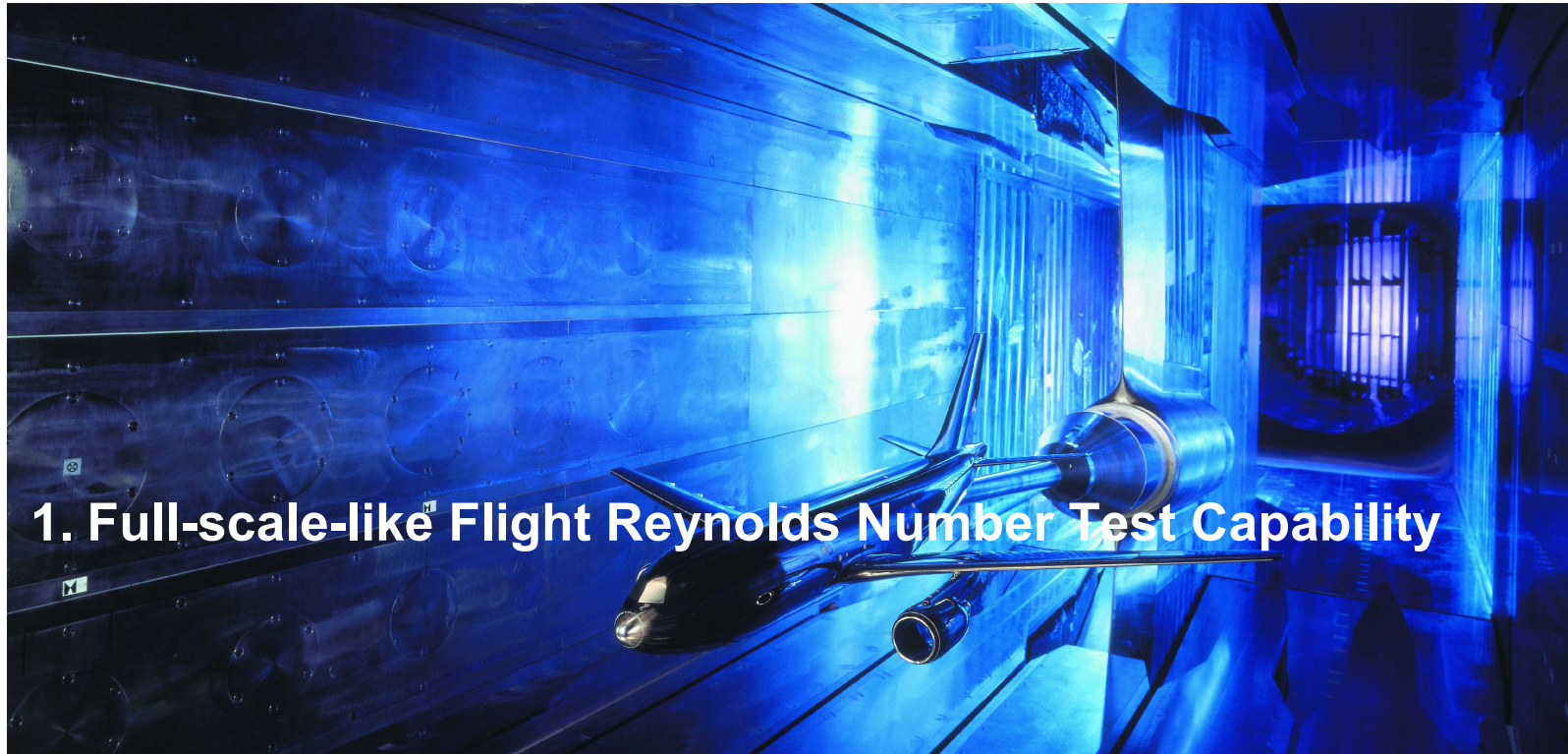
3. Full-scale-like Flight Reynolds Number Test Capability

- Allows early confidence in meeting design requirements
- Reduces risk of late design modifications and costly rework
- Is fast and reliable even for partly separated and/or unsteady flow

4. Independent Variation of Reynolds Number and Structural Loads

- > High Productivity and Costs Efficiency
- > Security and Client Confidentiality

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1. Full-scale-like Flight Reynolds Number Test Capability

NOT using Flight-Reynolds number testing formerly led to ...

- \$ 1 billion retrofit costs of wing structures (1964!)
- 300 kg tail ballast
- trim weights, too heavy structures, limited performance, etc.

1. Full-scale-like Flight Reynolds Number Test Capability

ETW specifications and Reynolds number envelope
Cryogenic, Gottingen-type tunnel

Test Section 2.4 m x 2.0 m
Slotted Walls 0% - 7.4%

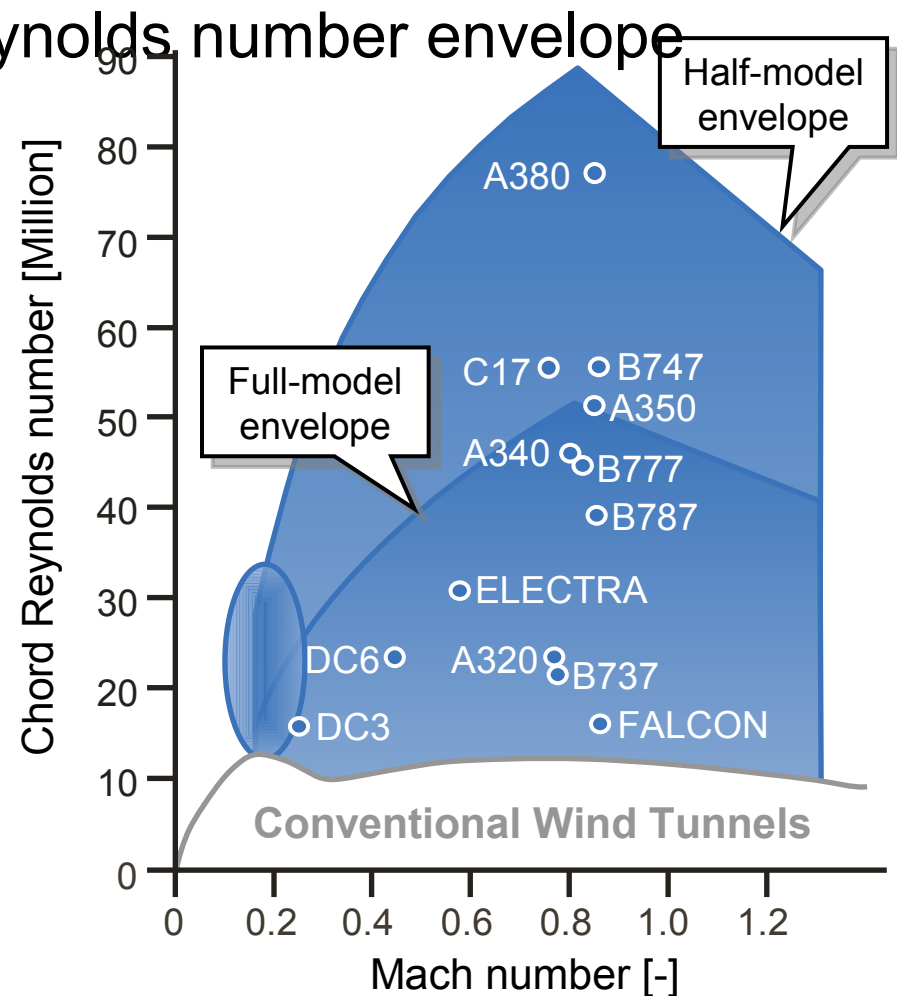
Mach Number **0.15 - 1.35**
Stability $\pm 0.0005 - \pm 0.0010$

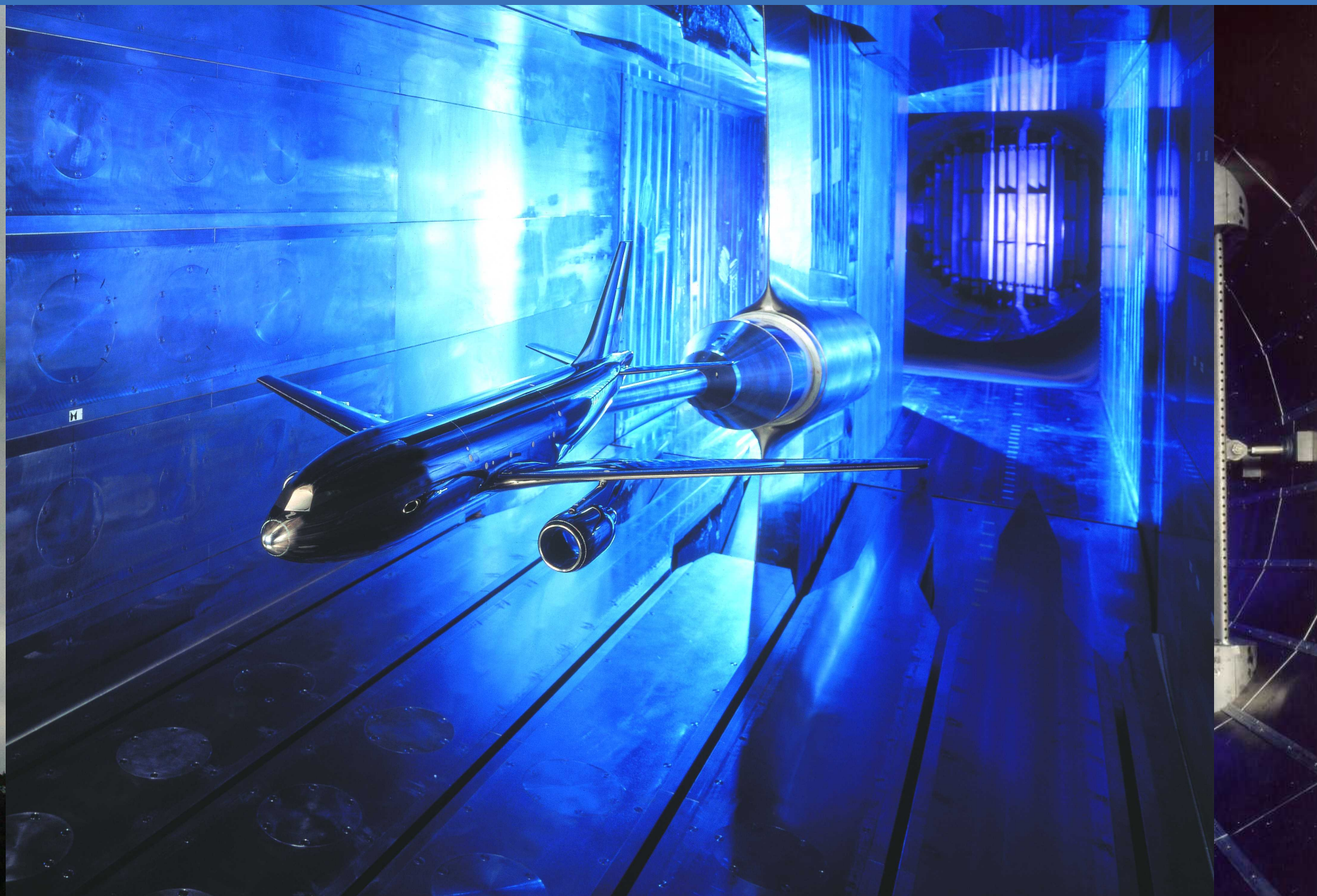
Total Pressure **1.15 bar - 4.5 bar**
Stability $\pm 0.1\%$

Temperature **110 K - 313 K**
Stability ± 0.25 K

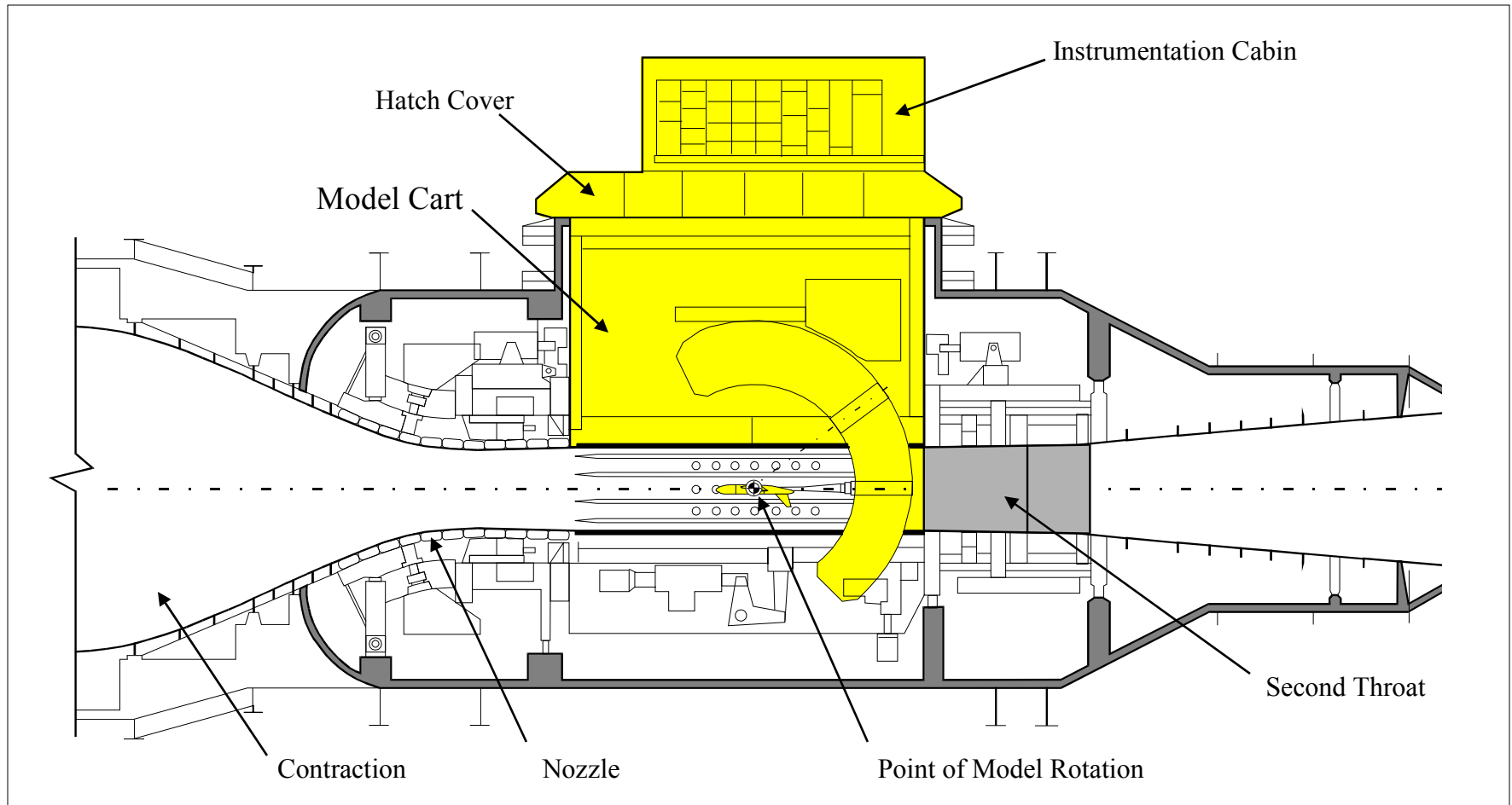
Max. Reynolds number 50 million
full-span models

Max. Reynolds number 90 million
semi-span models





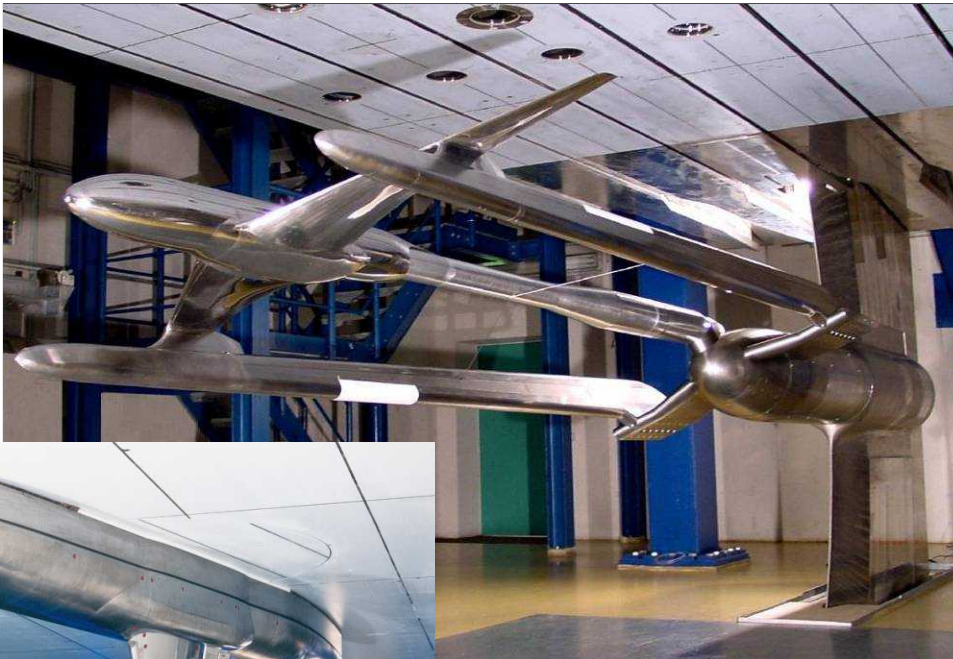
- **Full-scale-like Flight Reynolds Number Test Capability**
Model Cart Considerations





- **Full-scale-like Flight Reynolds Number Test Capability**
High Reynolds Number Testing

Transport Aircraft

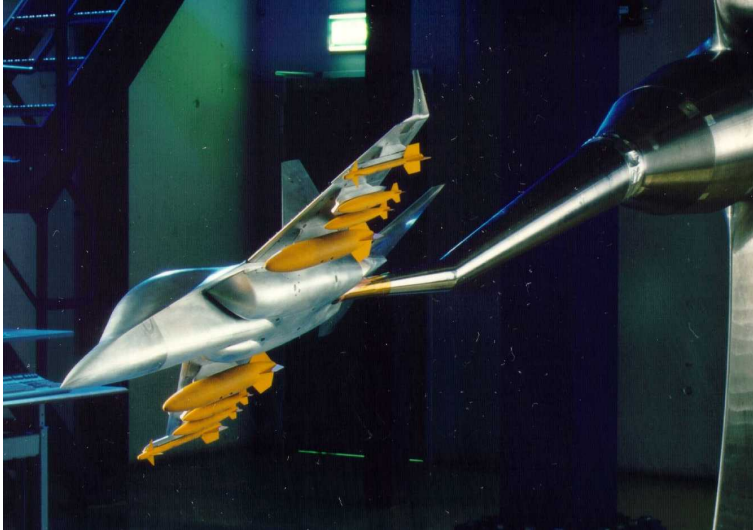


- **Full-scale-like Flight Reynolds Number Test Capability**
High Reynolds Number Testing

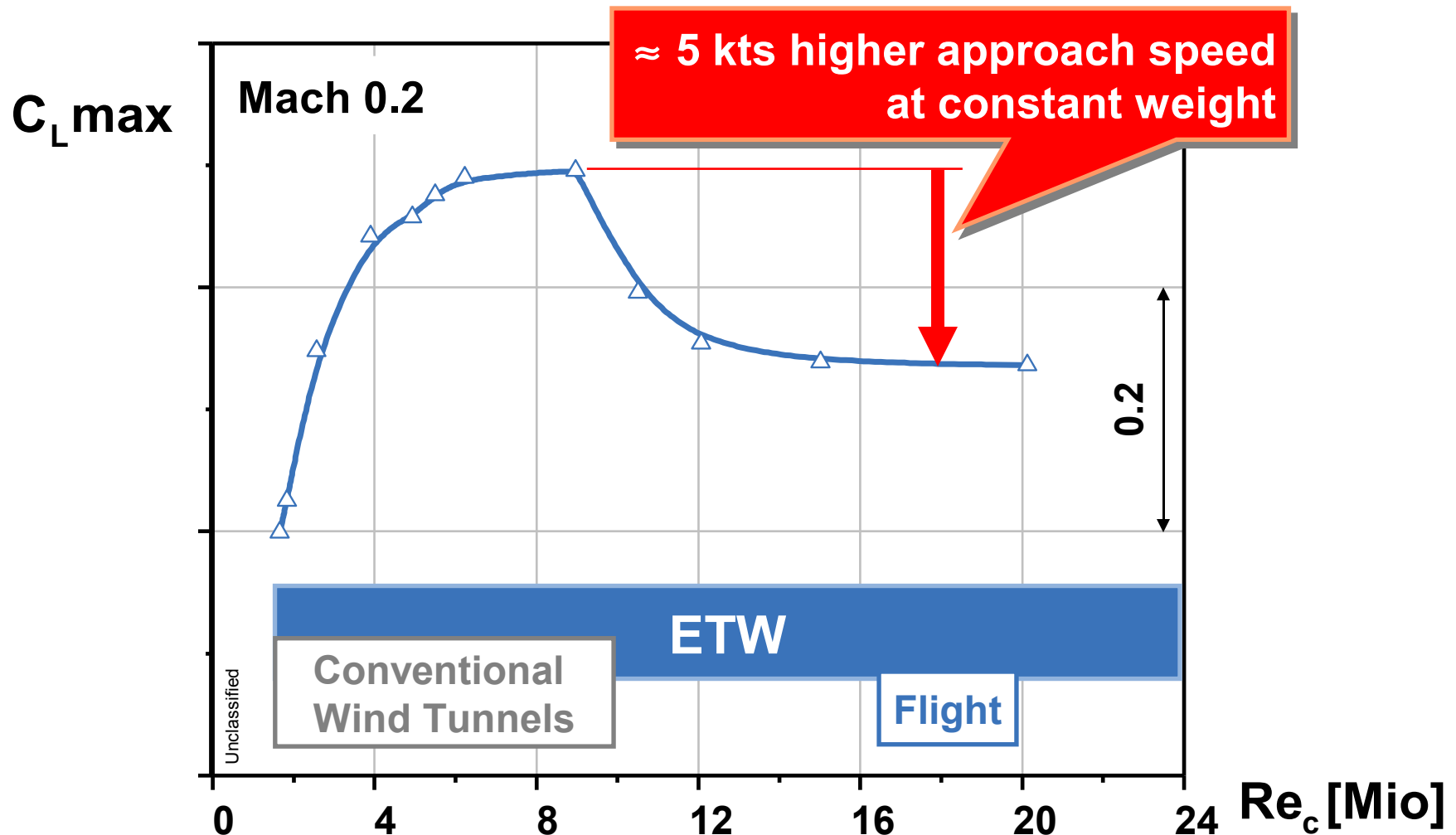
Business Jets



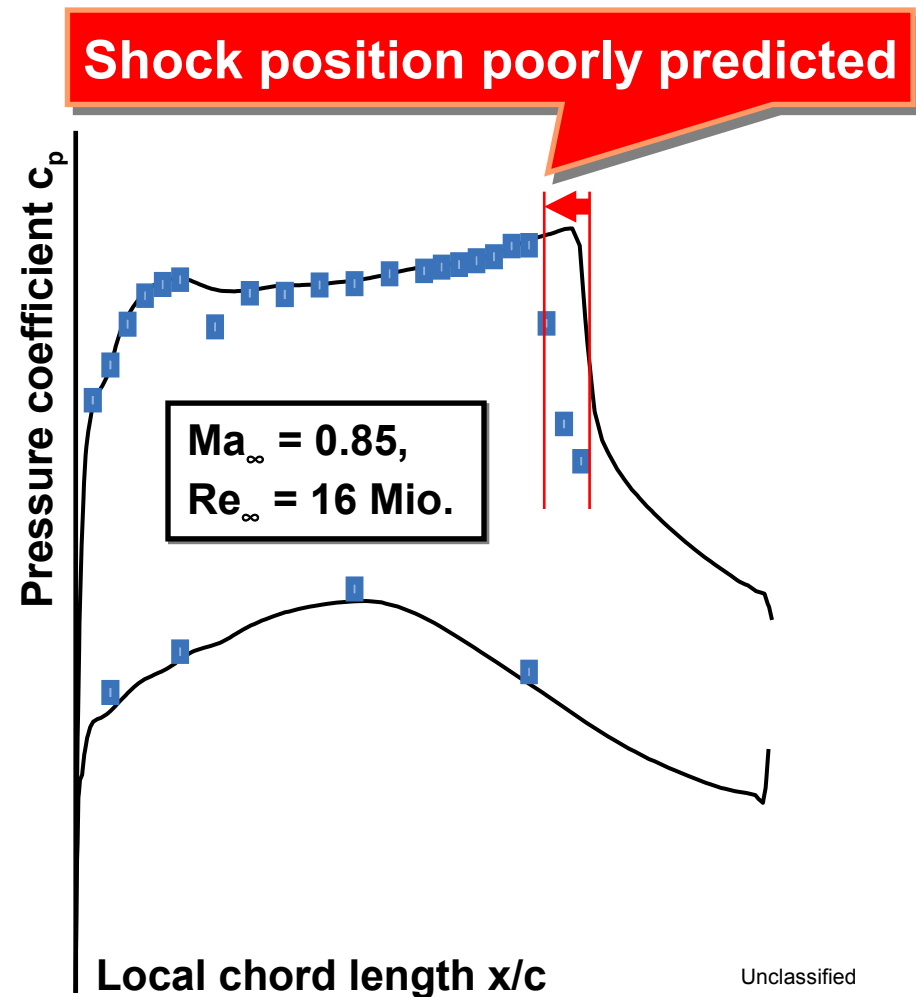
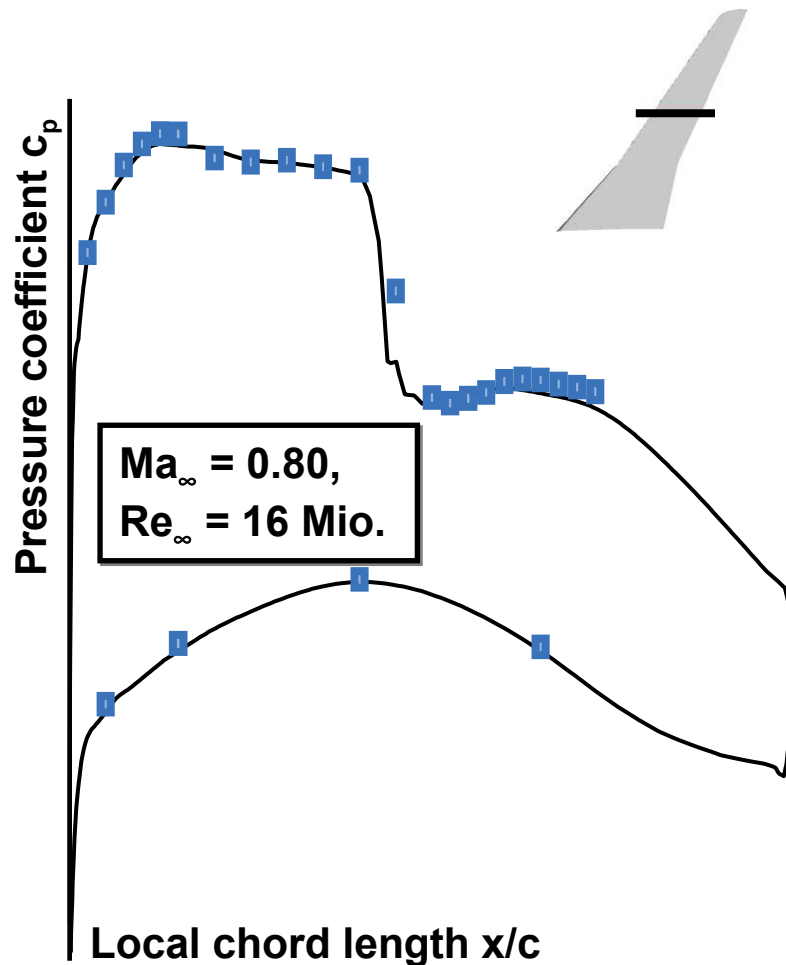
- **Full-scale-like Flight Reynolds Number Test Capability**
Military and Space



- **Full-scale-like Flight Reynolds Number Test Capability**
Reynolds-number effect on maximum lift

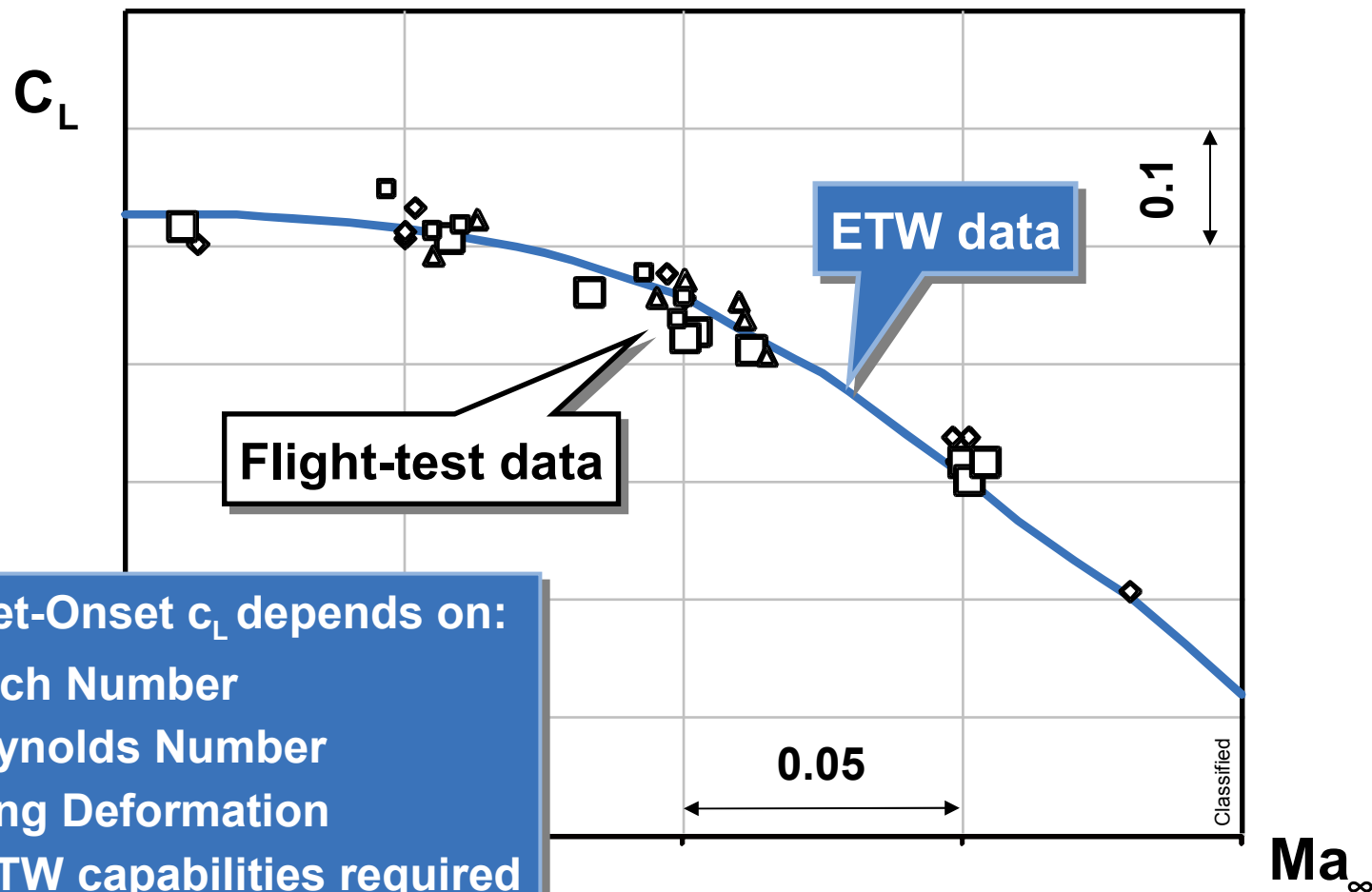


- Full-scale-like Flight Reynolds Number Test Capability**
 Pressure distribution – Comparison with RaNS-CFD data

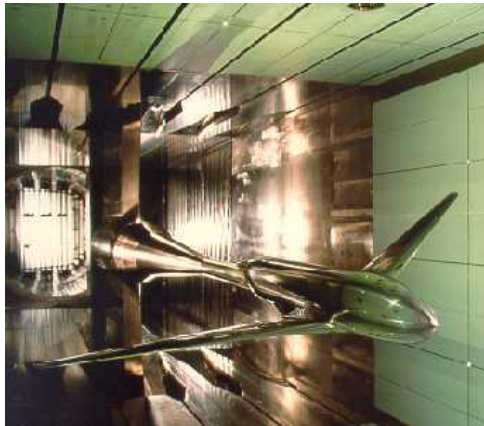


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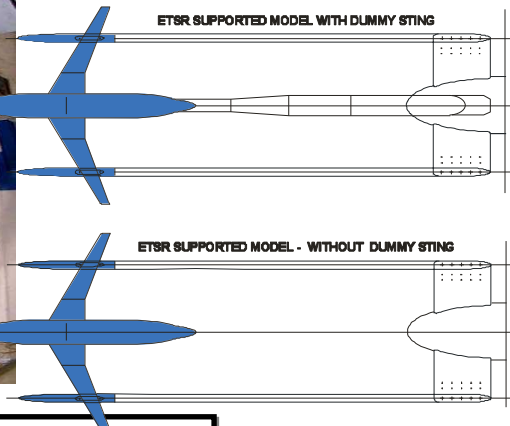
- **Full-scale-like Flight Reynolds Number Test Capability**
Buffet-onset boundary – Comparison with flight-test data



- **Full-scale-like Flight Reynolds Number Test Capability**
Data Corrections and Confidence



96% Confidence



99% Confidence

- > Performance data based on corrected low & high Reynolds data
- > Single-sting data complete model / body alone plus deformation data
- > Assessment of sting interference using CFD for the body alone config.
- > Wind-tunnel calibration data & robust wind-tunnel interference correction methodology
- > Absolute performance data
- > Low impact of sting correction method on final flight estimate
- > Prediction of flight test data with a final increment less than 1%

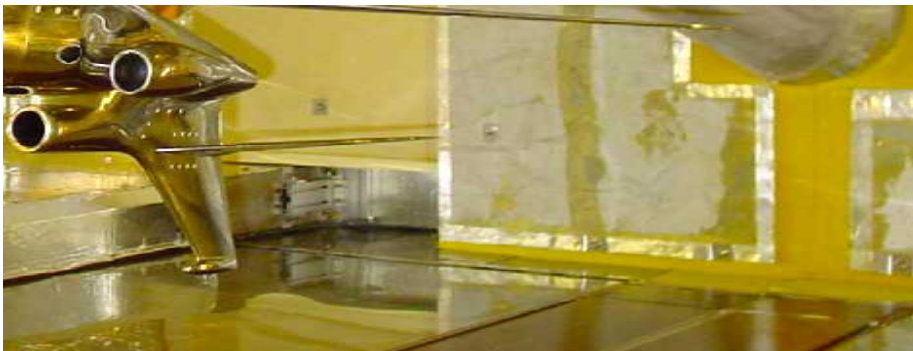
1. Full-scale-like Flight Reynolds Number Test Capability

Advanced sting designs to limit far field sting interaction



New Sting-Support Systems

- > Developed and tested within ongoing EU projects
- > First assessment of forward-blade support test data encouraging



ETW is a Unique, Worldwide Leading Facility with respect to time-cost-quality

1. Full-scale-like Flight Reynolds Number Test Capability

- Allows early confidence in meeting design requirements
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- Is fast and reliable even for partly separated and/or unsteady flow

2. Independent Variation of Reynolds Number and Structural Loads

- Enables high-performance, optimized, structurally efficient design
- Enables separation of Reynolds-number and aeroelastic distortion
- Minimizes flight testing to resolve fluid-structure interaction issues

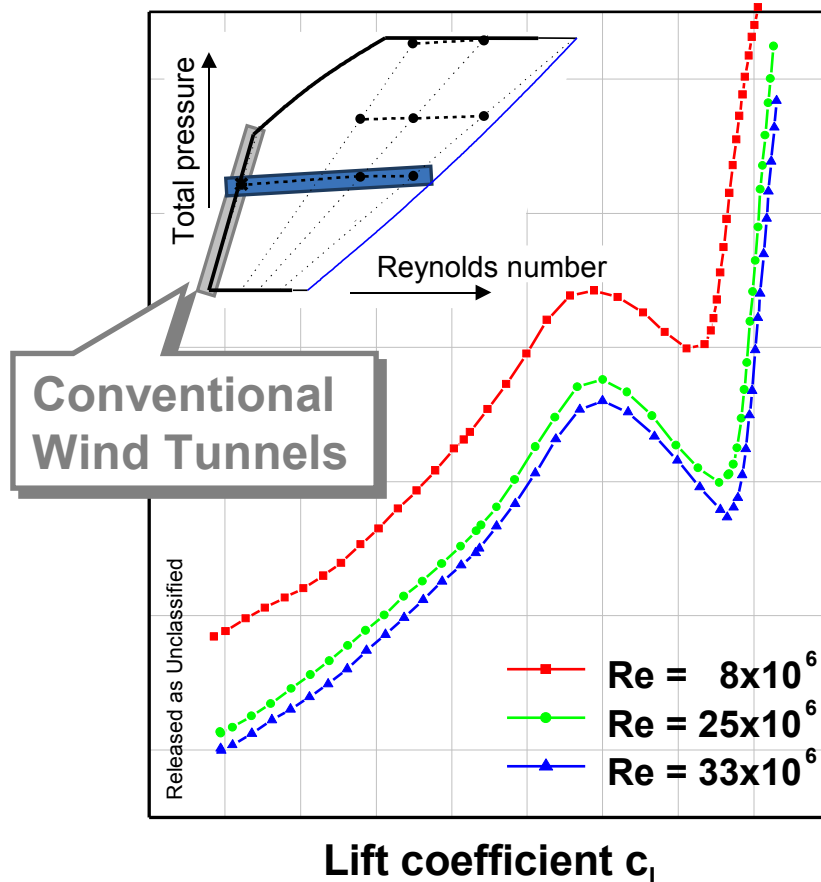
3. High Productivity and Costs Efficiency

4. Security and Client Confidentiality

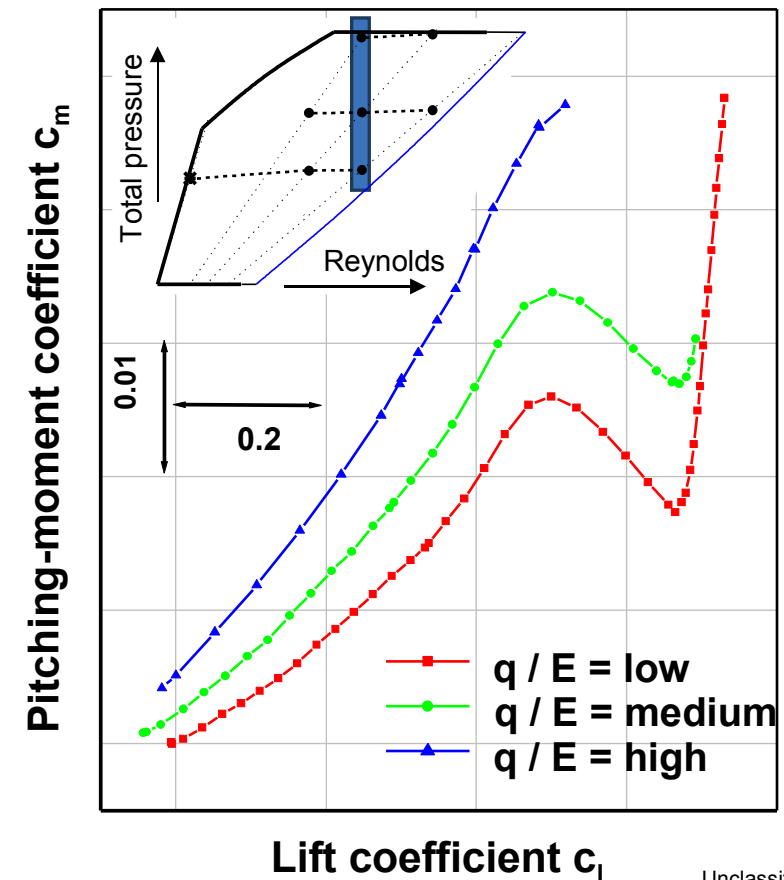
2. Independent Variation of Re-Number & Structural Loads

Pitching-moment / lift characteristics

Reynolds Variation at const. Airloads



Airloads Variation at const. Reynolds

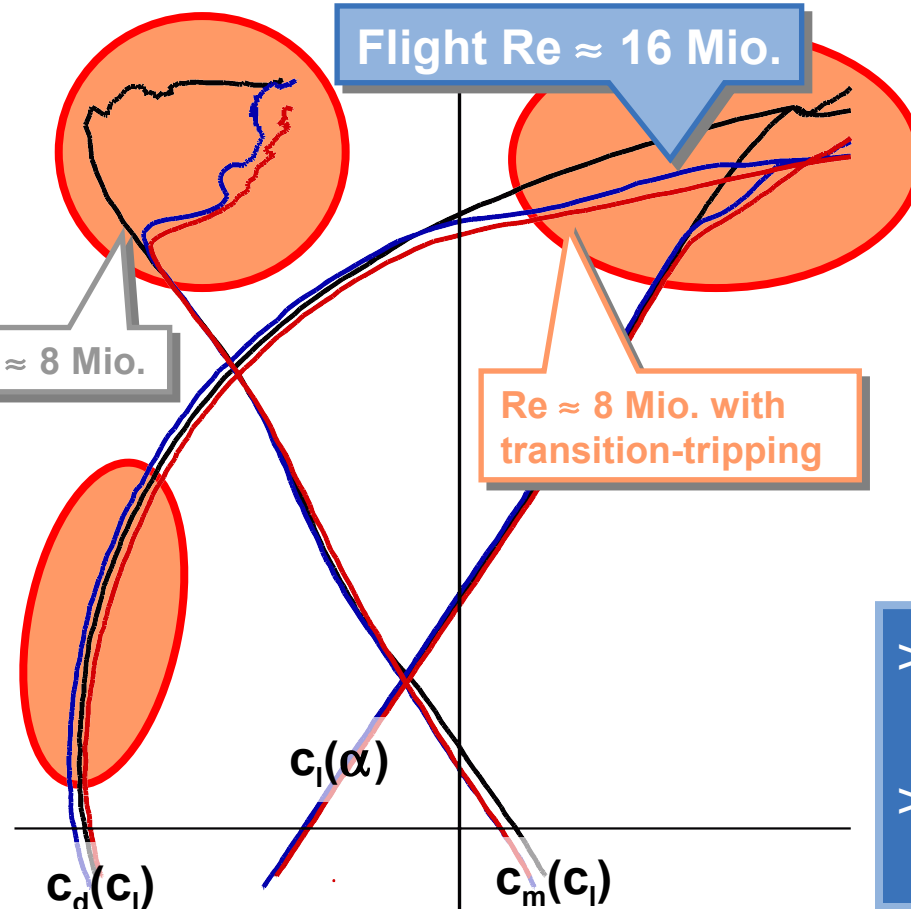


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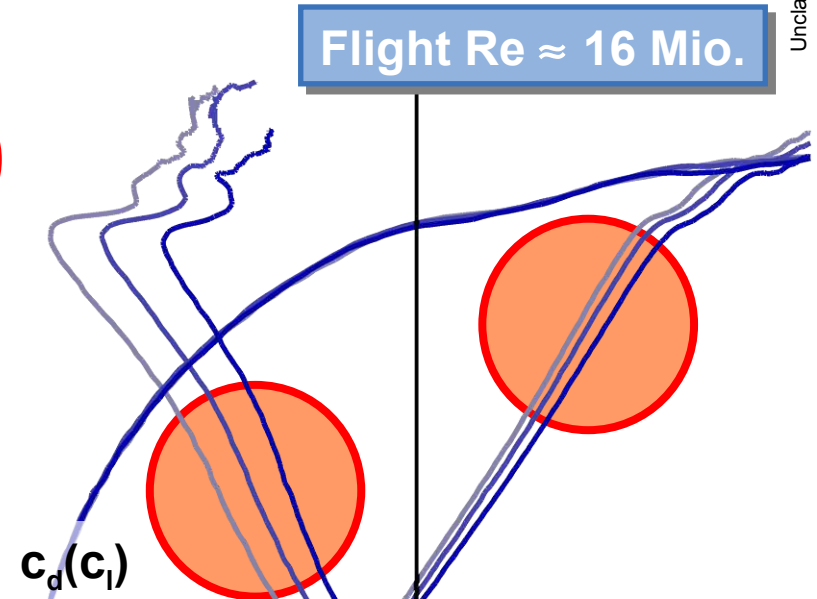
2. Independent Variation of Re-Number & Structural Loads

Lift, drag, pitching-moment characteristics Falcon 7X (1:10)

Reynolds Variation at const. Airloads



Airloads Variation at const. Reynolds



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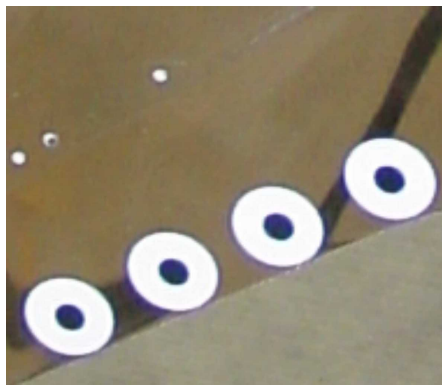
- > Reynolds Number strongly affects aircraft performance
- > Aeroelastic distortion strongly affects aircraft stability

2. Independent Variation of Re-Number & Structural Loads

Application of Markers at Full Span Model

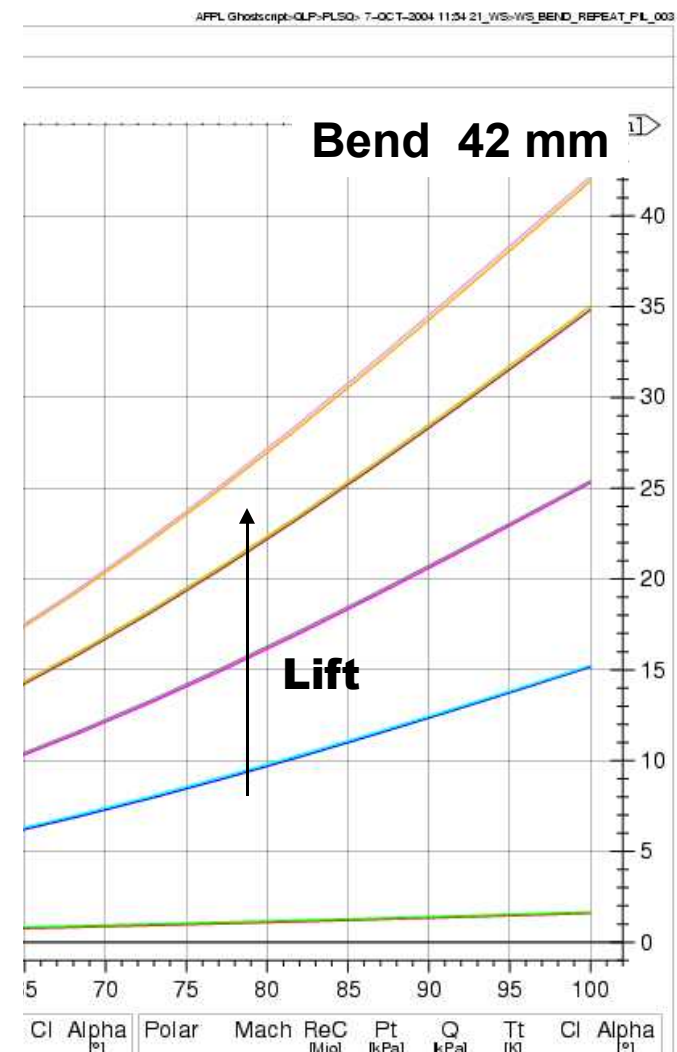
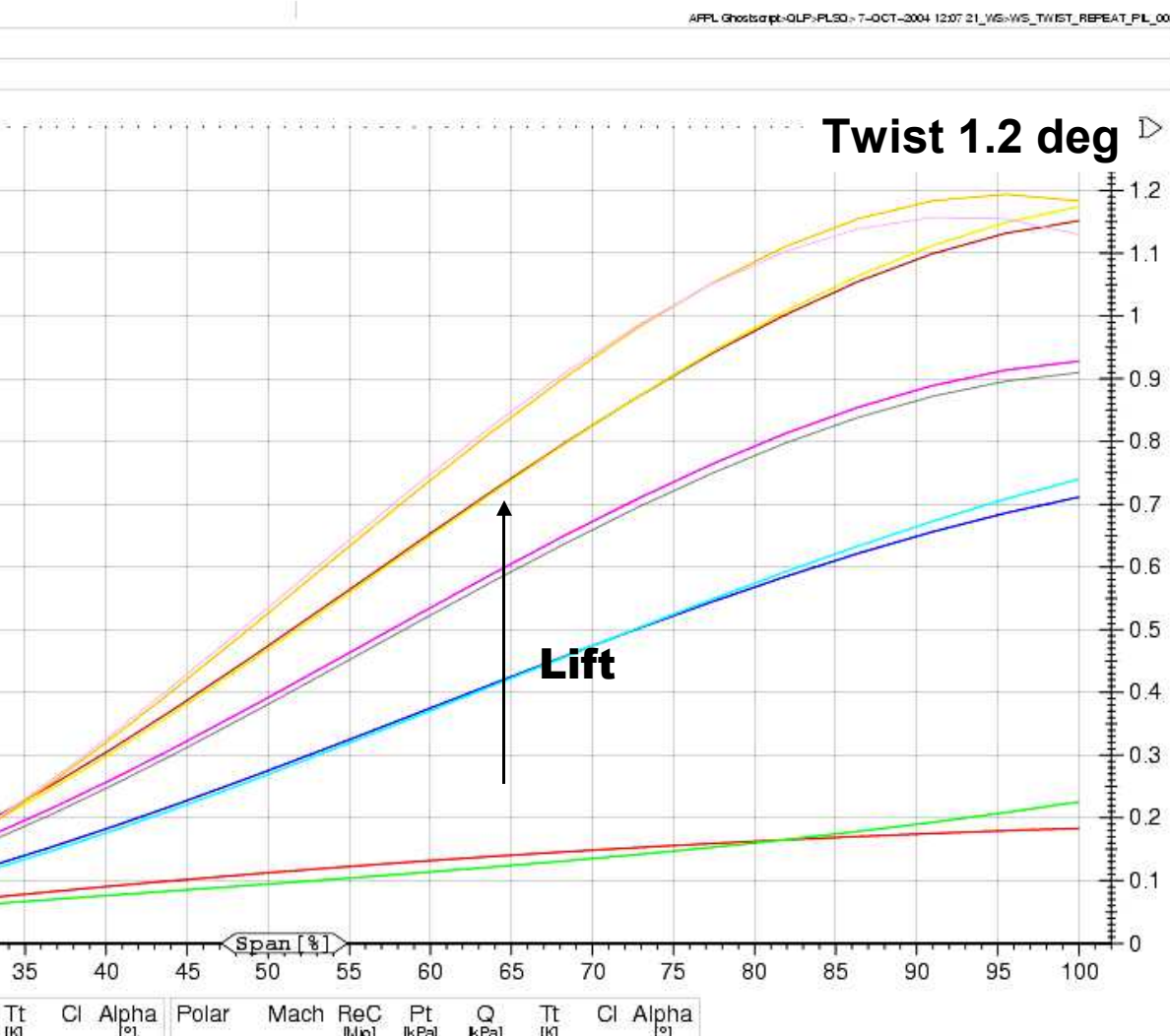
LETRASET Markers:

- Circular dots, approx. 15 pixels in diameter
- More markers near wing tip to compensate for chord length
- Good contrast to background



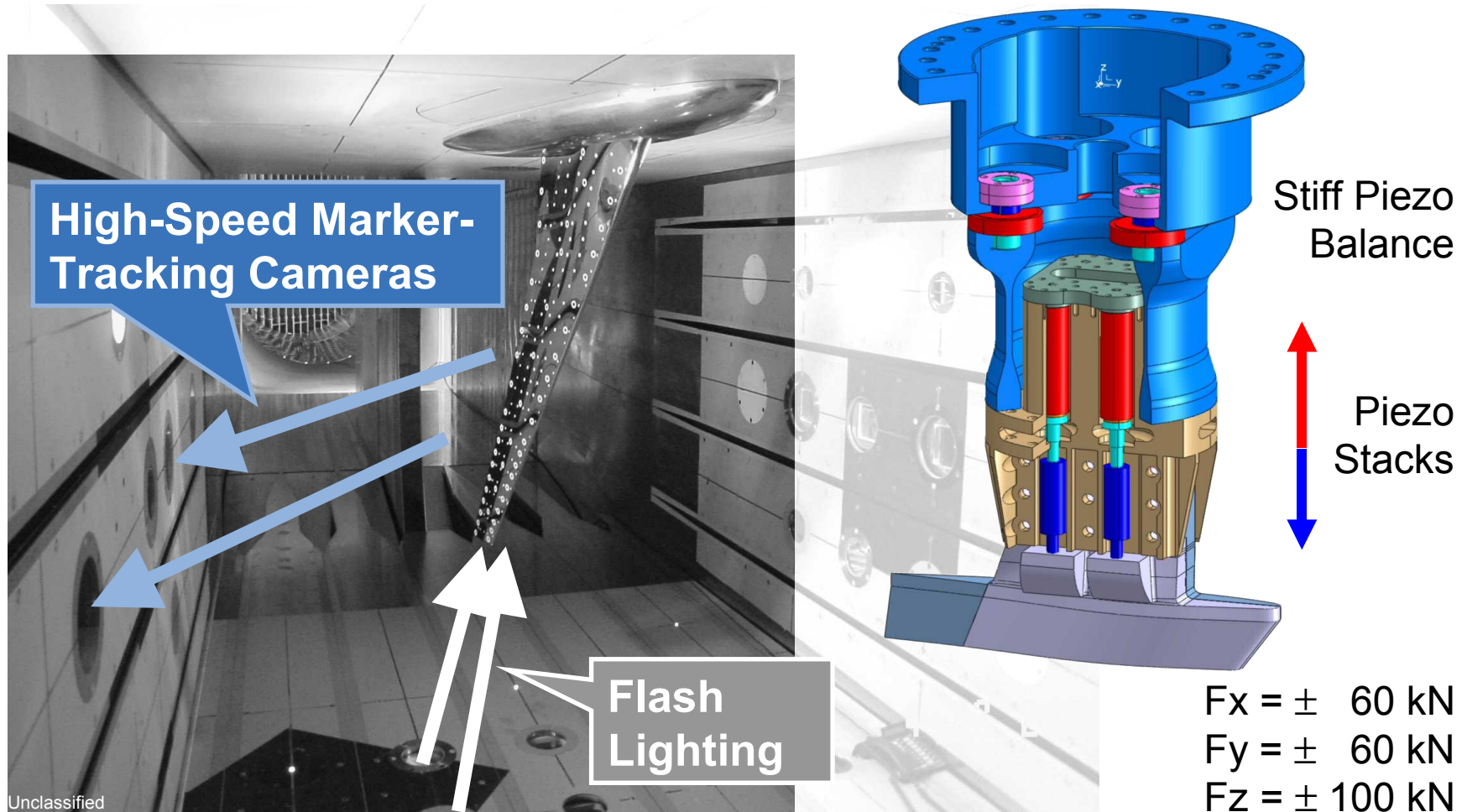
2. Independent Variation of Re-Number & Structural Loads

Wing Twist and Bending Measurements at Half Span Model



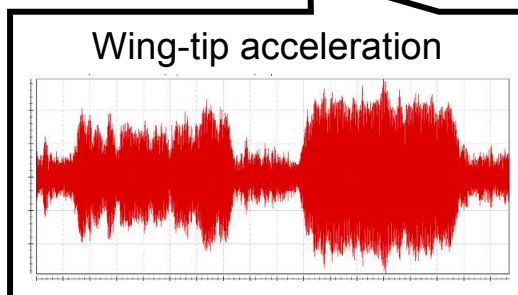
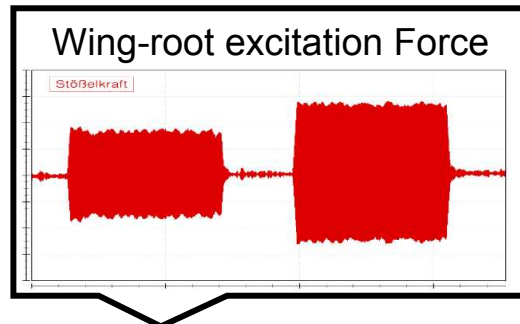
2. Independent Variation of Re-Number & Structural Loads

High Reynolds Number AeroStructural Dynamics HIRENASD



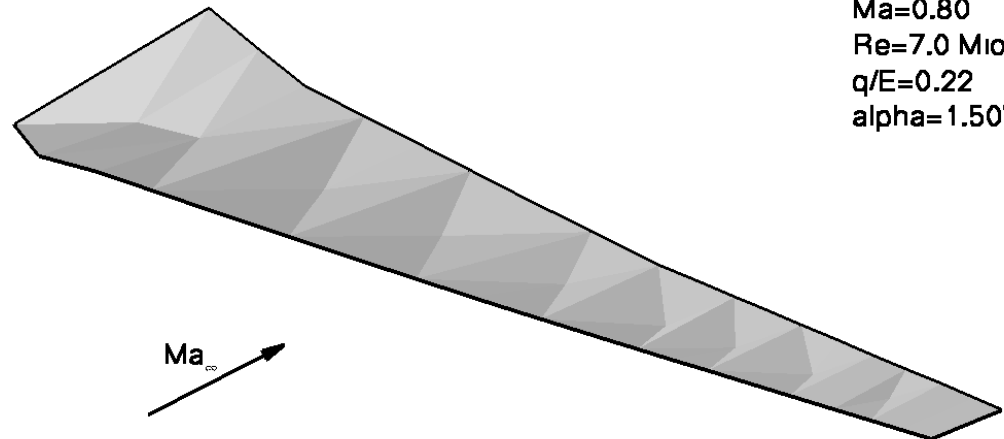
2. Independent Variation of Re-Number & Structural Loads

High Reynolds Number AeroStructural Dynamics HIRENASD



Instantaneous Model Deformation
from High-Speed Marker Tracking

Ma=0.80
Re=7.0 Mio.
q/E=0.22
alpha=1.50°



> **Forced-oscillation test capabilities**
demonstrated at **flight-relevant conditions:**

$$0.70 \leq Ma_\infty \leq 0.88$$

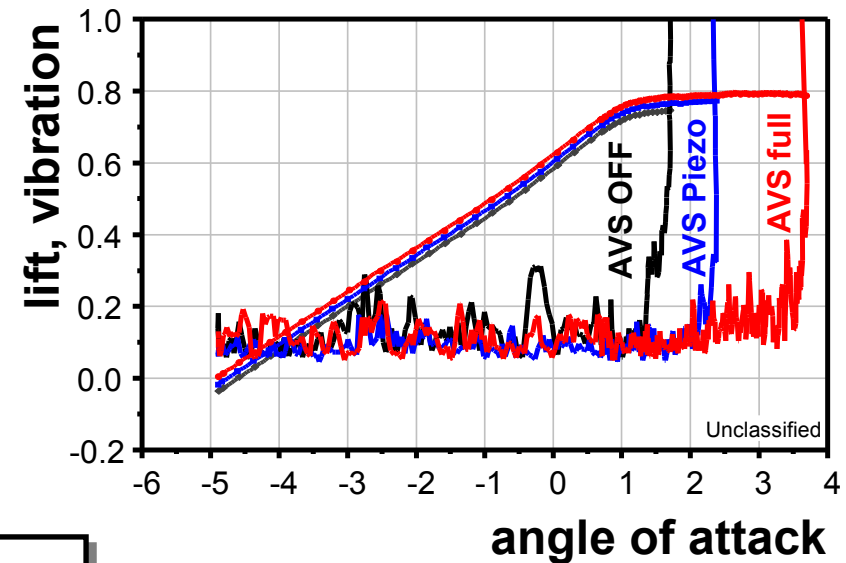
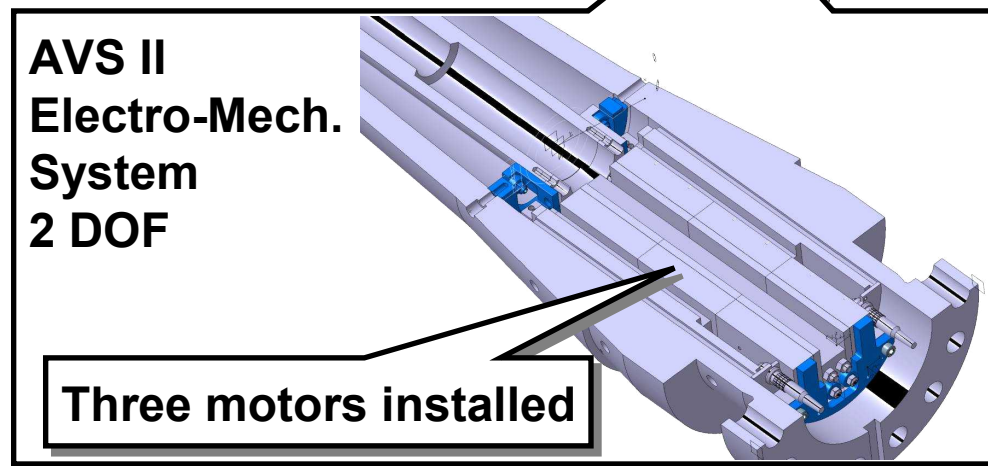
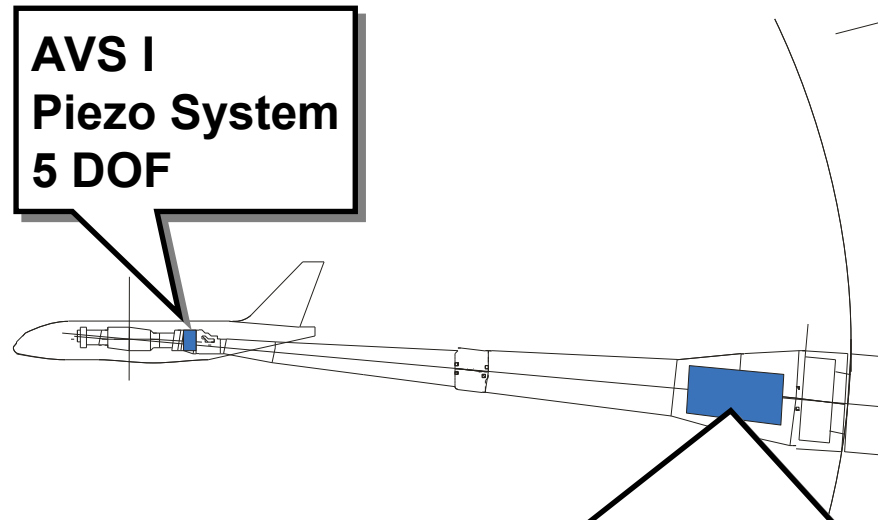
$$7 \text{ Mio.} \leq Re_\infty \leq 73 \text{ Mio.}$$

> **Follow-on test planned**

Unclassified

2. Independent Variation of Re-Number & Structural Loads

Anti Vibration Systems AVS I & AVS II



- > Enhanced AVS efficiency
- > Active Motion Mode for Eigenmode excitation
- ⇒ Limited full-model forced-oscillation test capabilities

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3. High Productivity and Costs Efficiency

- Provides much high-quality data in time, and at reasonable costs

4. Security and Client Confidentiality

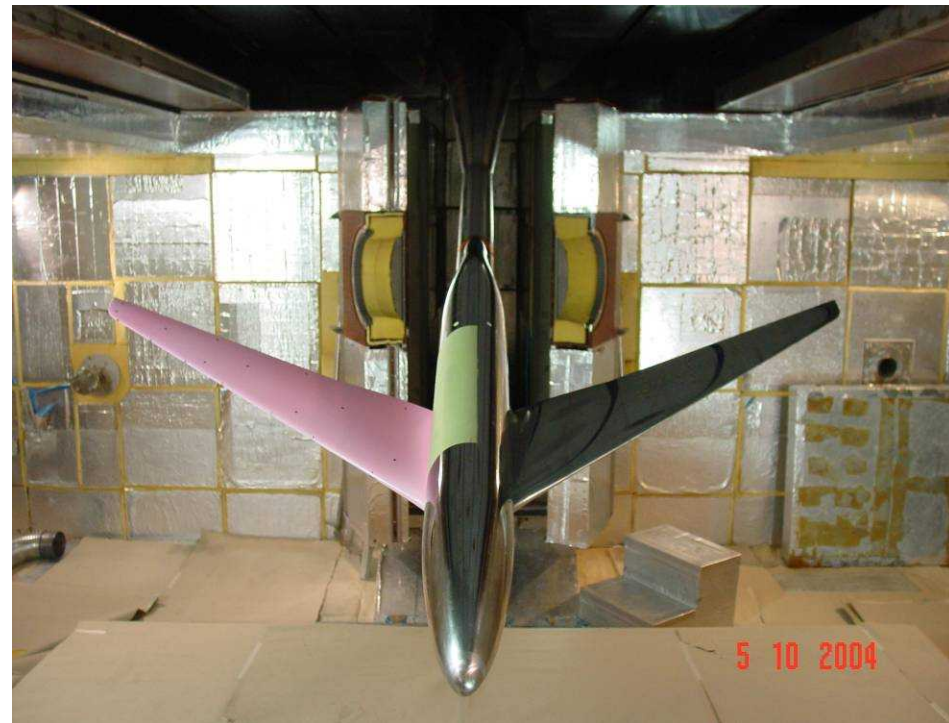
3. High Productivity and Costs Efficiency

More info in the same test

> TSP, PSP, and PIV cryo-proof & productive



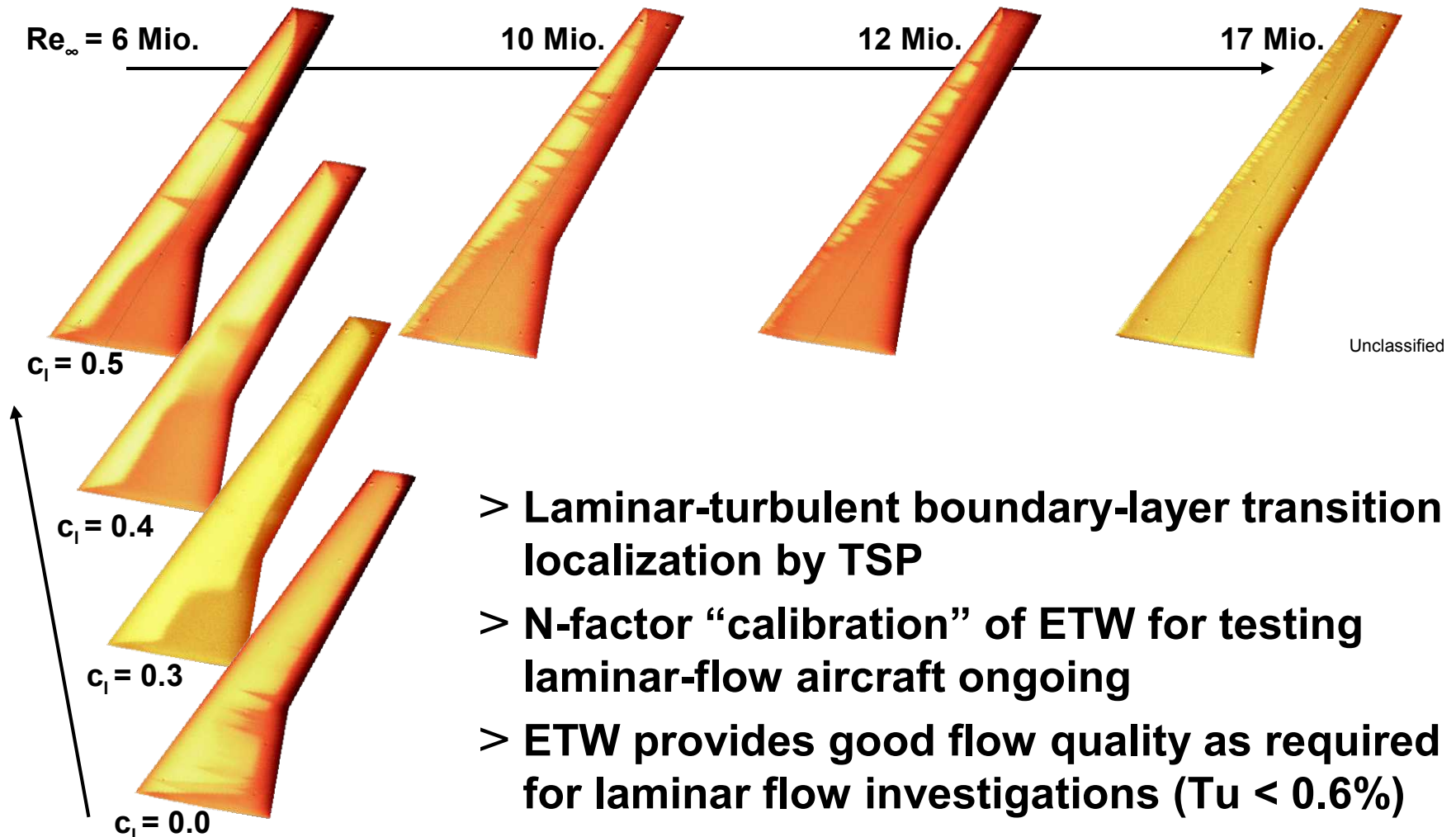
TSP



PSP

3. High Productivity and Costs Efficiency

More info in the same test - Temperature Sensitive Paint TSP



3. High Productivity and Costs Efficiency

More info in the same test - Pressure Sensitive Paint PSP

First successful test in ETW

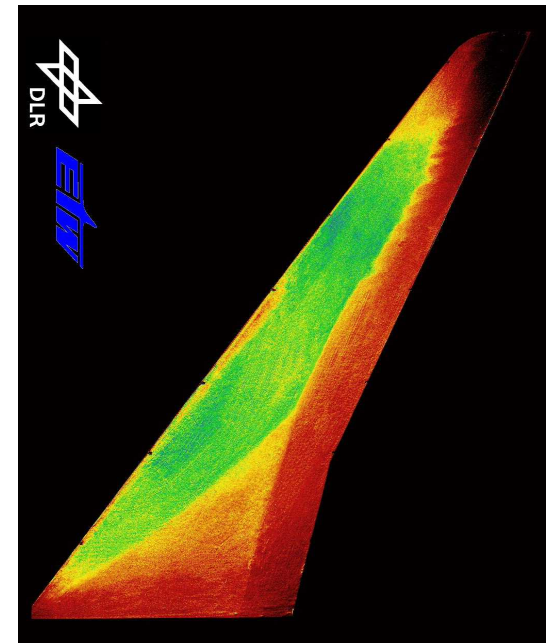
300 K – 160 K up to 340 kPa

**Oxygen Injection with
manual control**

**Stabilisation of Oxygen Level
at requested amounts of
700, 1000 and 1500 ppm**

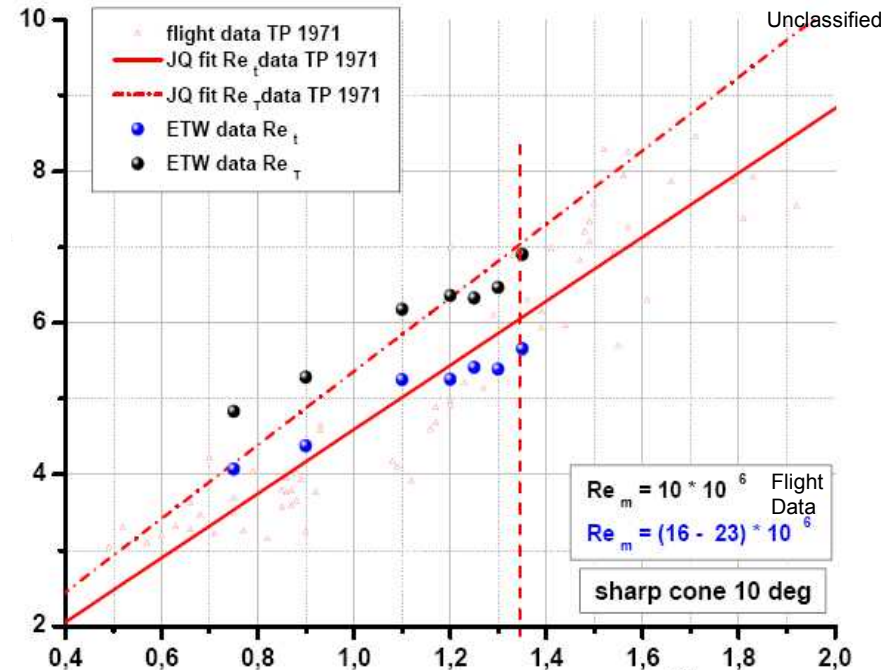
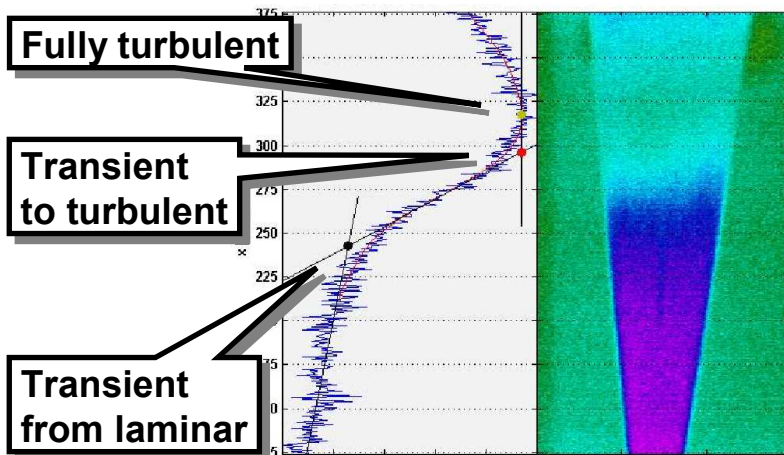
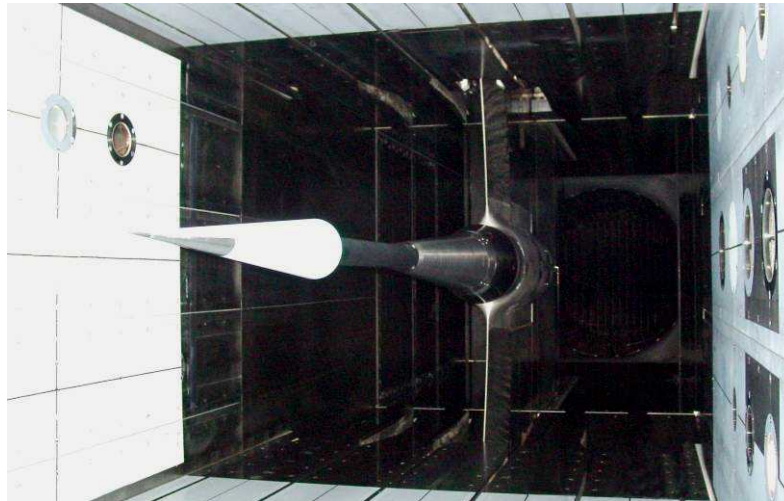
Images successfully acquired

Surface roughness of paint 0.3 μ m



3. High Productivity and Costs Efficiency

More info in the same test – Infra-Red Camera



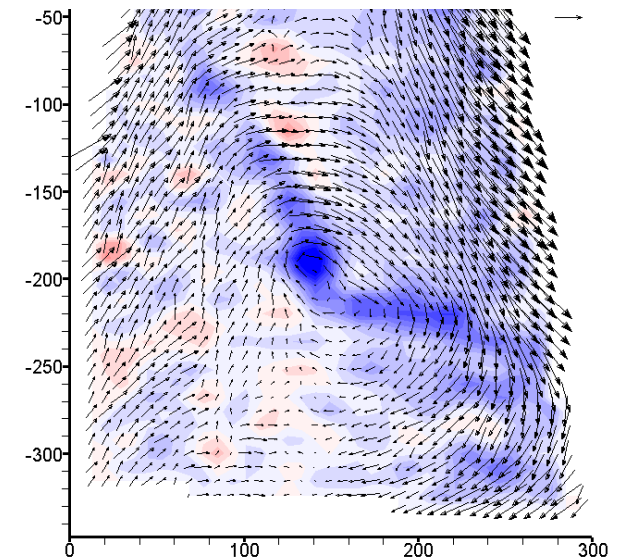
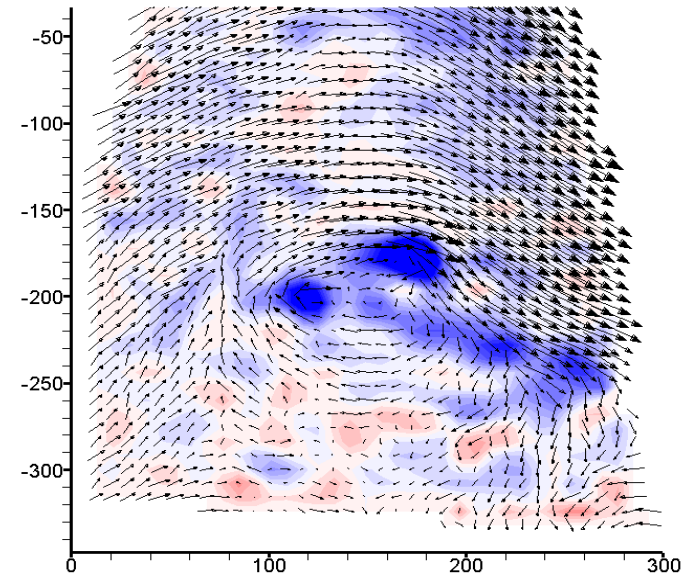
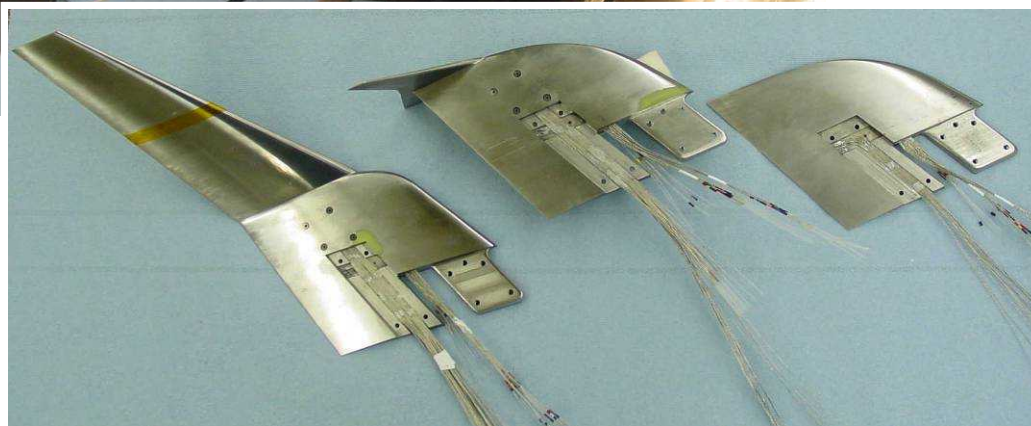
- > N-Factor “calibration” yields $N \approx 10$ at $Ma_\infty = 1.35$, $Re/m = 23.3$ Mio.
- > **Good flow quality also for continuous supersonic ETW operation**

3. High Productivity and Costs Efficiency

Wake Measurement - DGV System

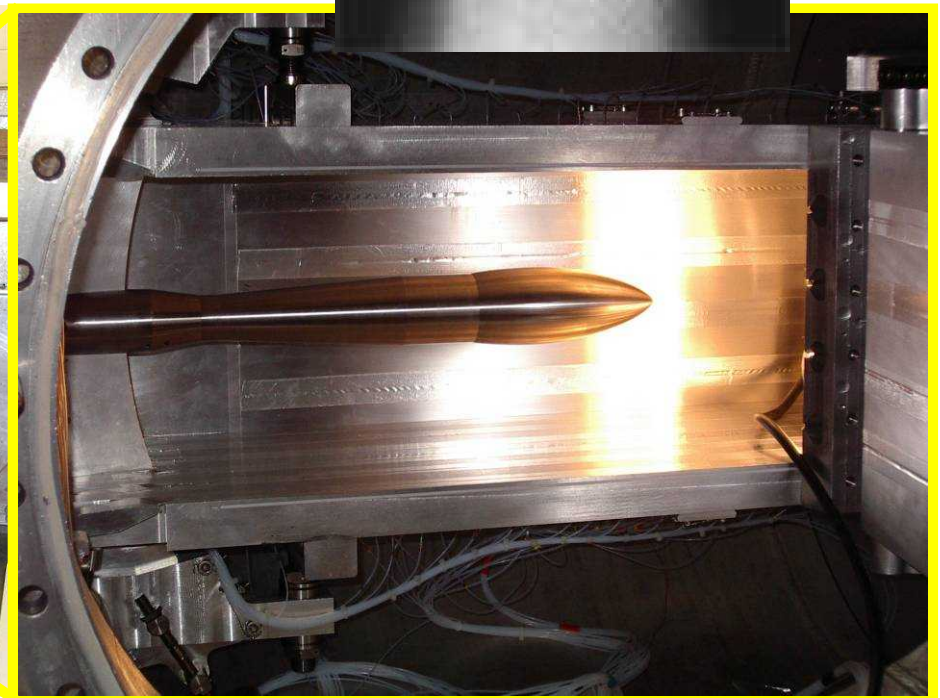
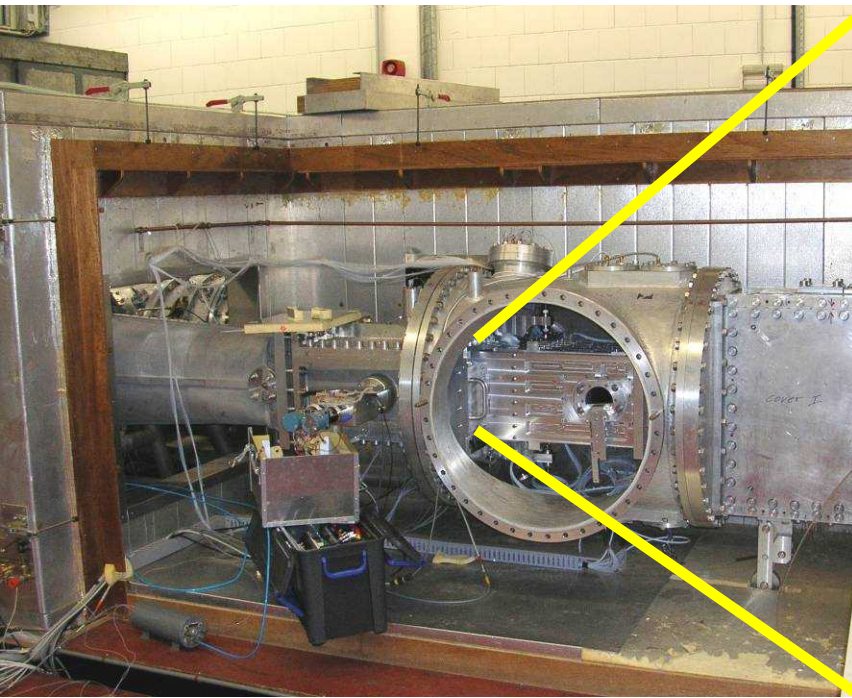
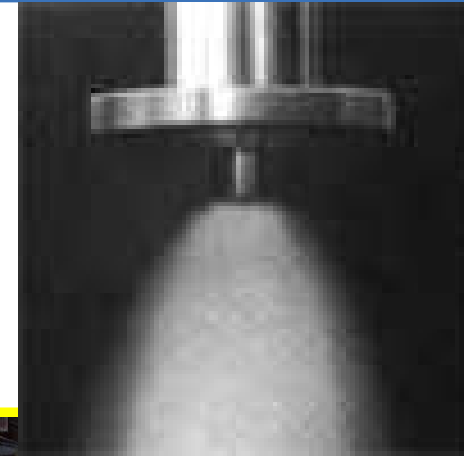


**MDAW
Project**

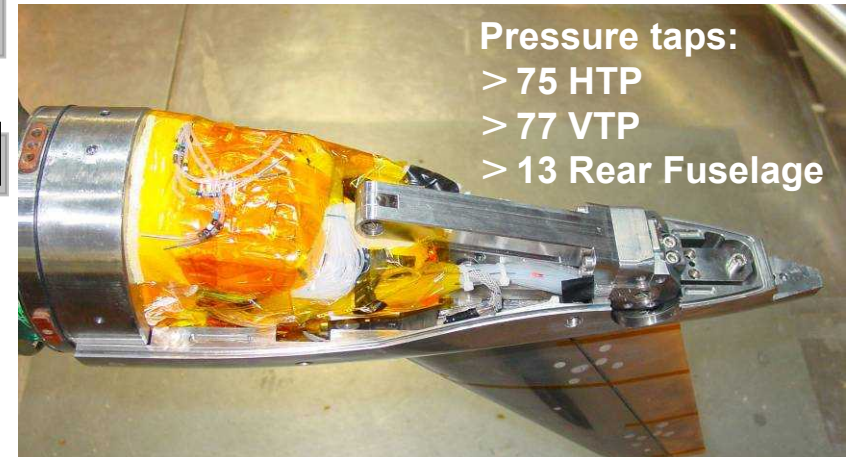
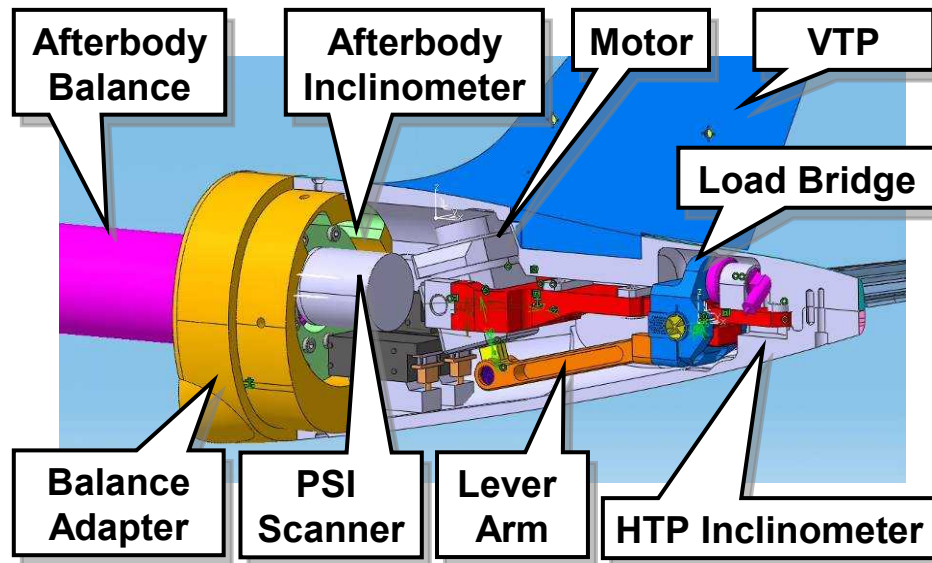


3. High Productivity and Costs Efficiency

PETW Developments > PIV



3. High Productivity and Costs Efficiency by using remotely controlled HTP



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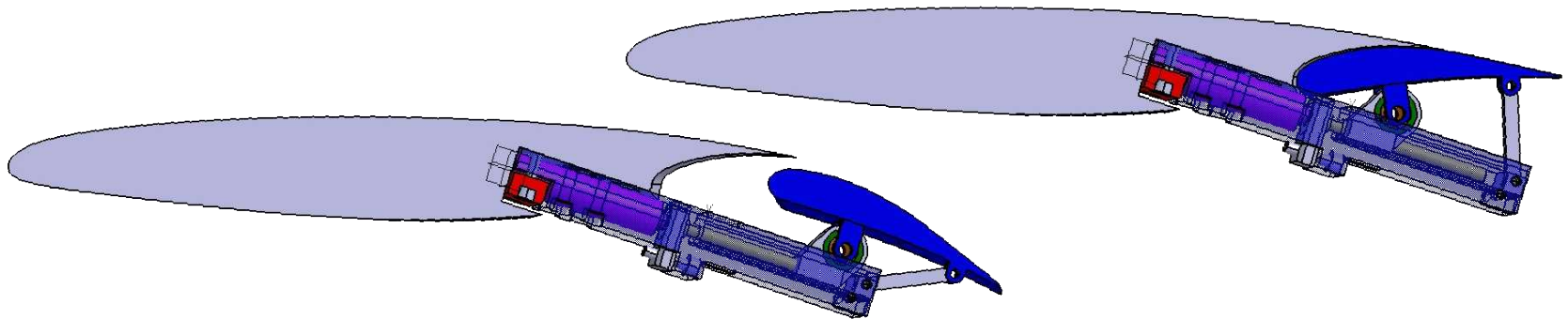
Reached Objectives:

- > Handling quality, and loads data at flight Reynolds numbers
- > Avoid model-transport/-change, and -conditioning time

3. High Productivity and Costs Efficiency

More info in the same test – Technical Developments

- > **Remotely controlled model components for half model techniques**
First PETW test set-up in preparation



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3. High Productivity and Costs Efficiency

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4. Security and Client Confidentiality

- Receive the highest of priorities at ETW
- Military compliant by design

4. ETW Security and Client Confidentiality

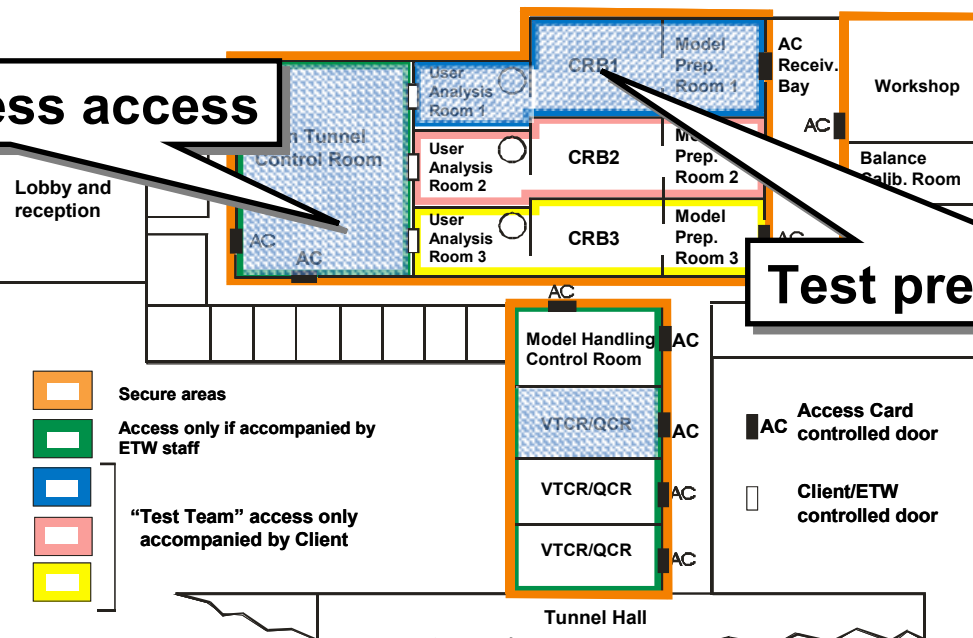
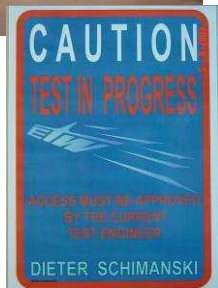
Building Security

> Three restricted-access client zones

- access control by magnetic cards, recorded
- new access codes for each test and on demand
- depending on test phase

Mechanical Restriction Concept

Test in progress access



Test preparation access



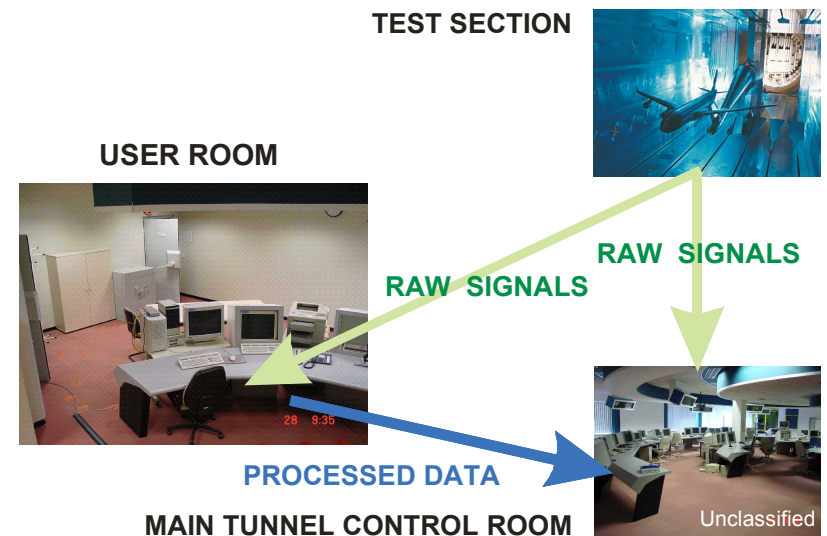
4. ETW Security and Client Confidentiality

Computer and Data Systems Security

- > **Isolated, access controlled OpenVMS System**
- > **Client data storage disk**
 - located in the customer zone
 - may be removed & stored in a client high-security safe
- > **Data backups are kept in the client safe**
- > Data disks can be taken by the client or stored for future reference

- > ETW does not have access to any test data without client's permission
- > ETW does not retain ANY data without client's permission

Circuit Isolation Concept

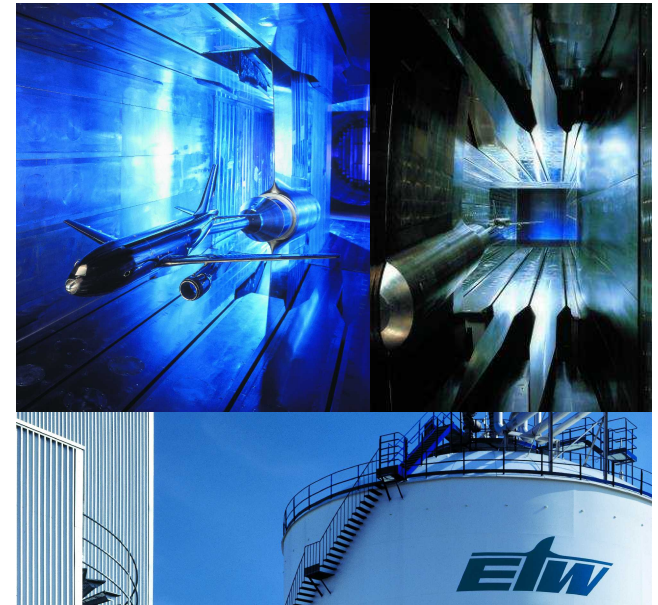


Conclusion

Benefit in Aircraft Development by ETW Windtunnel Testing

ETW provides

- > **“Early Flight Testing”**
 - Flight-Reynolds Windtunnel Testing
 - Independent Variation of Reynolds Number & Structural Loads
- > **High productivity & costs efficiency**
- > **Security & client confidentiality**



- ⇒ **High-performance, optimized aircraft design**
- ⇒ **Early confidence** in meeting design requirements
- ⇒ **Reduced risk** of late design modifications and costly rework
- ⇒ **Overall reduced development time and costs**