



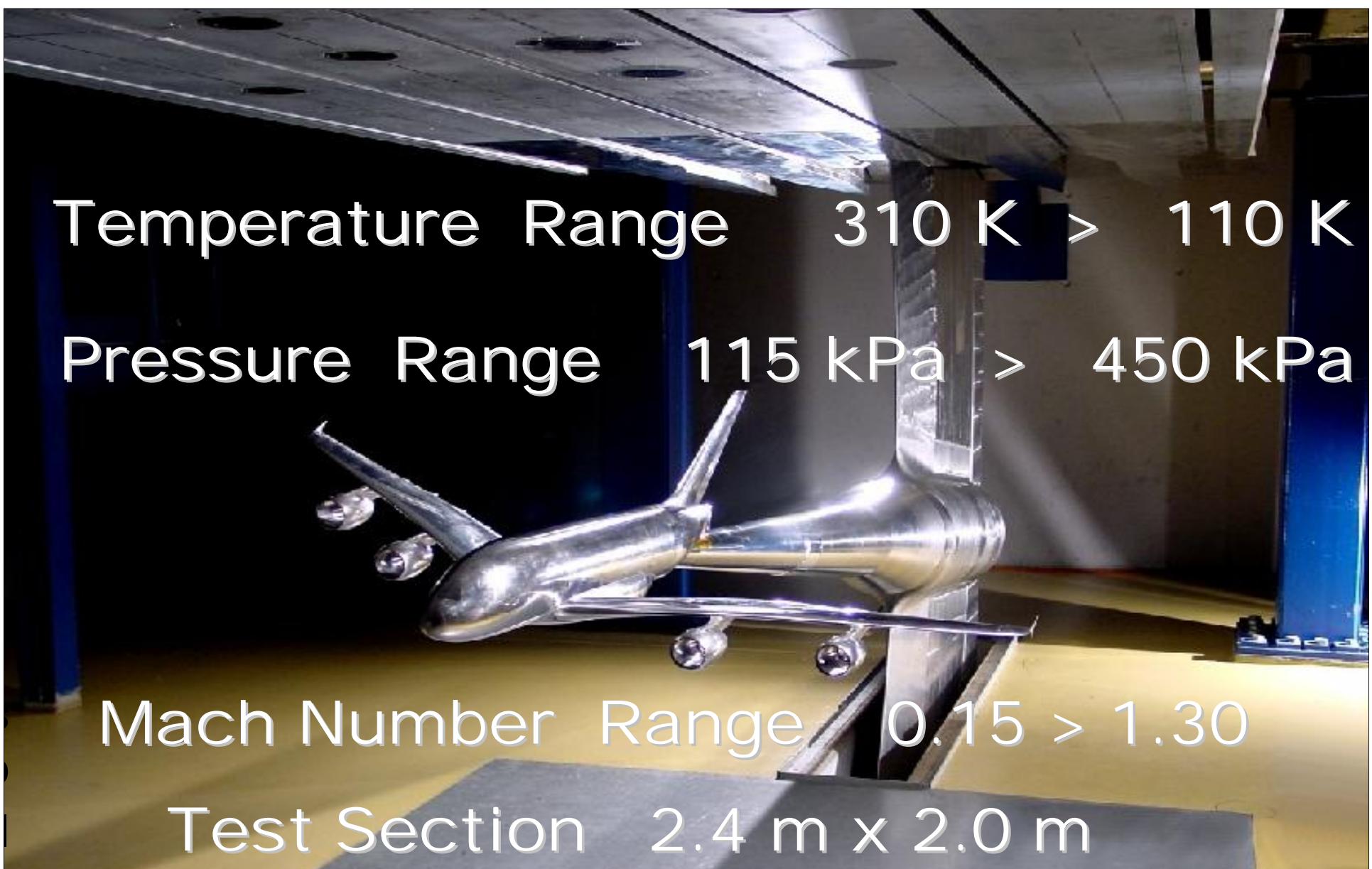
## Advanced Measurement Techniques at High Reynolds Number Testing in the European Transonic Windtunnel



## CRYOGENIC TEMPERATURES and MODERATE PRESSURE INCREASE



# Flight Reynolds Number Testing Capability



Temperature Range  $310\text{ K} > 110\text{ K}$

Pressure Range  $115\text{ kPa} > 450\text{ kPa}$

Mach Number Range  $0.15 > 1.30$

Test Section  $2.4\text{ m} \times 2.0\text{ m}$

## STANDARD MEASUREMENT TOOLS

Strain Gauge Balances  
Incidence Measurement Units

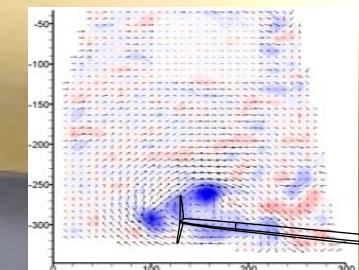
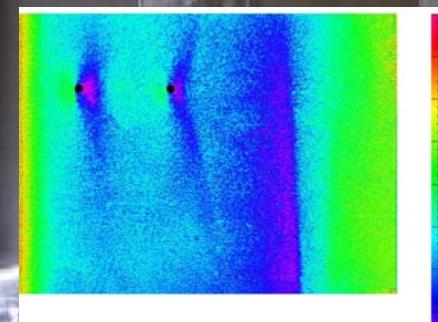
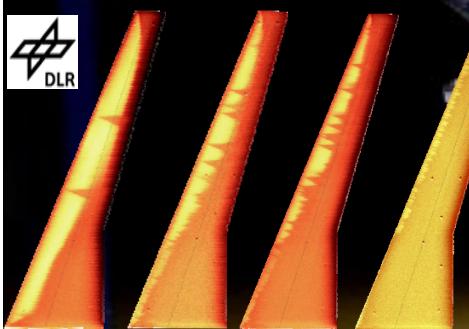
Pressure Scanners

SINCE 10 YEARS IN OPERATION

# ADVANCED MEASUREMENT TECHNIQUES

Wing Deformation Measurement

Temperature  
and Pressure  
Sensitive Paint

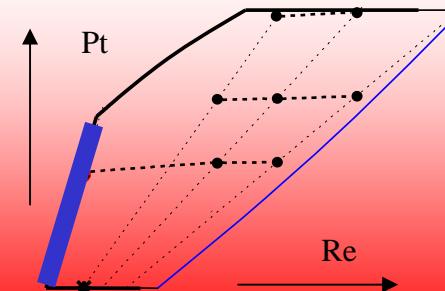


Flow Visualization and Measurement

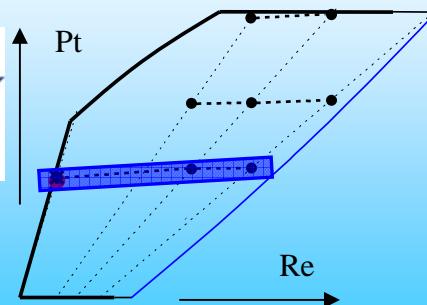
# Independent Variation of Tunnel Parameters

Ambient Temperature Facilities

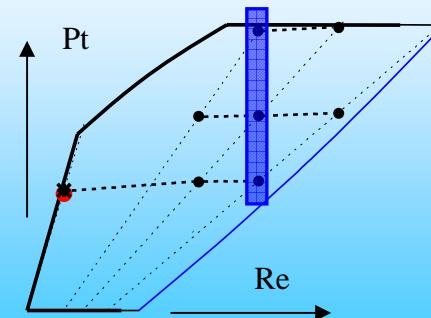
Pseudo Reynolds Number Effects



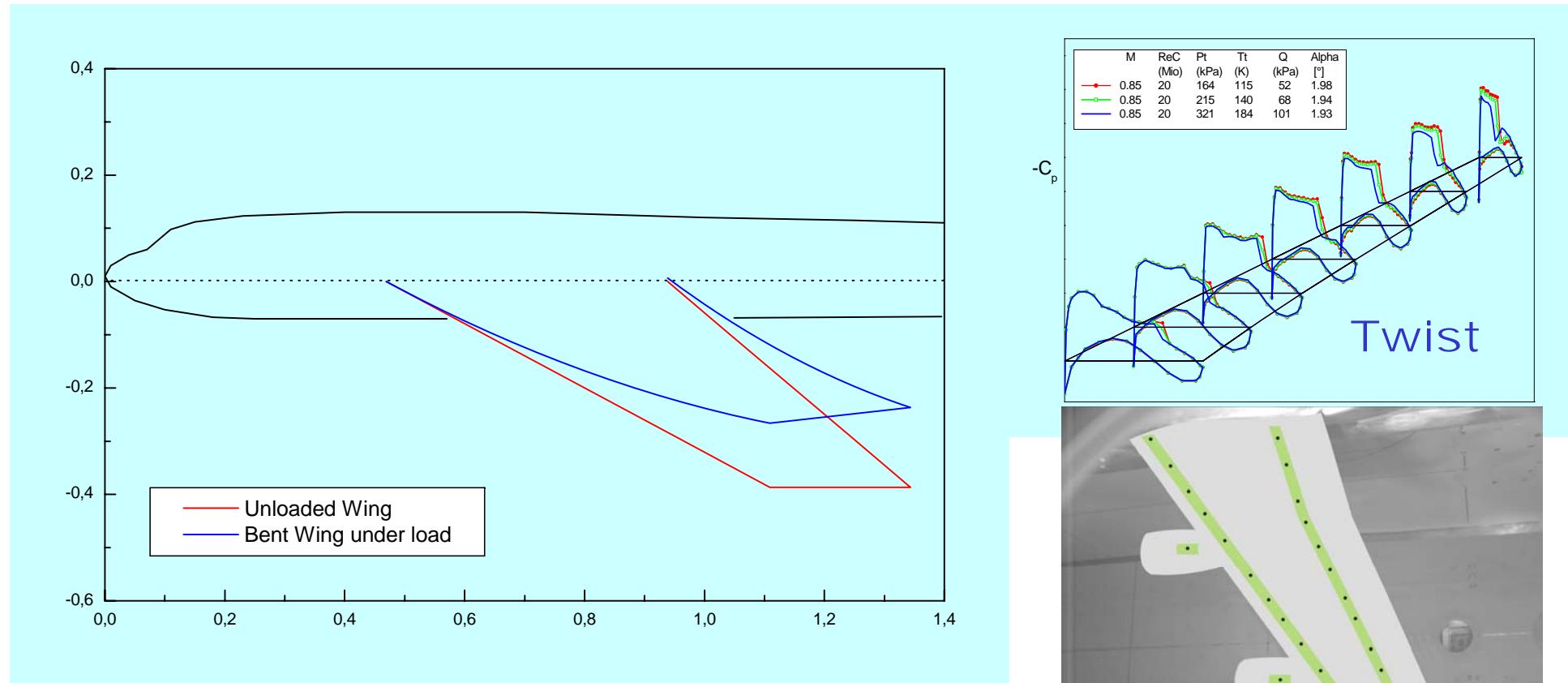
Pure Reynolds Number Variation



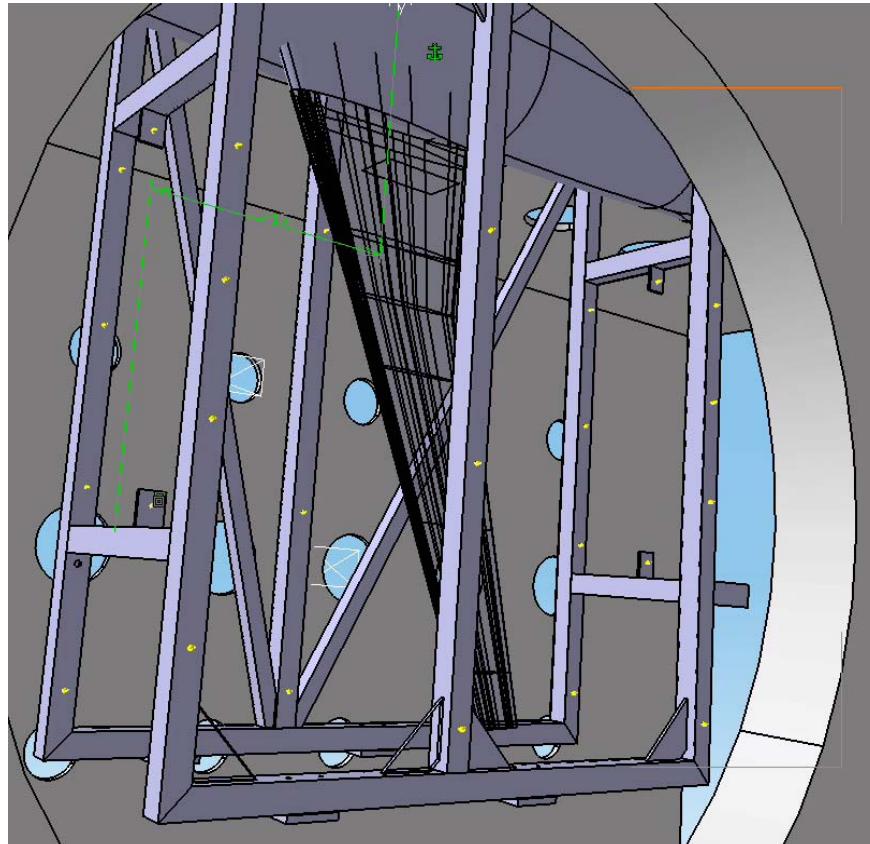
Aeroelastic Effect at const Re



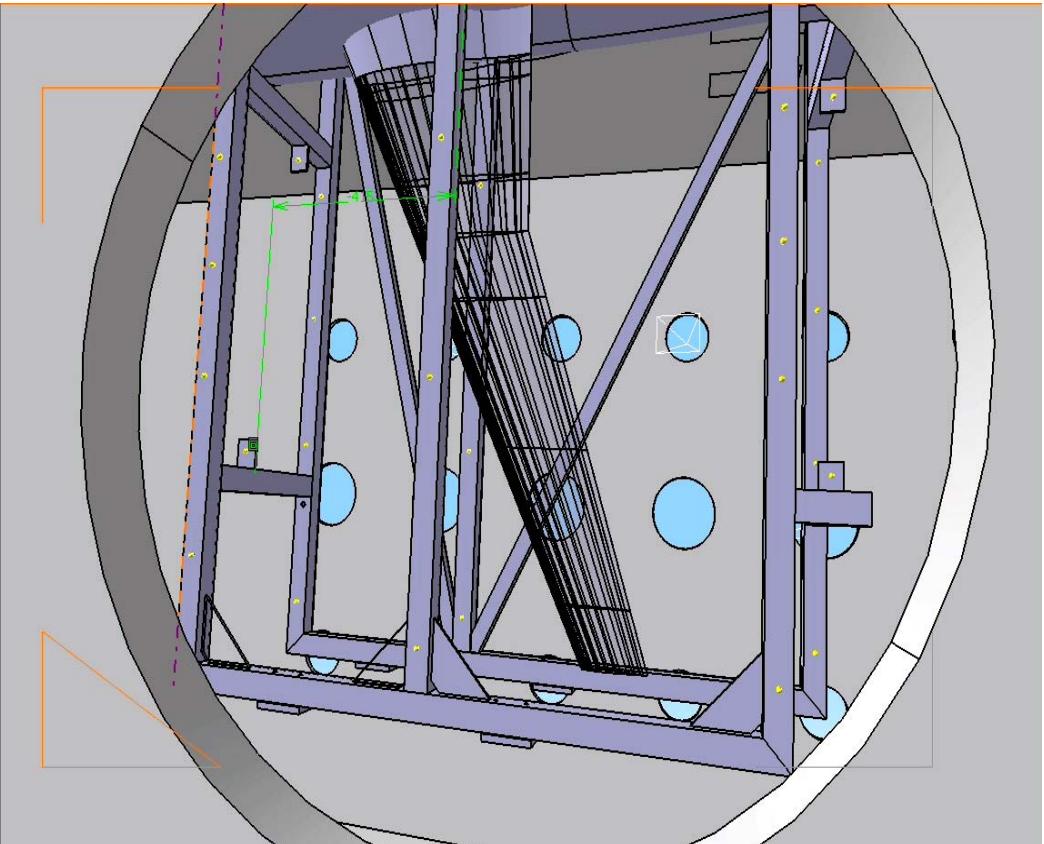
# Wing Deformation Measurement



# Stereo Pattern Tracking System Half Models



upstream



downstream

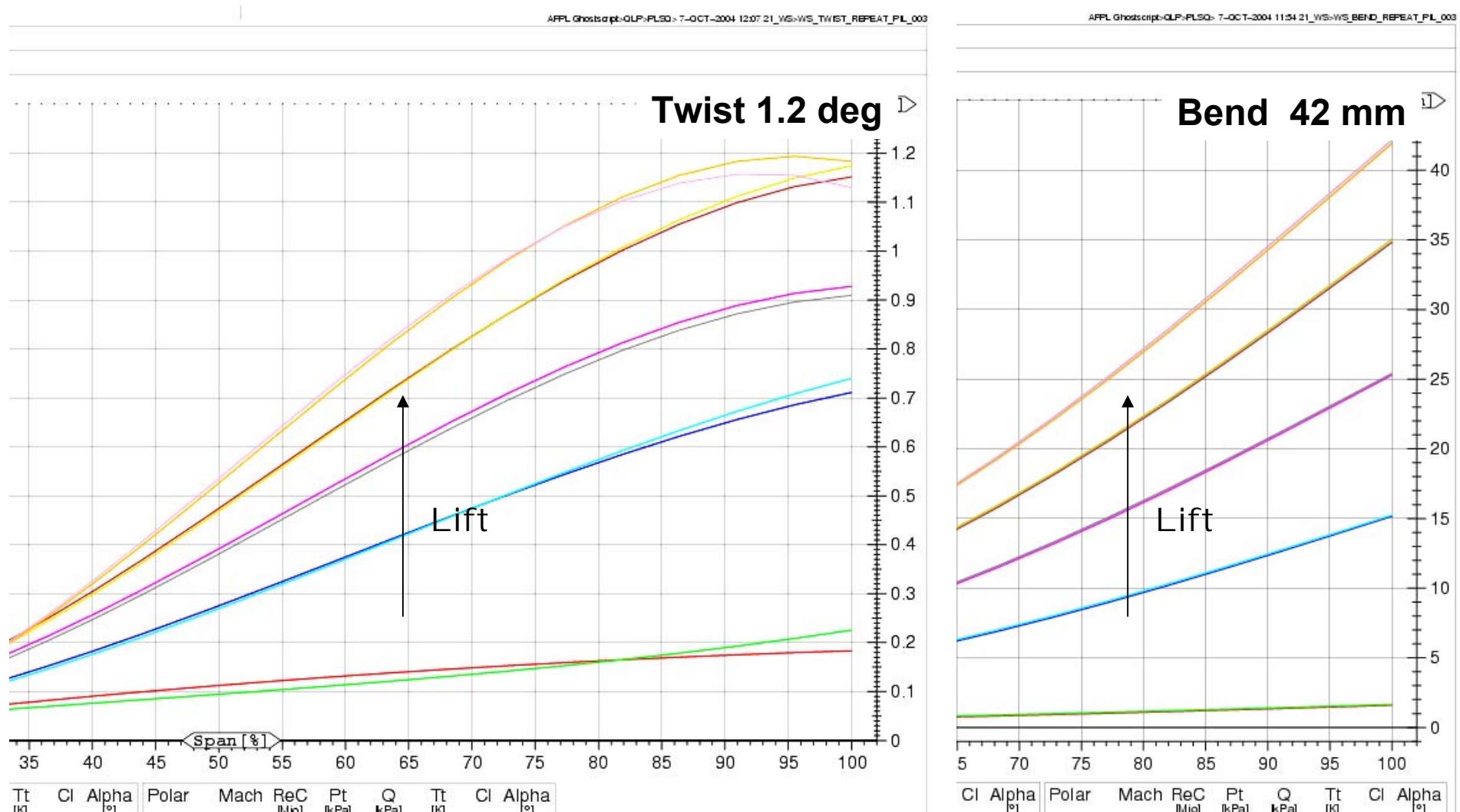
# Application of Markers at Half Span Model

## LETRASET Markers:

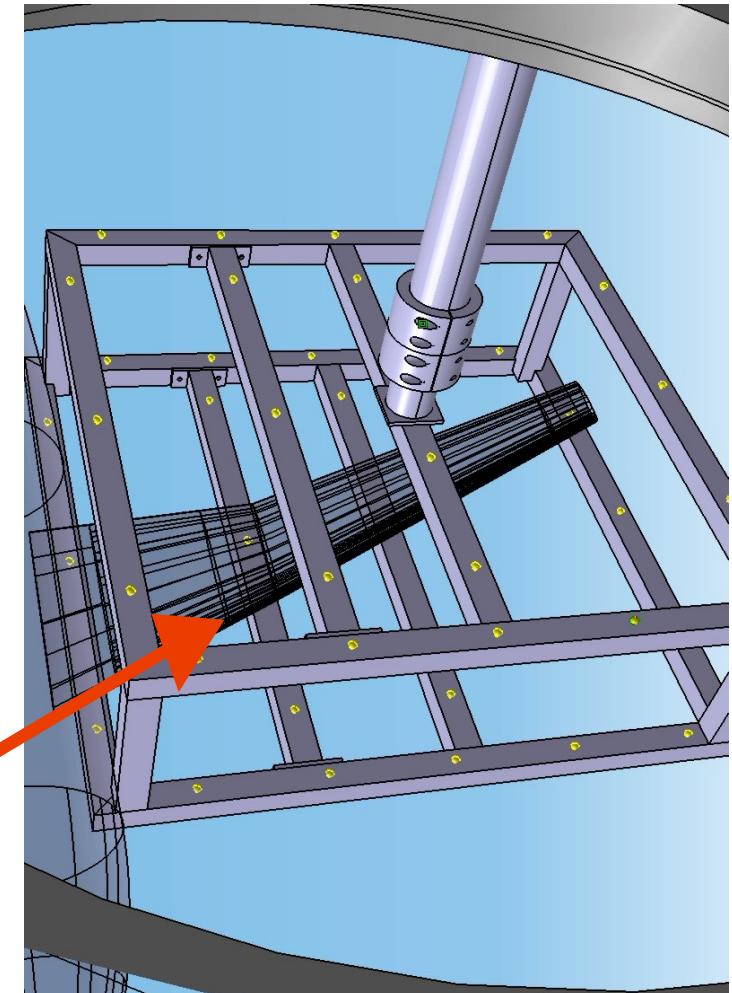
- Circular dots,  
approx. 15 pixels in diameter
- More markers near wing tip to  
compensate for chord length
- Good contrast to background



# Wing Twist and Bending Measurements



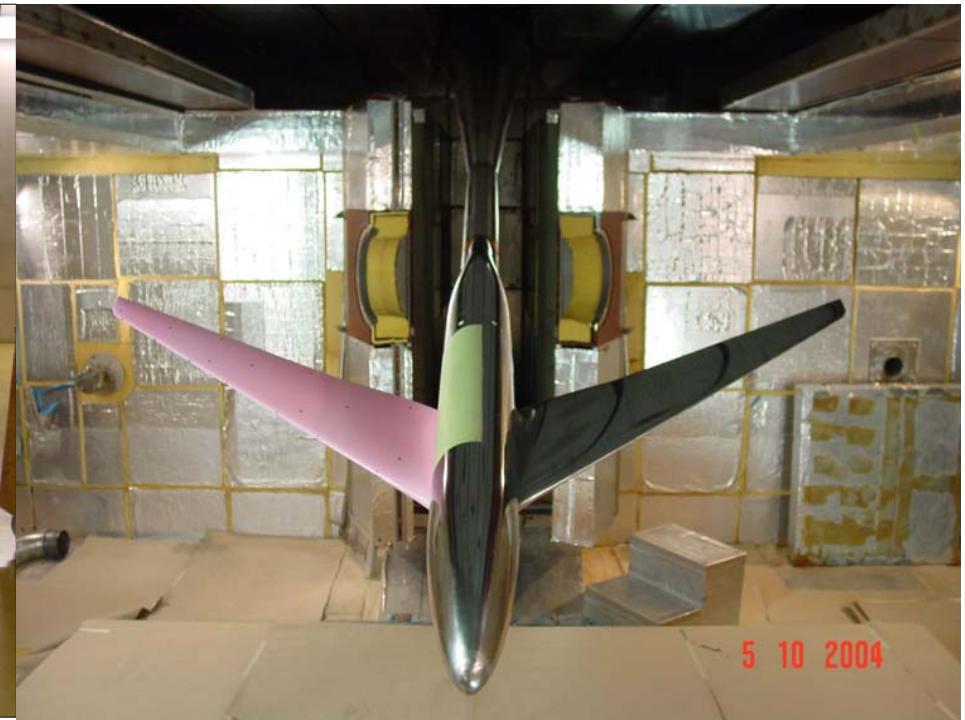
# Calibration Frame for Full Span Models



# Temperature and Pressure Sensitive Paint

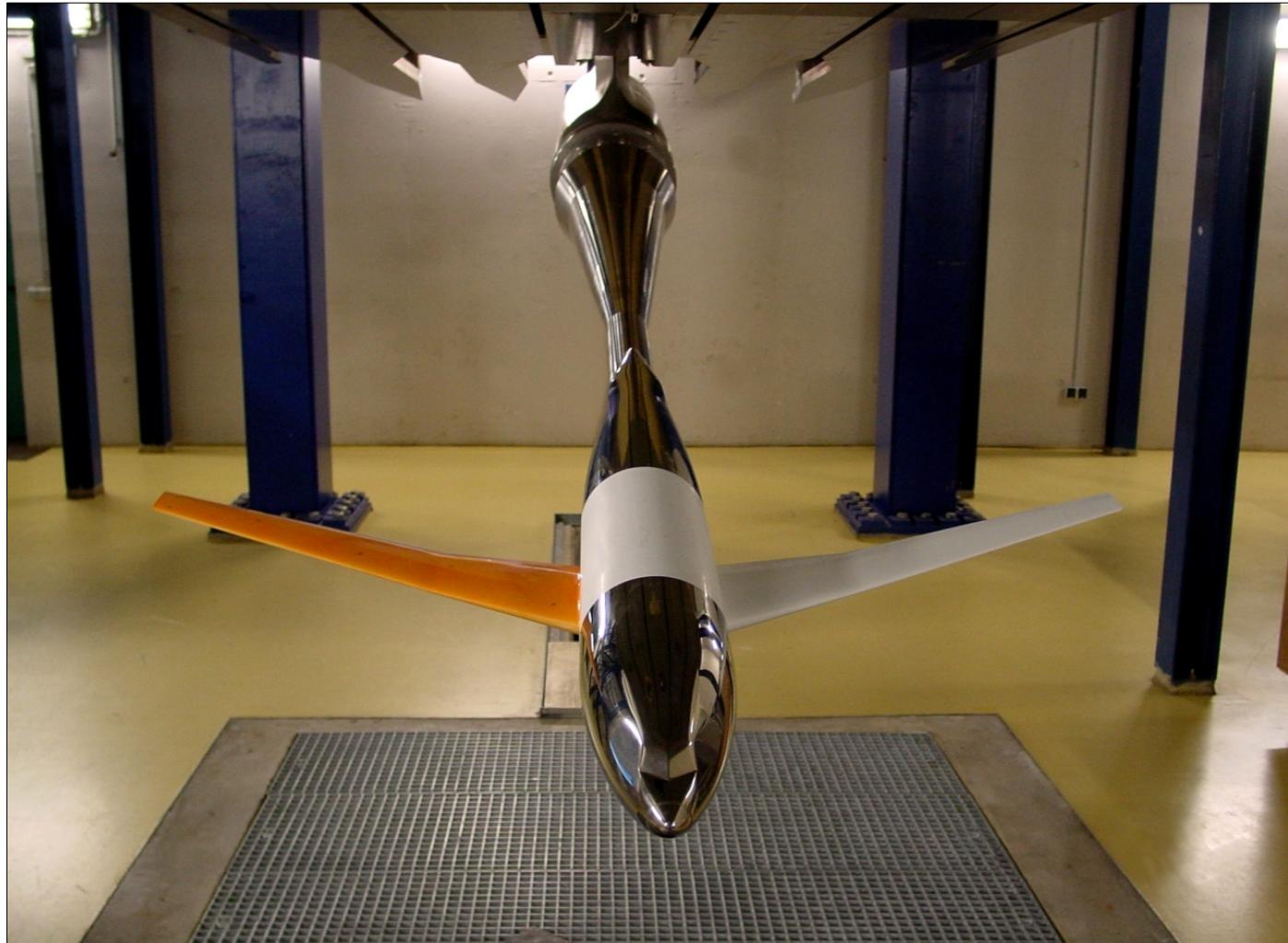


TSP



PSP

# Transition Detection by Temperature Sensitive Paint



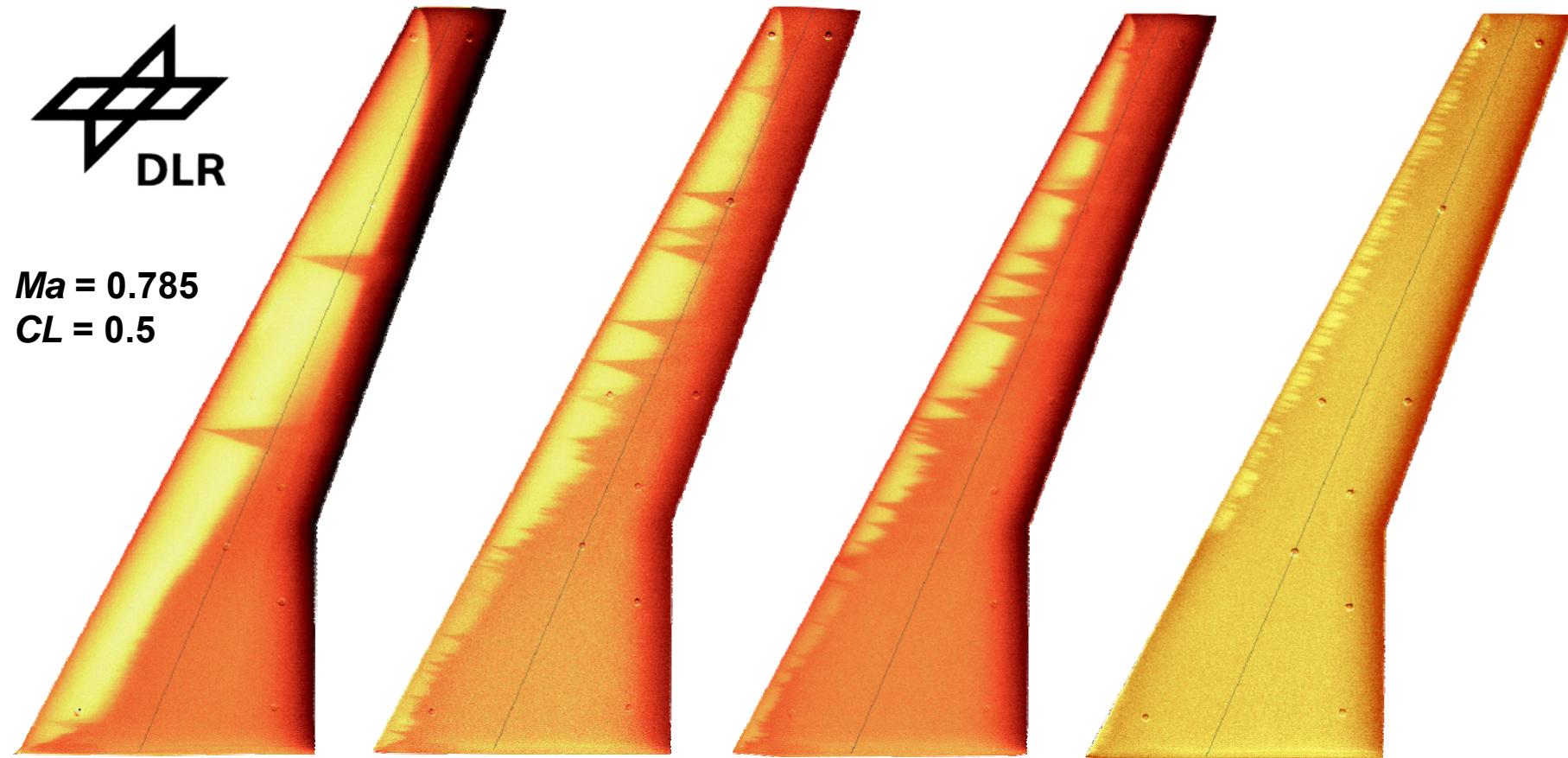
# Transition Detection by Temperature Sensitive Paint



# Development of Transition with Reynolds Number



$Ma = 0.785$   
 $CL = 0.5$



$Re = 6 \text{ Mio}$

April 2005

$10 \text{ Mio}$

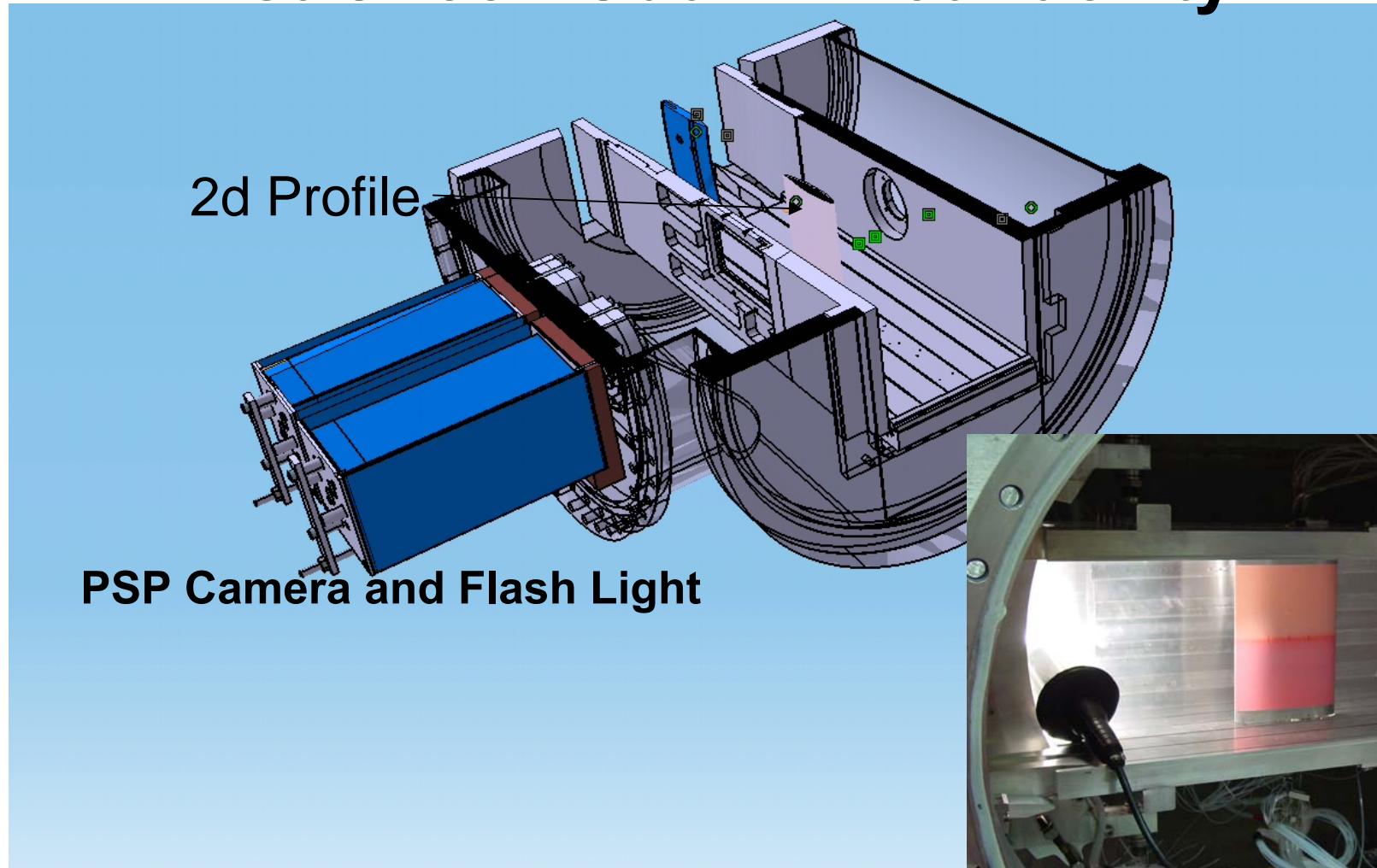
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$12 \text{ Mio}$

$17 \text{ Mio}$

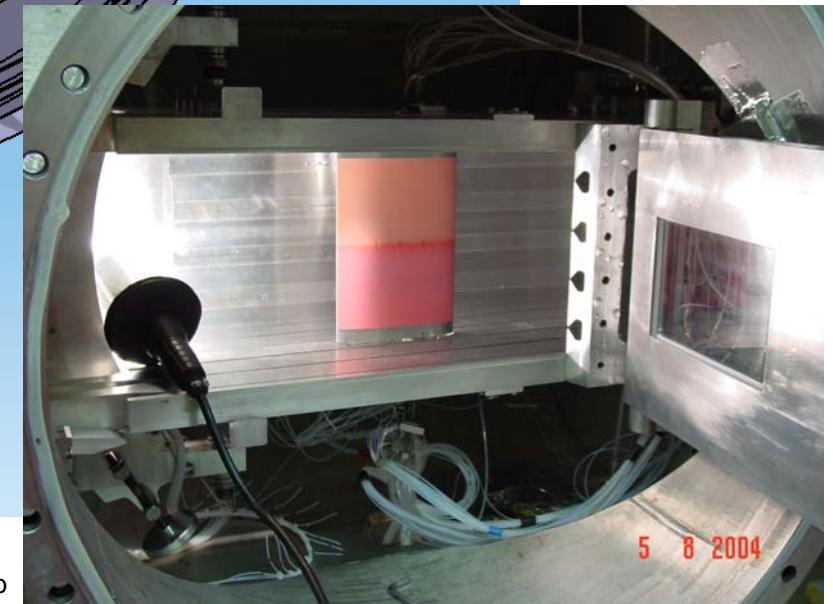
15

# Pressure Sensitive Paint First Check-Out in Pilot Facility PETW



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5 8 2004

# PSP - PETW Check-Out

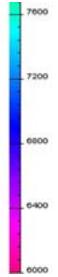
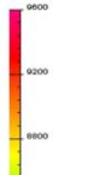
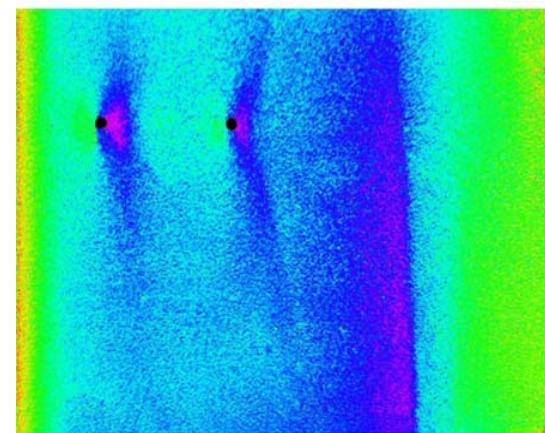
Oxygen Injection Capabilities

Control Stability of different  
Oxygen Concentration

Acquisition of Images  
at different Test Conditions

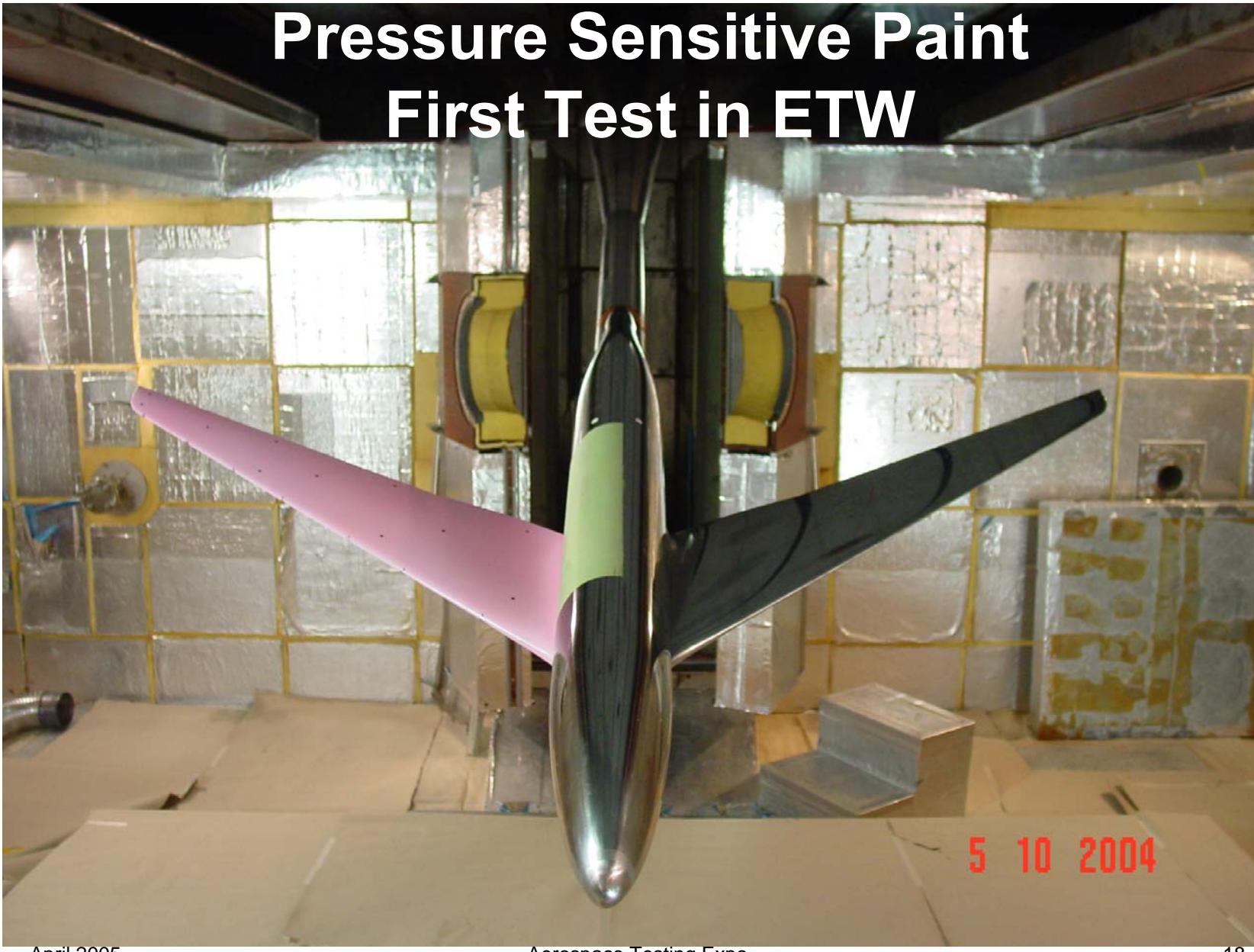
Check-out of TSP Equipment

Test Preparation and Handling



$T_{tot}=230\text{K}$ ,  $P_{tot}=120\text{ kPa}$ ,  $\text{Ma}=0.79$

# Pressure Sensitive Paint First Test in ETW



# PSP - First Test in ETW in October 2004

Oxygen Vapourizer  
during Operation  
 $0.5 \text{ Nm}^3/\text{sec}$



Oxygen Pipeline in Tunnel Building

# PSP - First Test in ETW in October 2004

First successful test in ETW

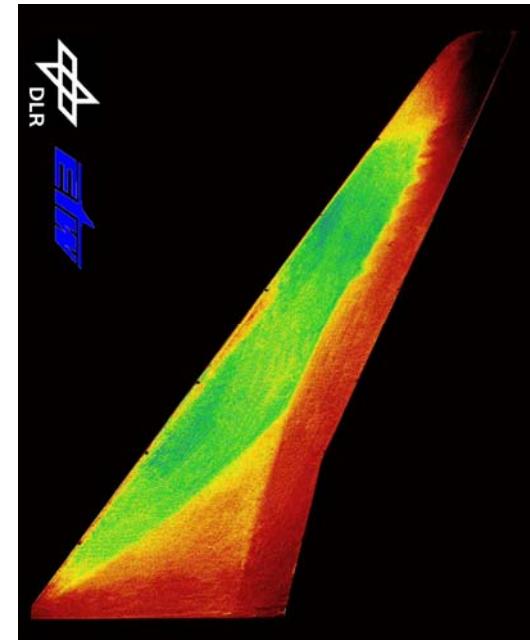
300 K – 160 K up to 340 kPa

Oxygen Injection with  
manual control

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

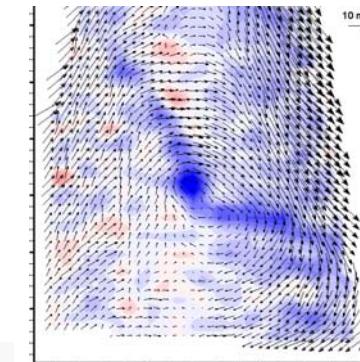
Images successfully acquired

Surface roughness of paint 0.3µm

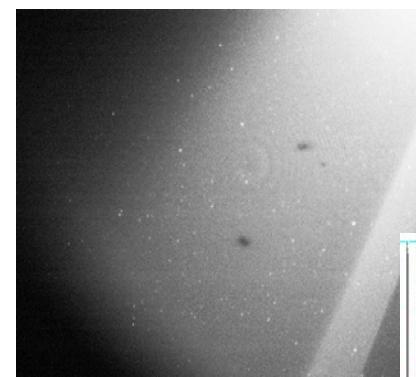


# Flow Visualisation and Measurement

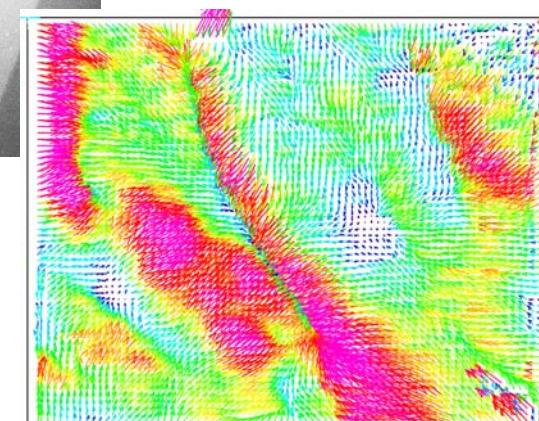
Doppler Global Velocimetry



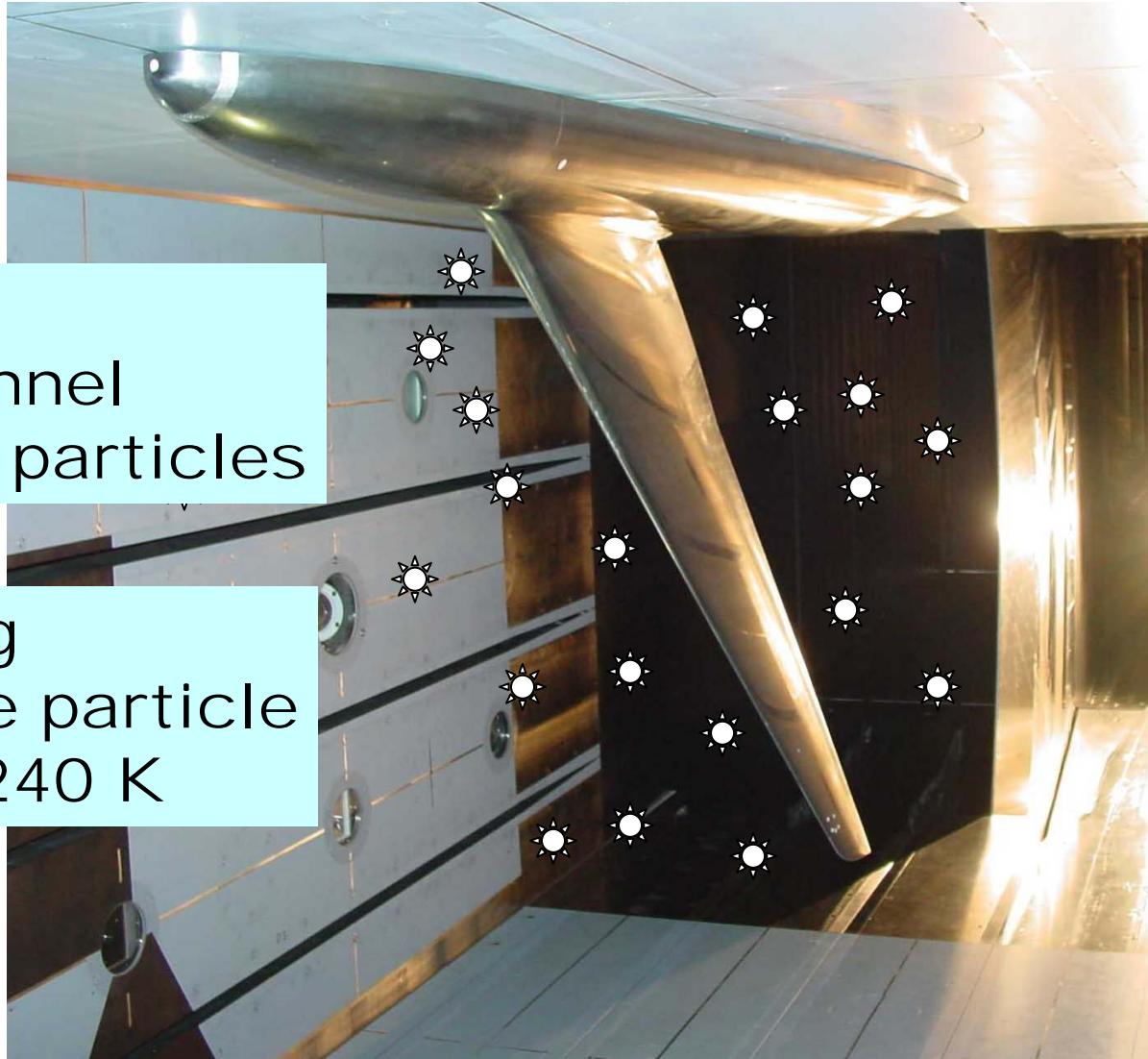
Laser Light Sheet



Background Oriented Schlieren



# LASER Systems require Seeding



ETW -  
wind tunnel  
without particles

Seeding  
with ice particle  
below 240 K

# Wake Measurement - DGV System

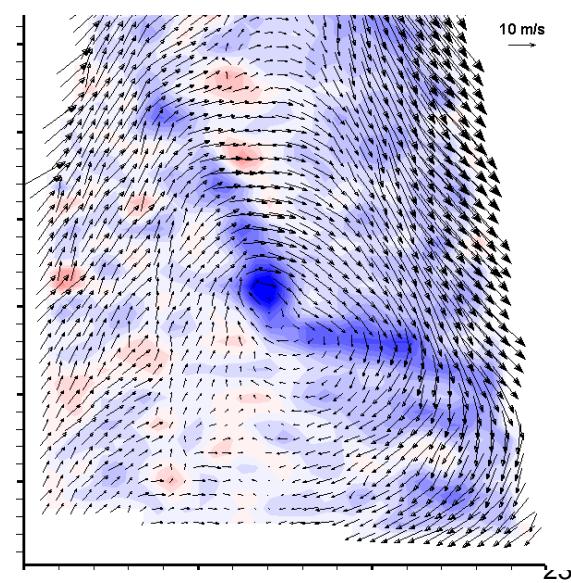
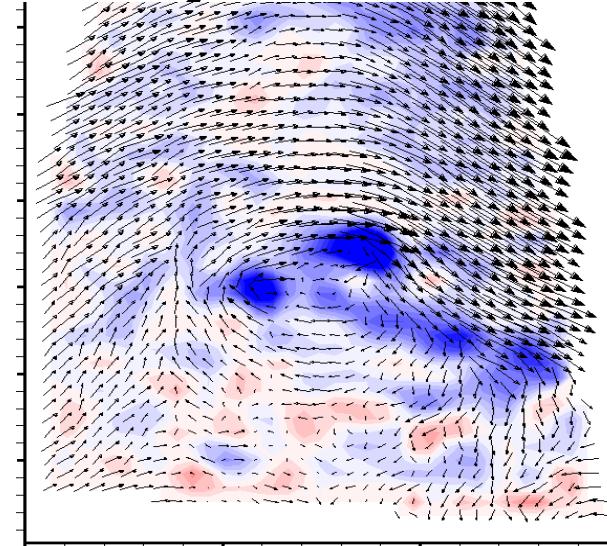


MDAW  
Project



April 2005

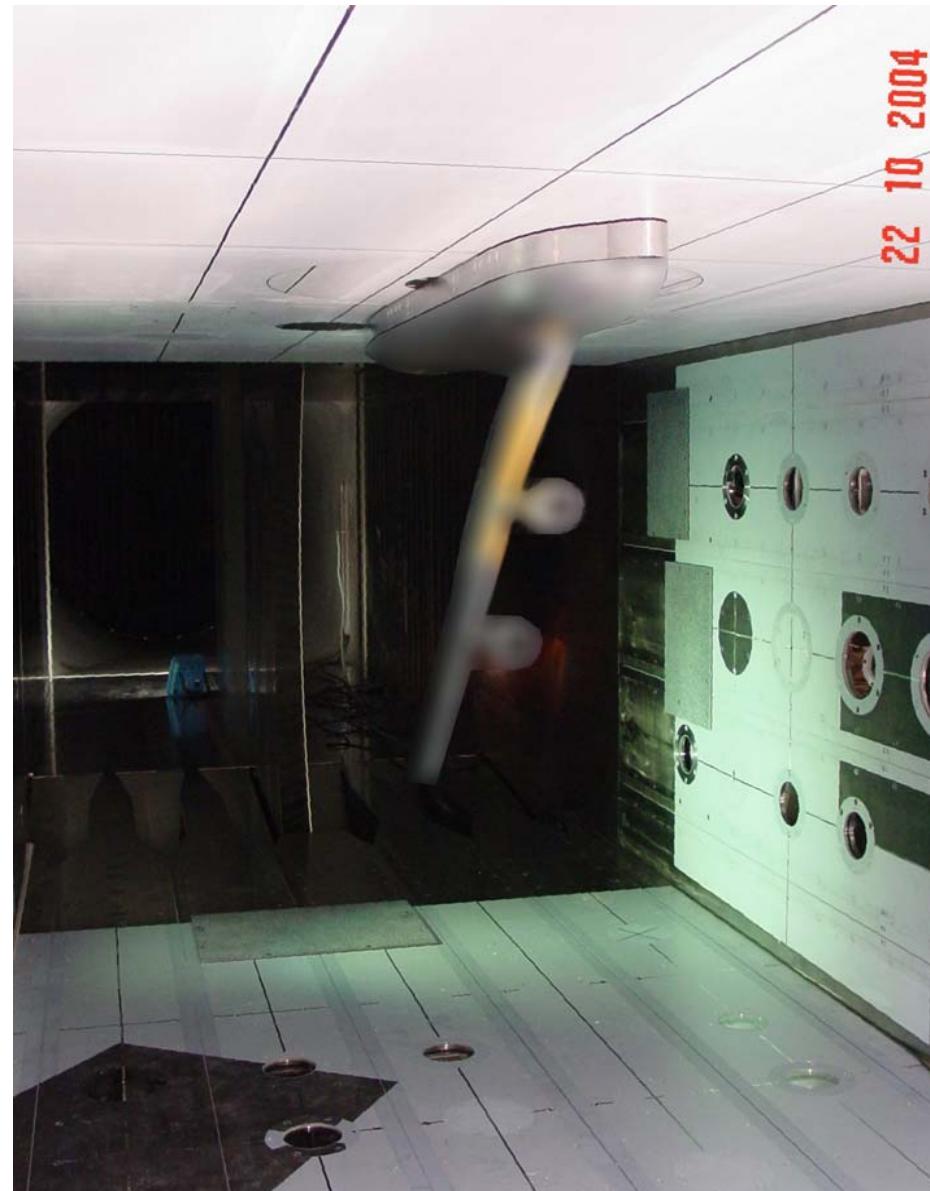
Aerospace Testing Expo



Laser  
Light  
Sheet  
Background  
Oriented  
Schlieren

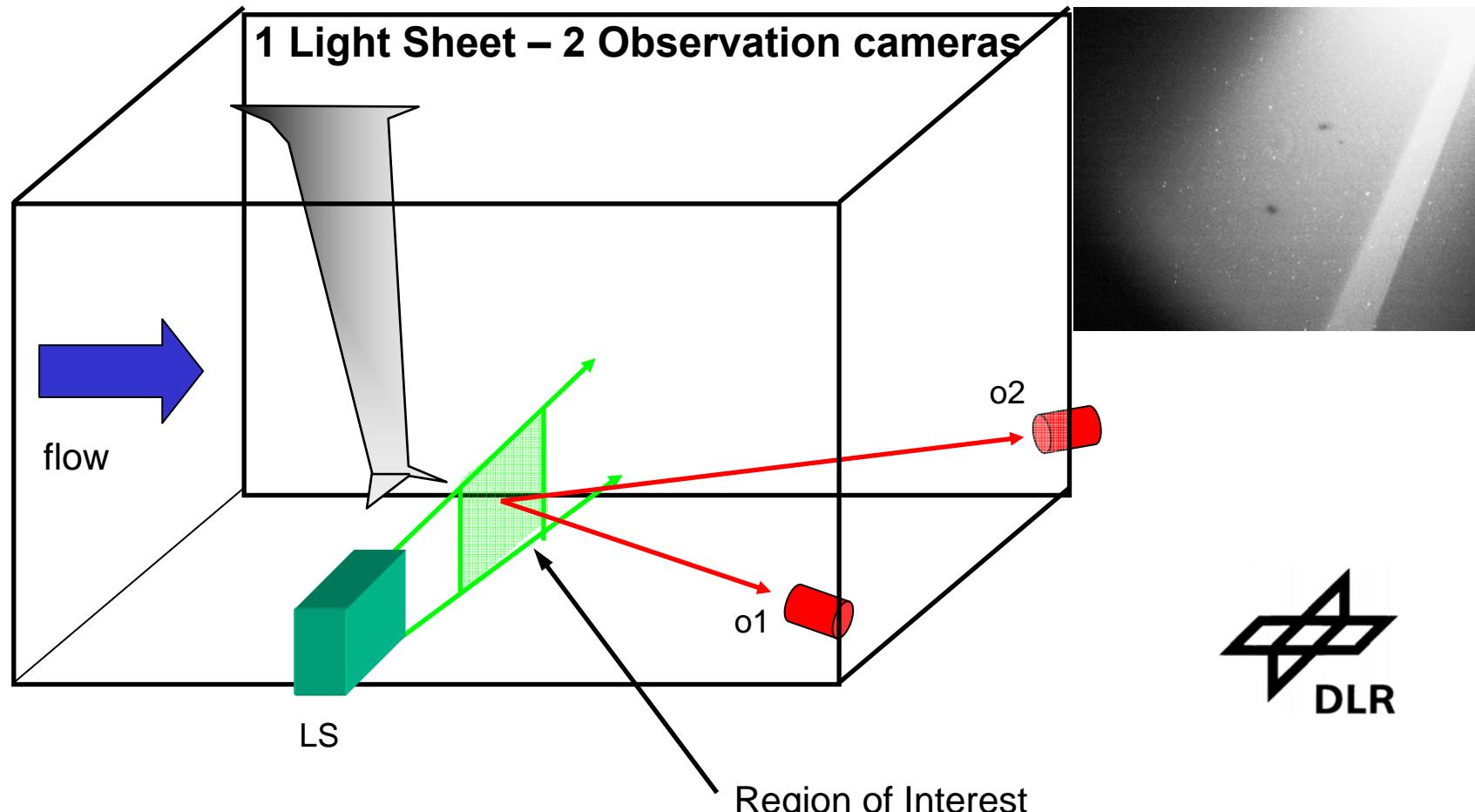
Reynolds Number  
Influence on Wake  
Vortex Position

LUFO -  
AIRWI

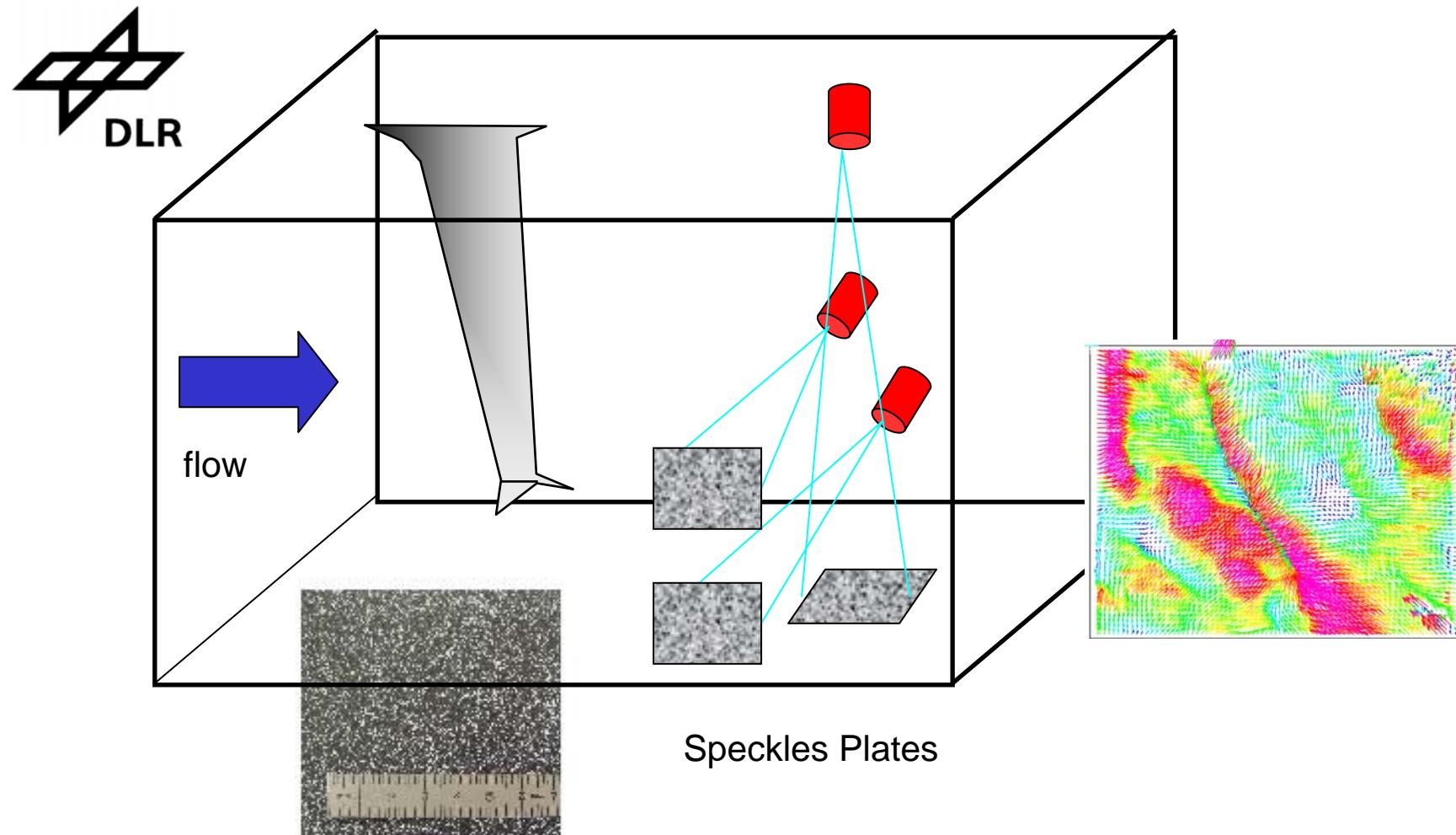


Aerospace Testing Expo

# Laser Light Sheet (LLS)



## Background Oriented Schlieren (BOS)



## Further Development

- Pressure Sensitive Paint for cryogenic conditions
- Standard operation of optical systems for
  - Model Deformation Measurement
  - Flow Visualization
- Testing tools for Aeroelastic Investigations

Importance of

## FLIGHT REYNOLDS NUMBER TESTING

demonstrated

High Standard on

## TESTING TECHNIQUES

achieved

Further Improvement on

## PRODUCTIVITY and COST EFFICIENCY



