EXPERIMENTAL AND CFD INVESTIGATION OF HELICOPTER BERP TIP AERODYNAMICS

by

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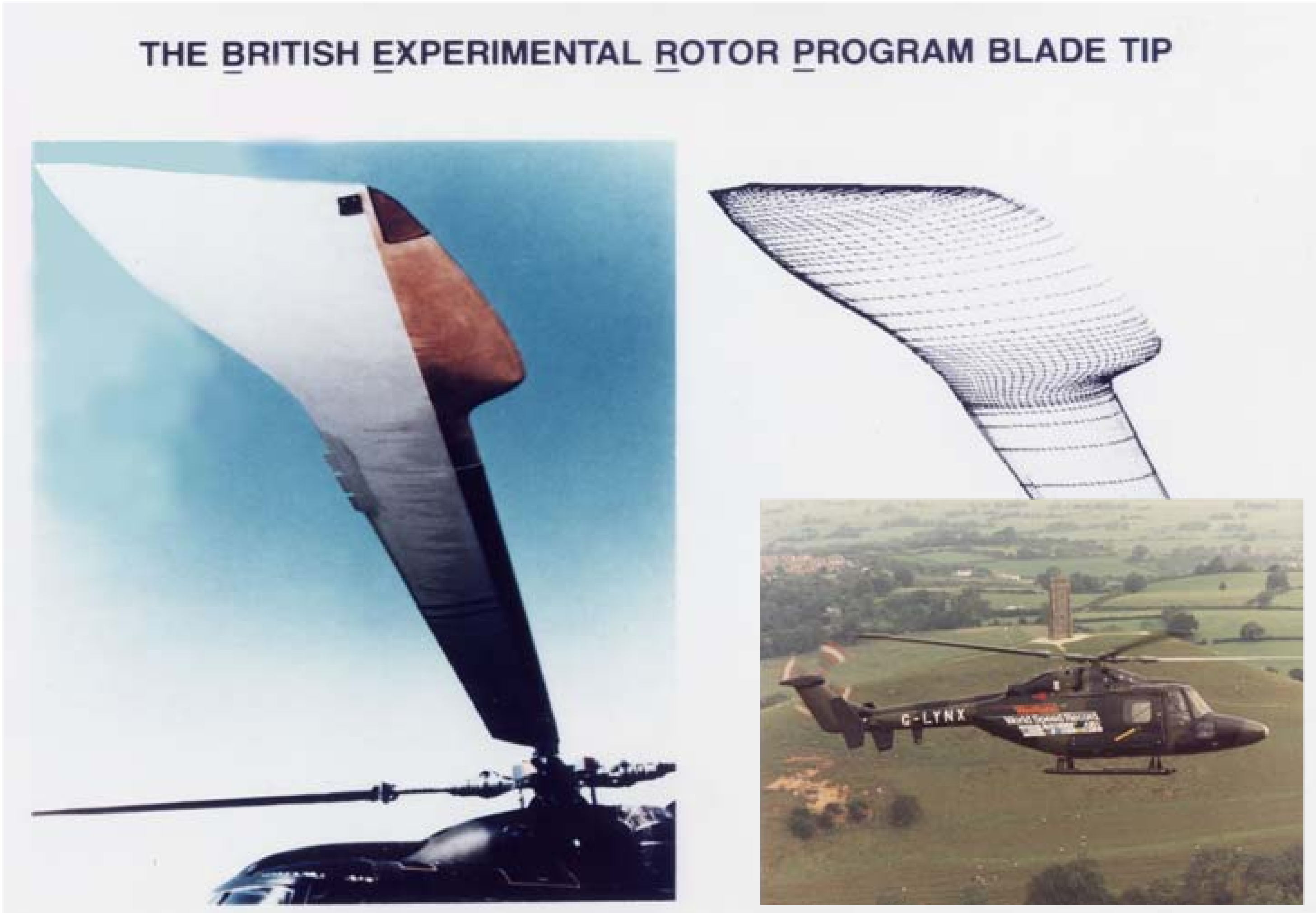
UNIVERSITY of GLASGOW

Conference on Computational and Experimental Methods
on the occasion of
Professor Bryan Richard's Retirement
10 September 2003

INVESTIGATION OF BERP TIP AERODYNAMICS



Lynx: World Speed Record400.87 km/hr, 216.3 kts, 250.54 mph

Introduction

WHL Wind Tunnel Experiments – Collaboration with NASA Ames (1989)

Comparison of Measurements and Computational Studies

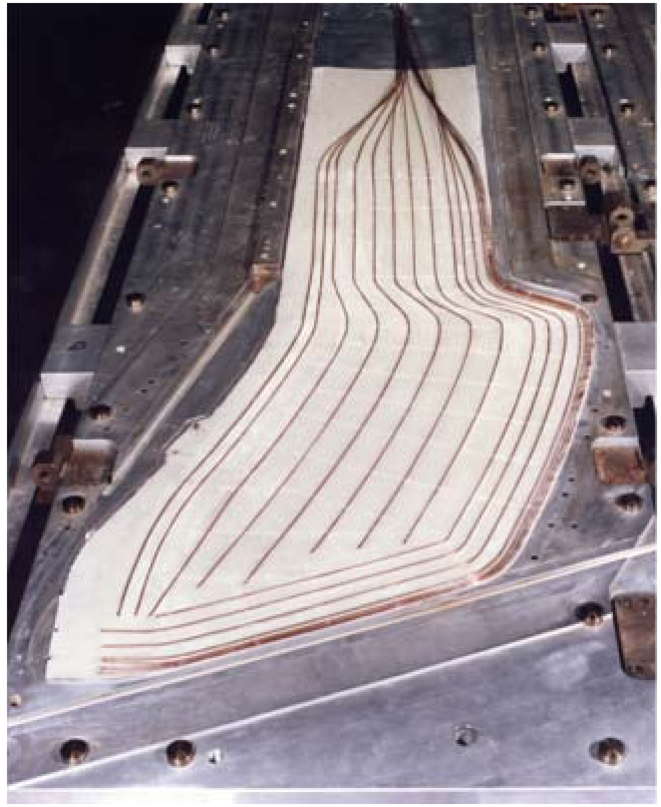
WHL Advancing Blade CFD and VSAERO Spanwise Loading

Analysis with the Glasgow Code – Unsteady Pitching Motion

WHL Wind Tunnel Tests on the NASA/BERP-III Wing

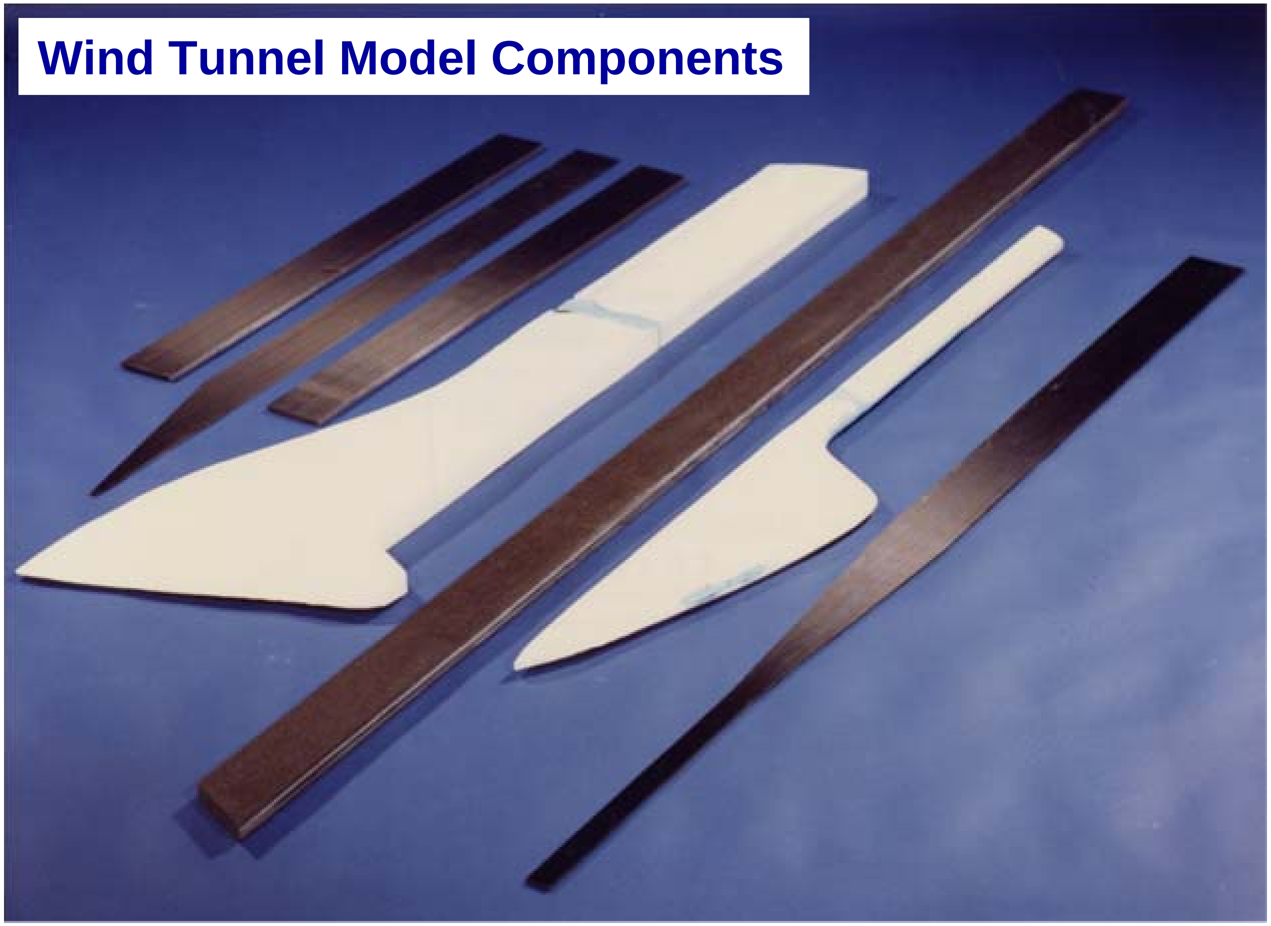
Pressure Tube Layout in Blade Skinning Tool

Upper Surface



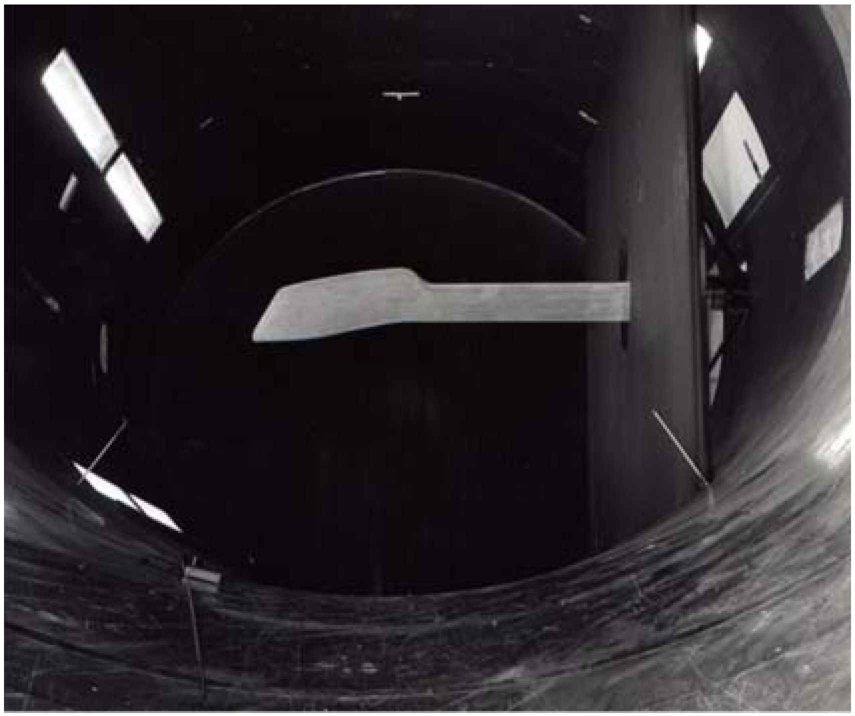
Lower Surface

WHL Wind Tunnel Tests on the NASA/BERP-III Wing

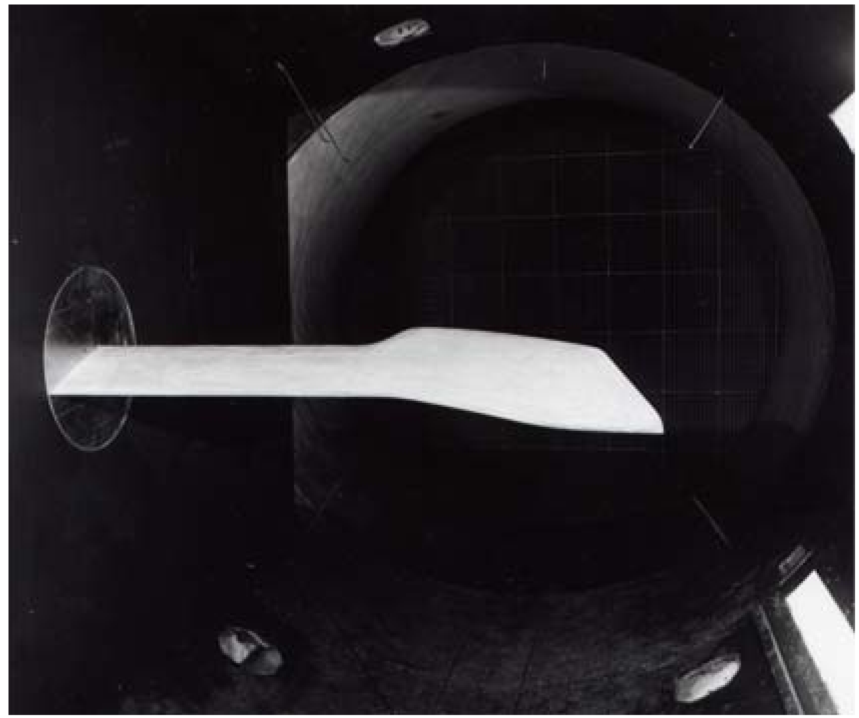


WHL Wind Tunnel Tests on the NASA/BERP-III Wing

BERP-III Wing Installed in the Tunnel

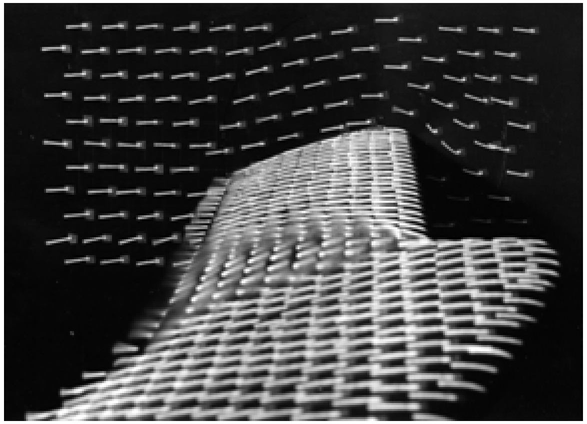


View from Up-Wind



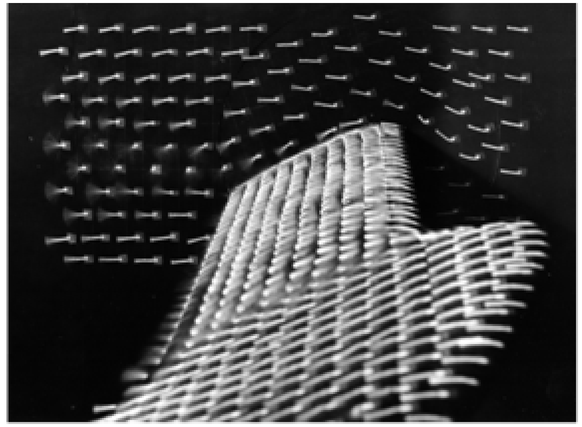
View from Down-Wind

WHL Wind Tunnel Tests on the NASA/BERP-III Wing

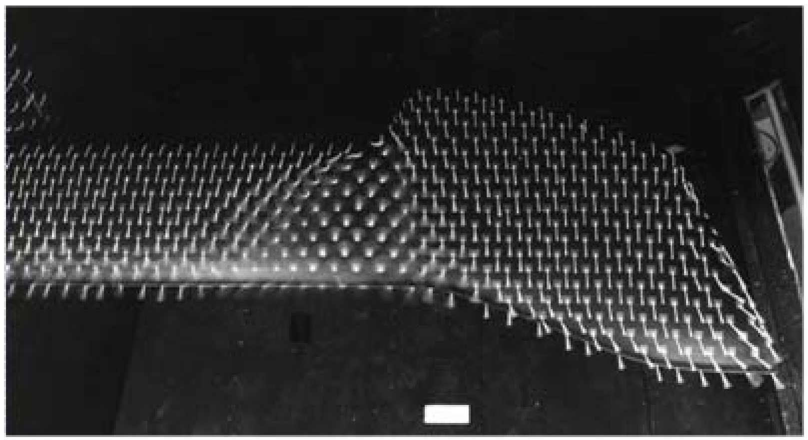


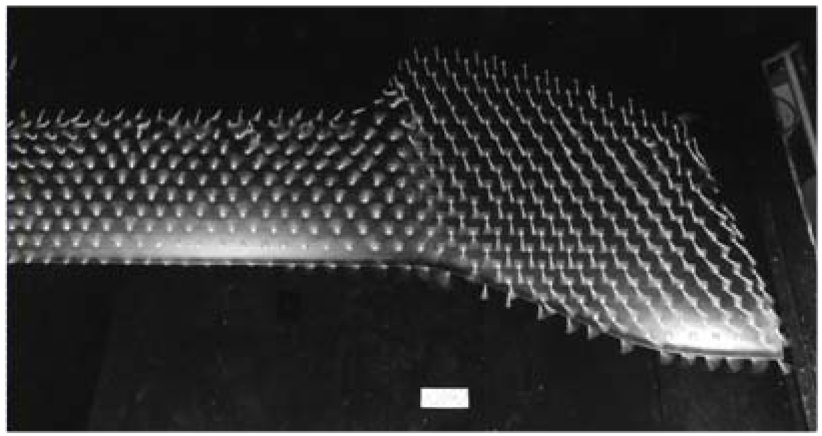
Wing Root Incidence 13 deg

Wool Tufts Flow Visualisation



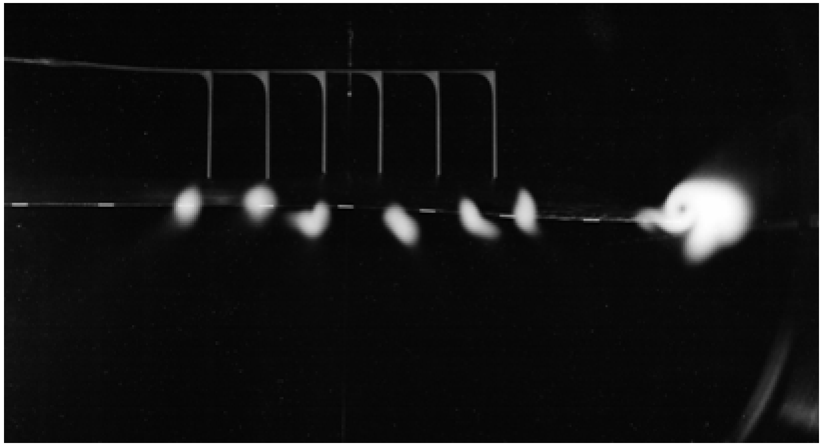
Wing Root Incidence 20 deg



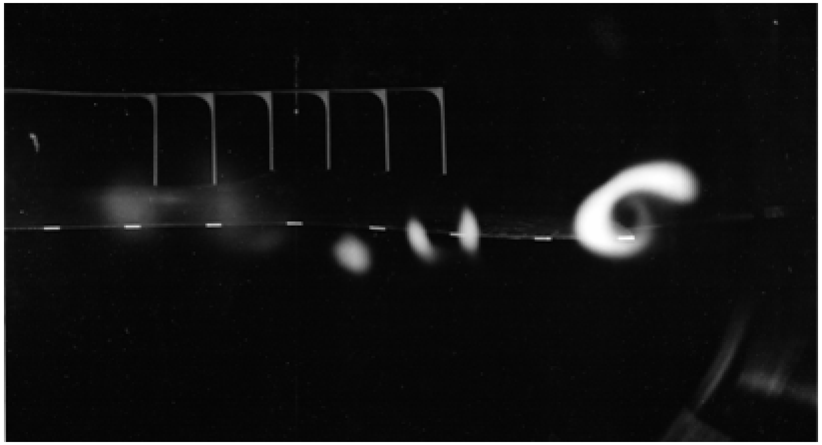


WHL Wind Tunnel Tests on the NASA/BERP-III Wing

Smoke Flow Visualisation



6 degrees



13 degrees

1.75 chords downstream

WHL Wind Tunnel Tests on the NASA/BERP-III Wing

Oil Flow Visualisation - Re=1.4million - Transition Fixed .007” thread

Wing Root Incidences

WHL Wind Tunnel Tests on the NASA/BERP-III Wing

Oil Flow Visualisation - Re=1.4million - Transition Free


14 deg


15 deg

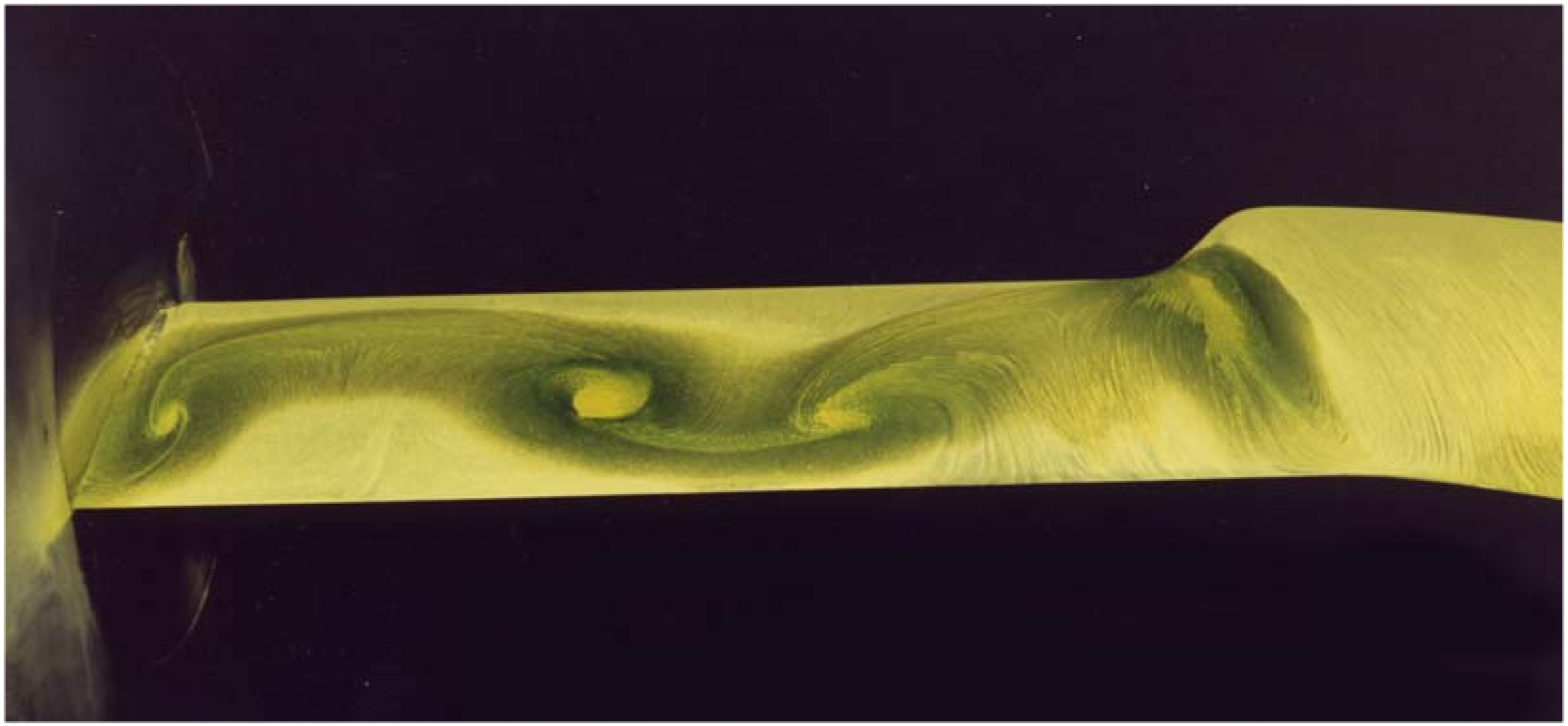

9 deg


11 deg


13 deg

WHL Wind Tunnel Tests on the NASA/BERP-III Wing

Oil Flow Visualisation – Re=1.4million - Transition Fixed - Inboard



Wing Root Incidence 14 degrees

WHL Wind Tunnel Tests on the NASA/BERP-III Wing

Layout of Pressure Taps

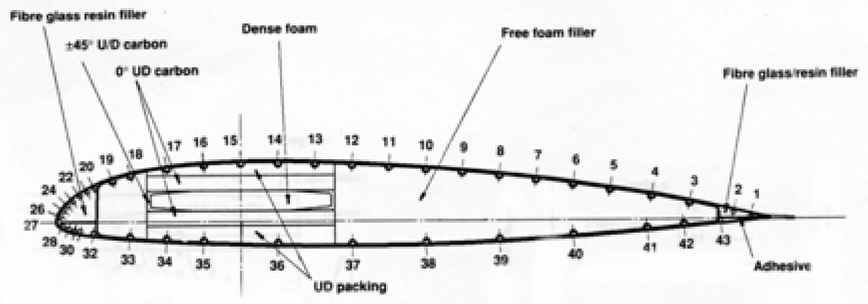


Fig. 5 Cross section illustrating typical construction of wing showing chordwise location of pressure taps.

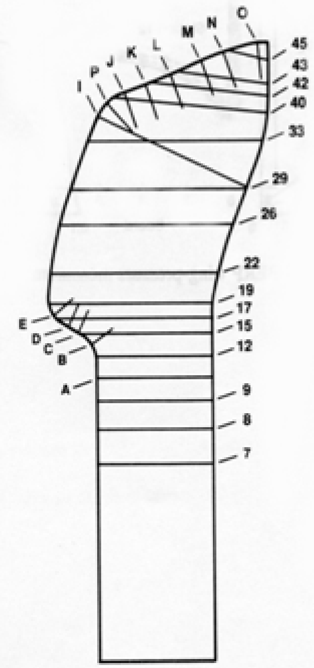
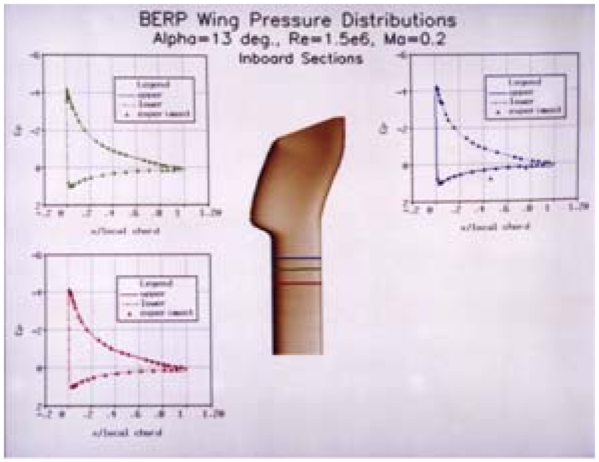
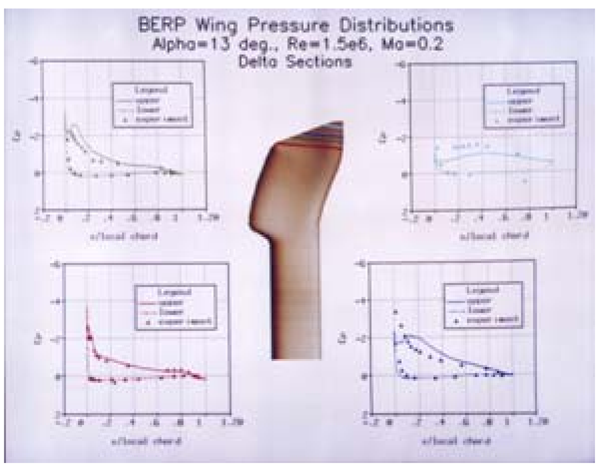


Fig. 6 BERP wing-pressure tapping stations.

Comparisons through Collaboration with NASA Ames



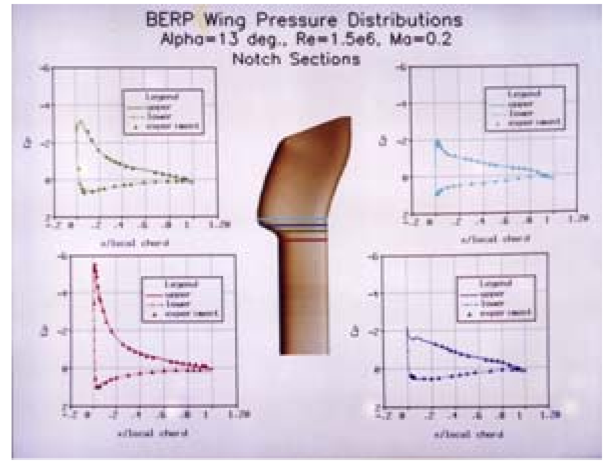


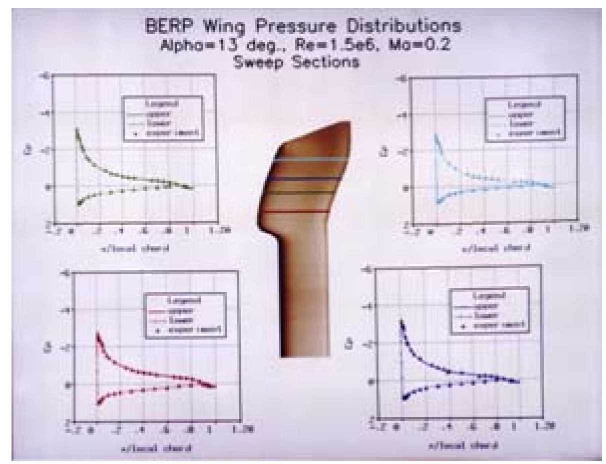
Navier-Stokes Computations by Earl Duque (NASA Ames)

compared to

WHL Wind Tunnel Measurements (1989)

Re=1.4 million





Comparisons through Collaboration with NASA Ames

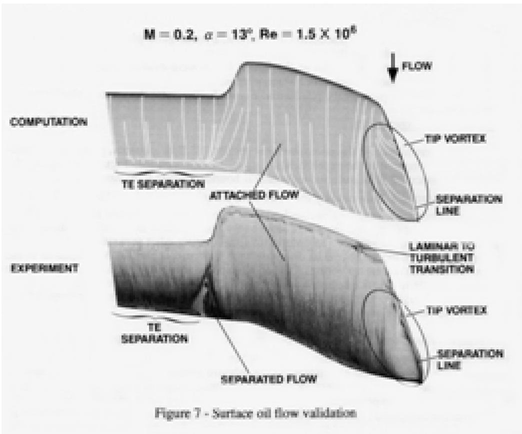


Figure 7 - Surface oil flow validation

13 degrees

WHL Wind Tunnel

Measurements

(1989)

Spanwise Lift Coefficient

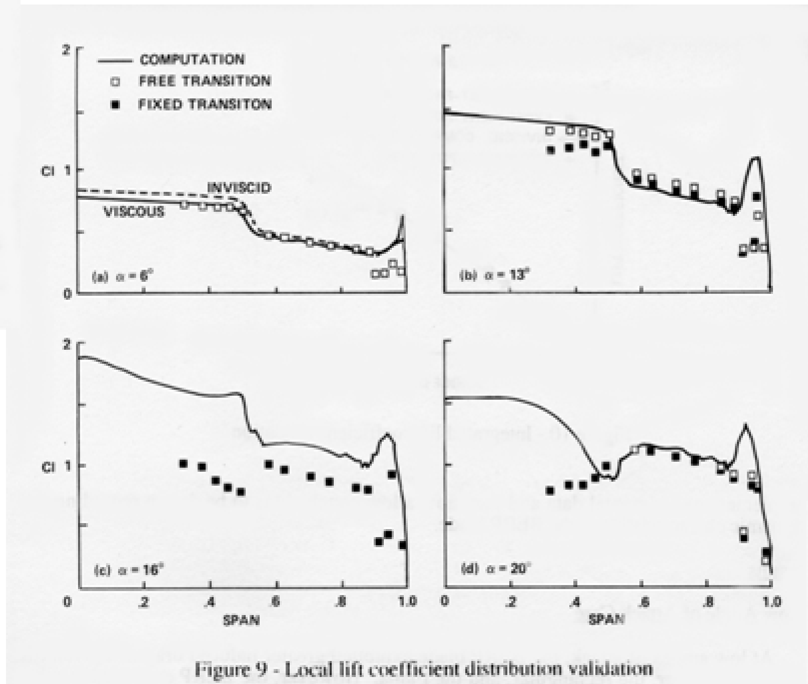


Figure 9 - Local lift coefficient distribution validation

6, 13, 16, 20 degrees

Navier-Stokes

Computations

by

Earl Duque

(NASA Ames)

20 degrees

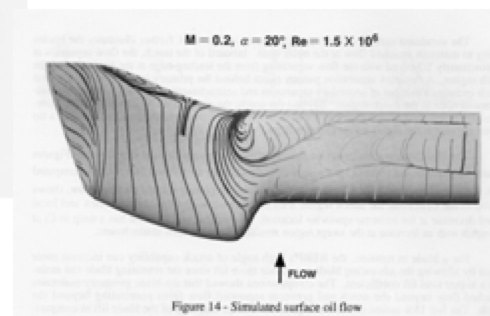
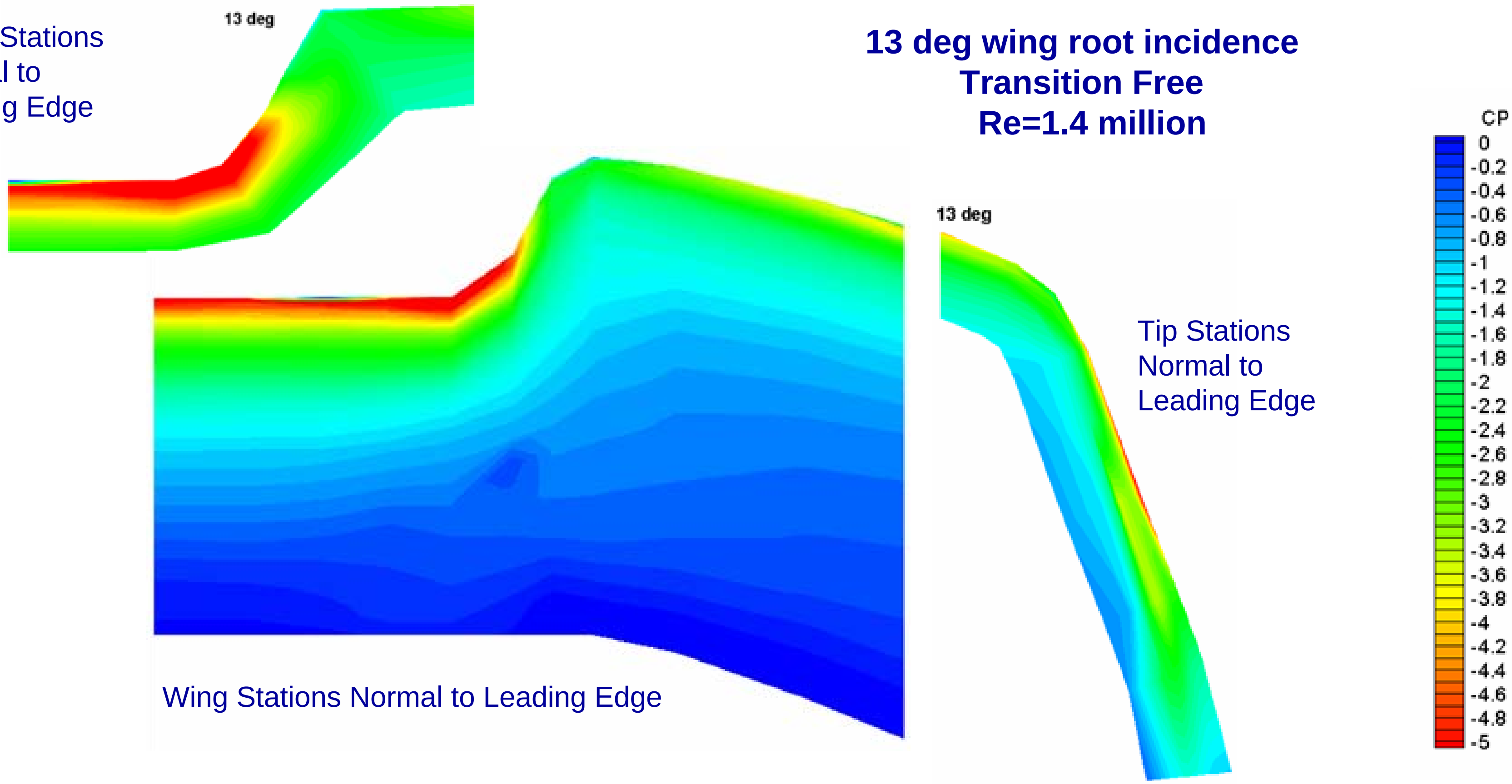


Figure 14 - Simulated surface oil flow

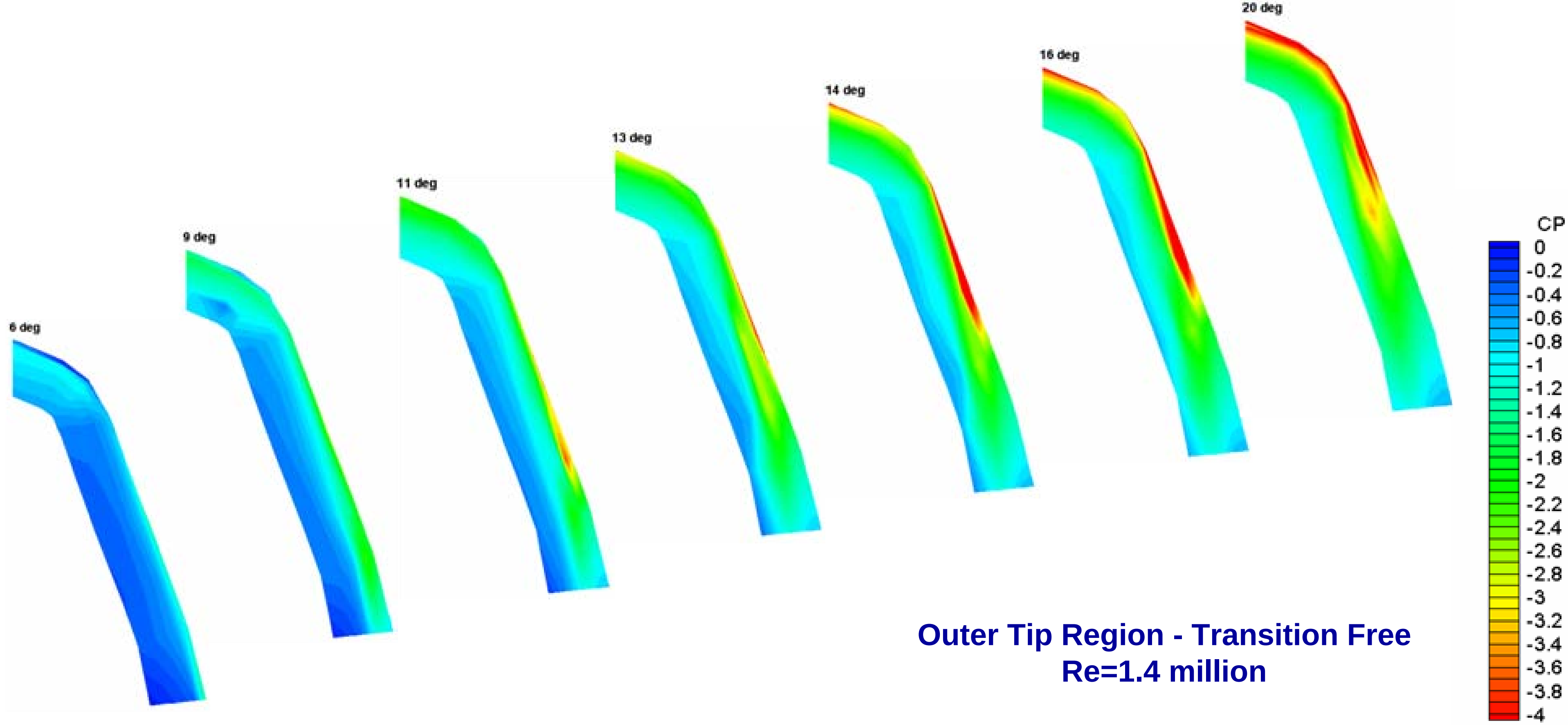
BERP Wing Pressure Contours from Test Data

Notch Stations
Normal to
Leading Edge

13 deg wing root incidence
Transition Free
Re=1.4 million



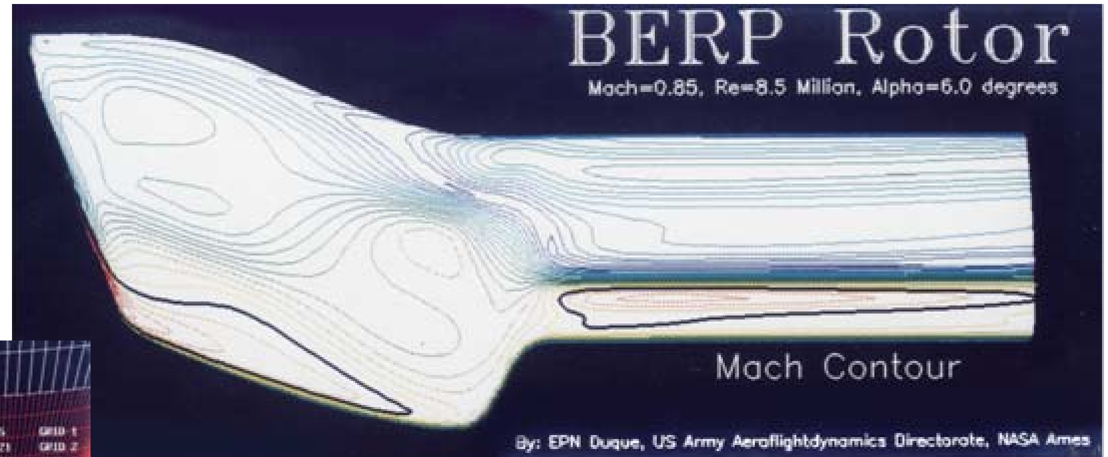
BERP Wing Tip Pressure Contours from Test Data

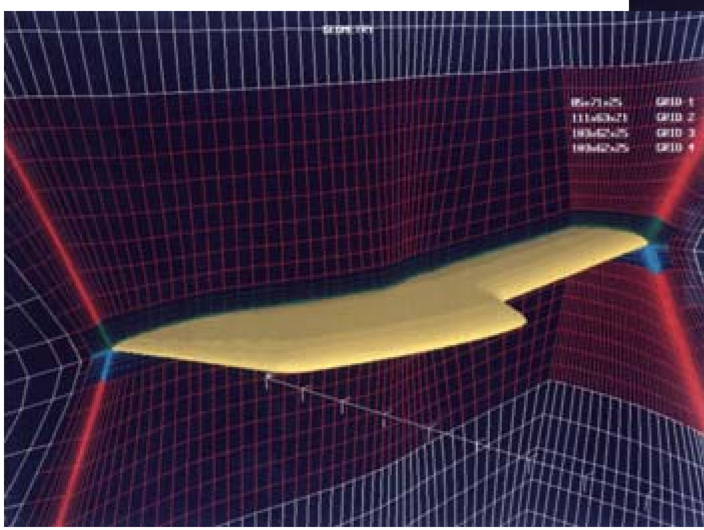


Outer Tip Region - Transition Free
Re=1.4 million

Advancing Blade CFD Analysis of the BERP Blade by NASA

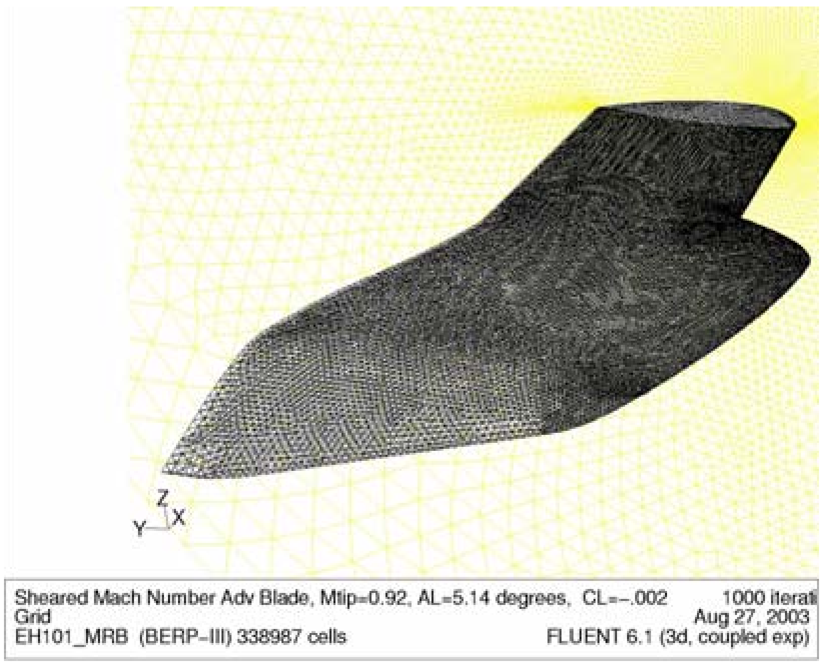
Sheared Mach Flow

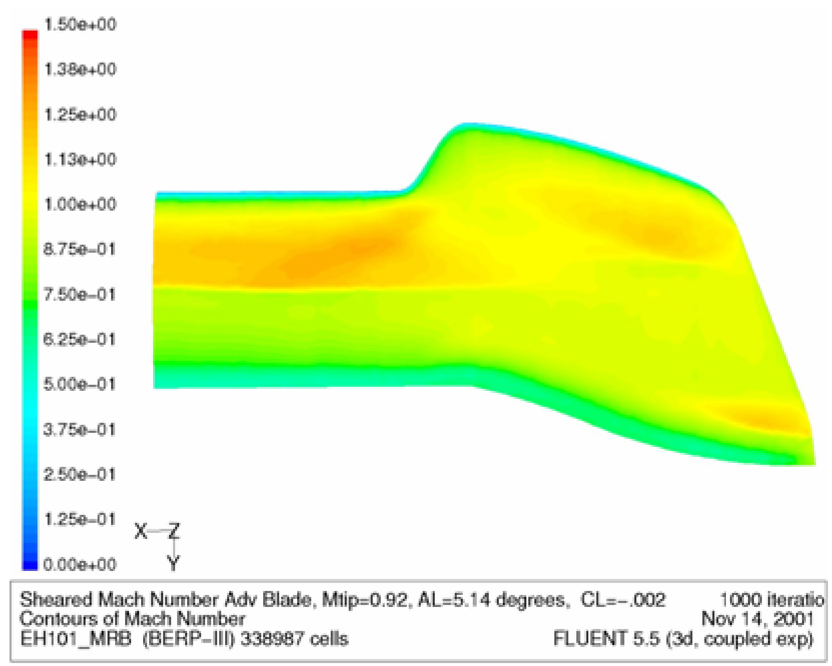




Advancing Blade Simulations

Westland CFD Analysis of Advancing Blade Tip

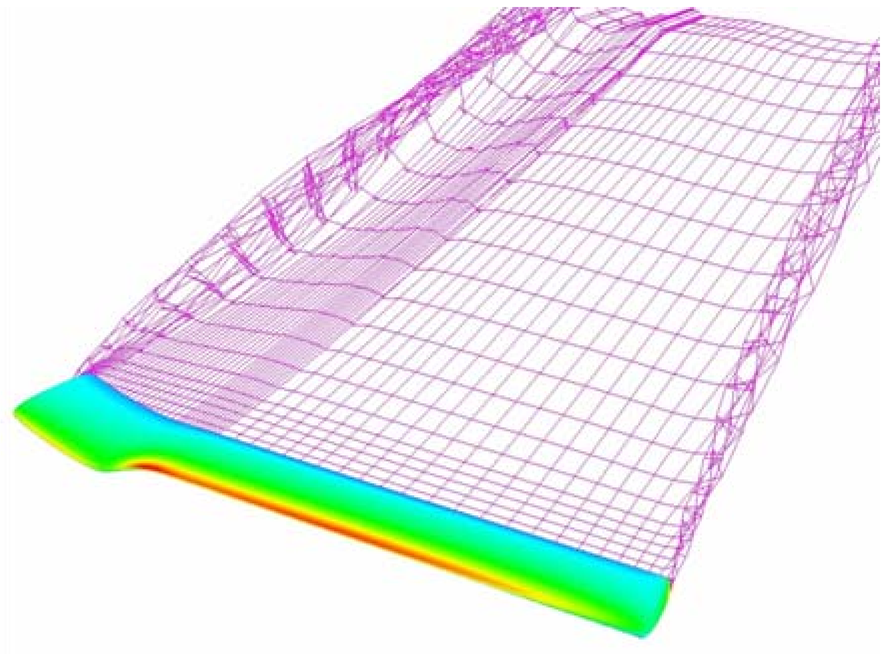


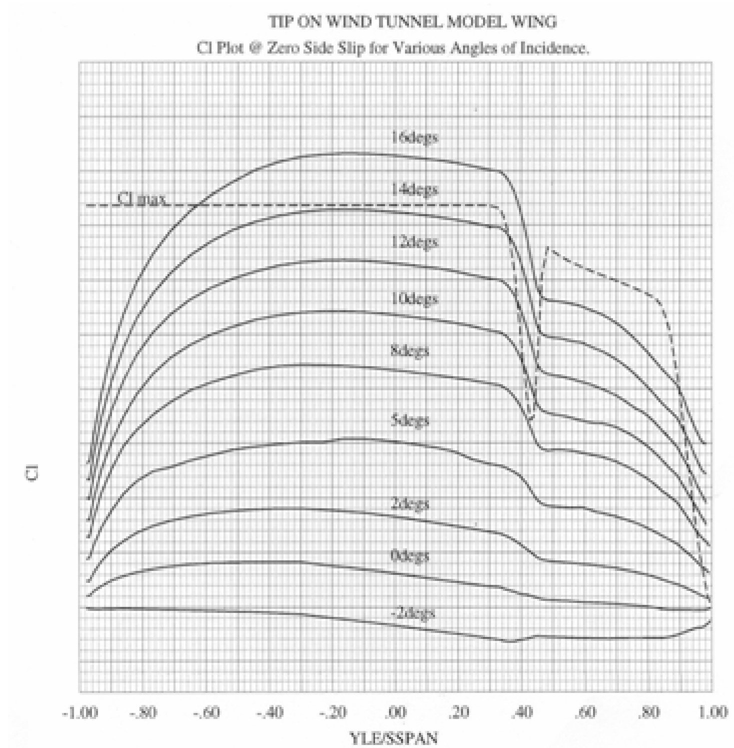


EH101 MRB Mtip=0.92 CL=0

Fluent CFD Code

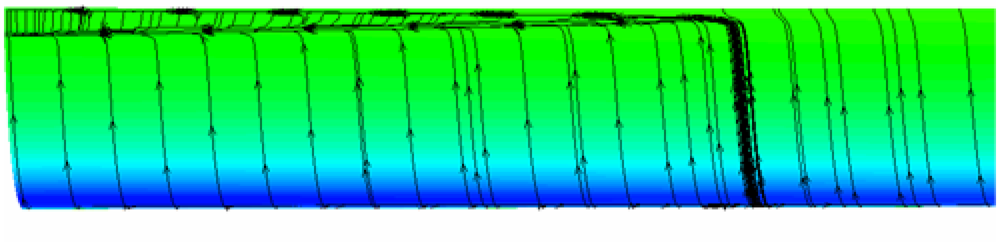
VSAERO Spanwise Loading for Tip Design



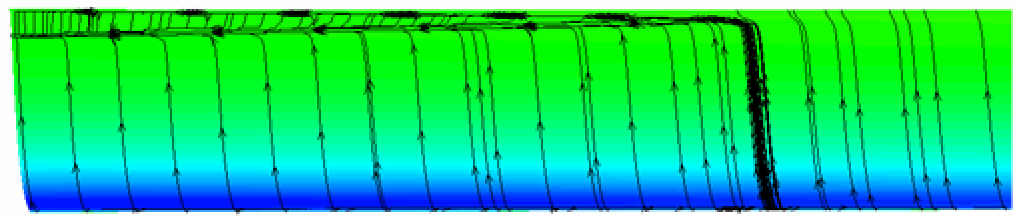


Lynx CMRB Wind Tunnel Model

3D Panel Code with Coupled Boundary Layer



Steady Calculation



Slow Ramping

Wind

Ramping BERP III wing
Re=1.4x10^6
M=0.16

k-ω turbulence model
455x10^3 cells

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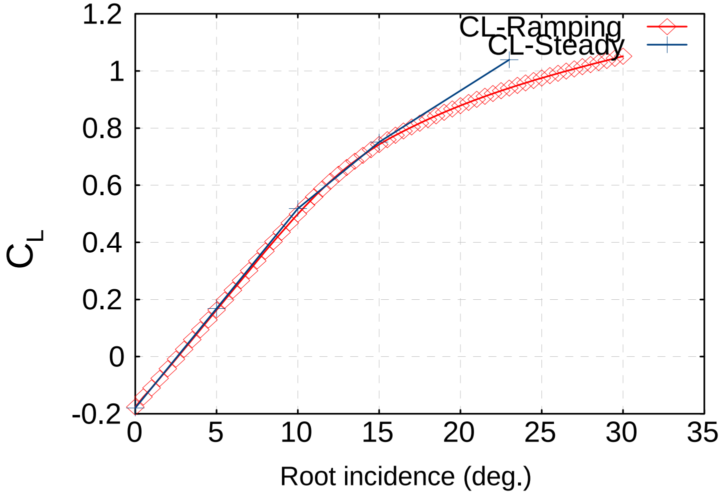
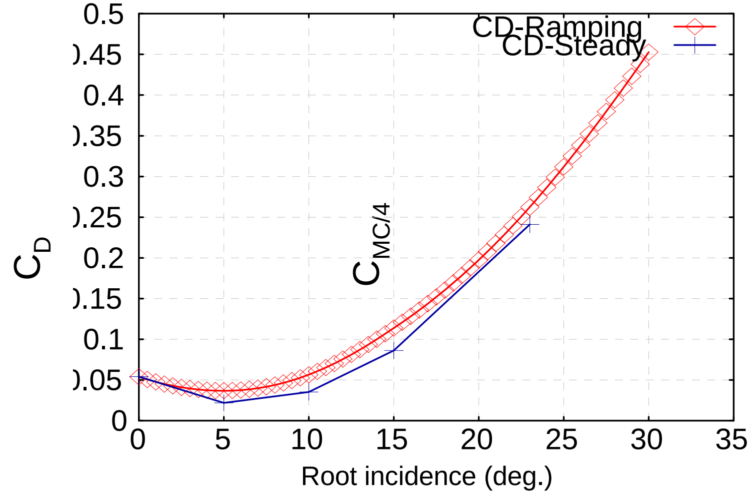




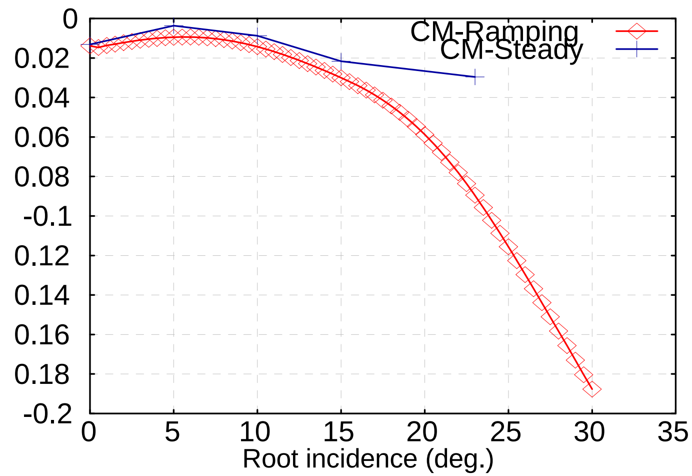
Ramping BERP III wing

Re=0.64x10^6

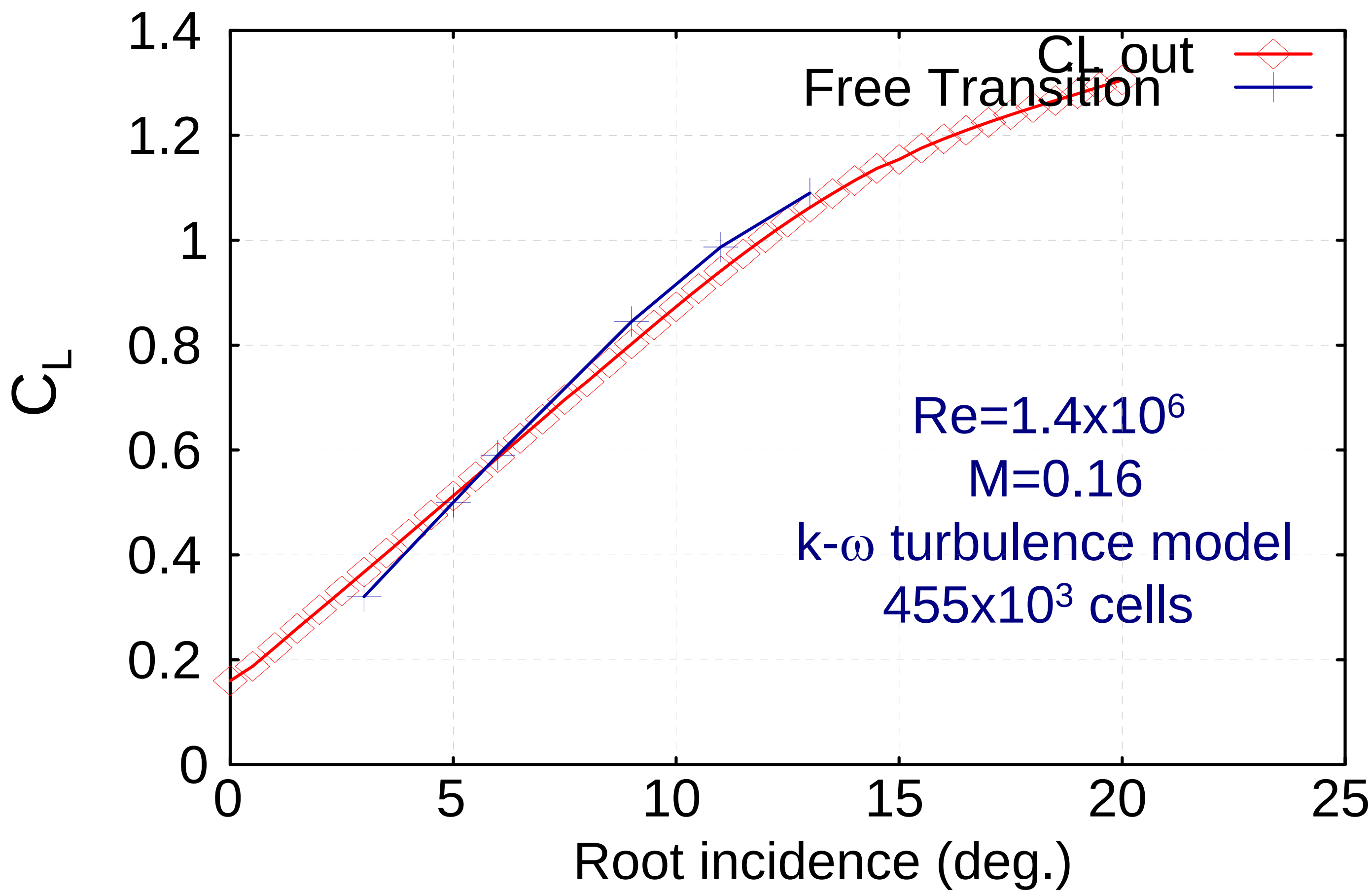
M=0.2

k-ω turbulence model

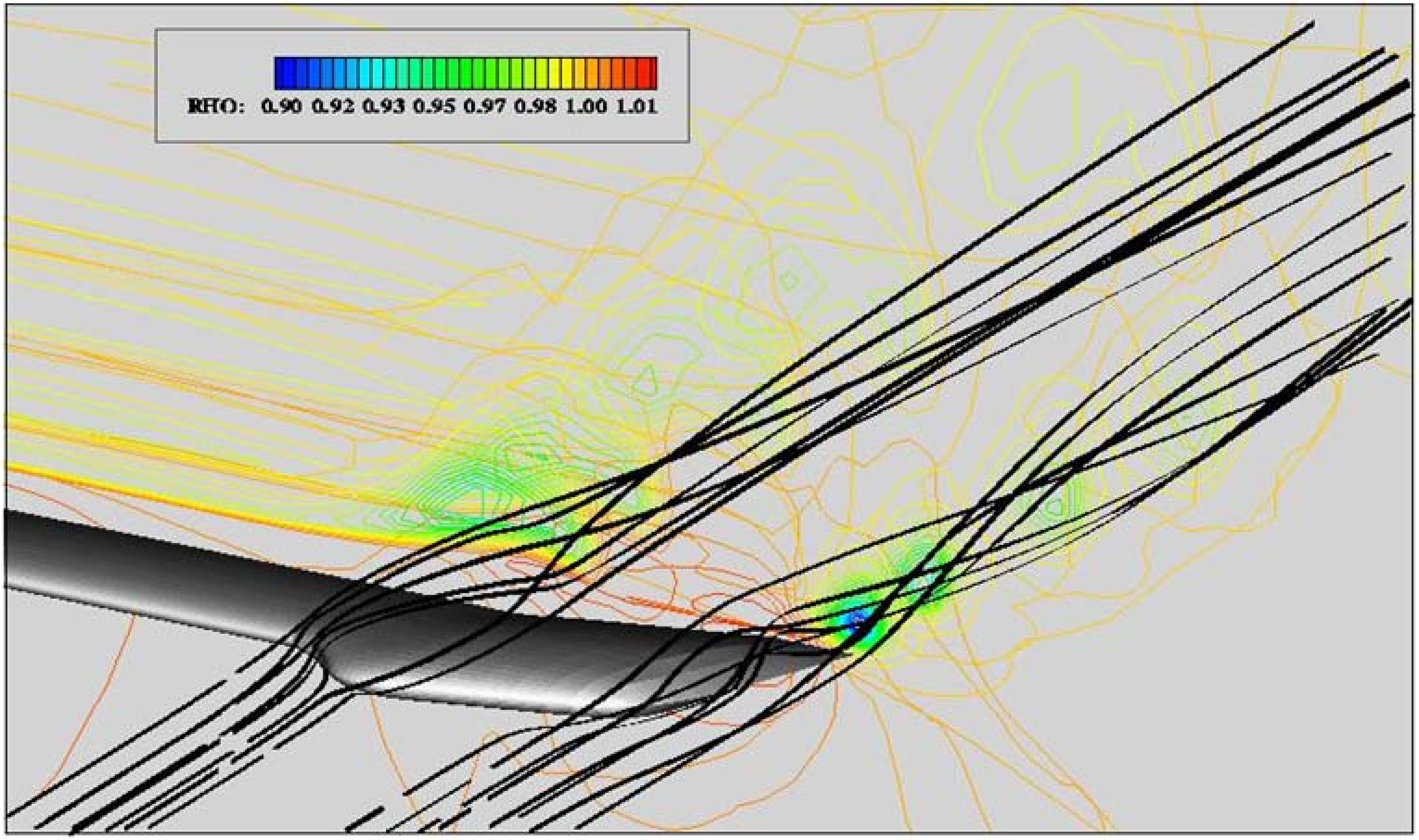
350x10^3 cells



Ramping BERP-III Wing



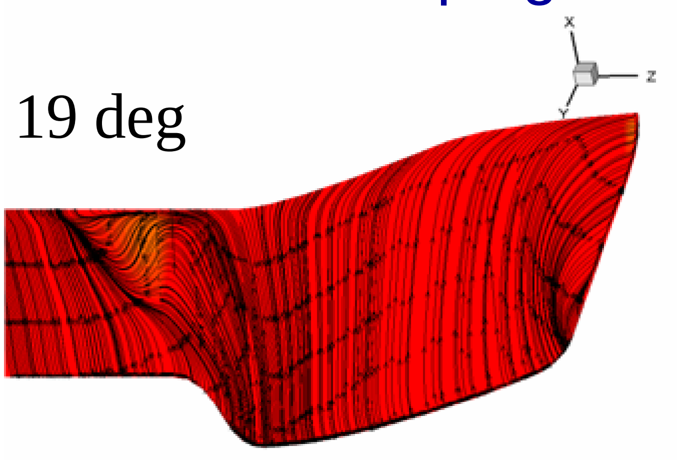
INVESTIGATION OF BERP TIP AERODYNAMICS

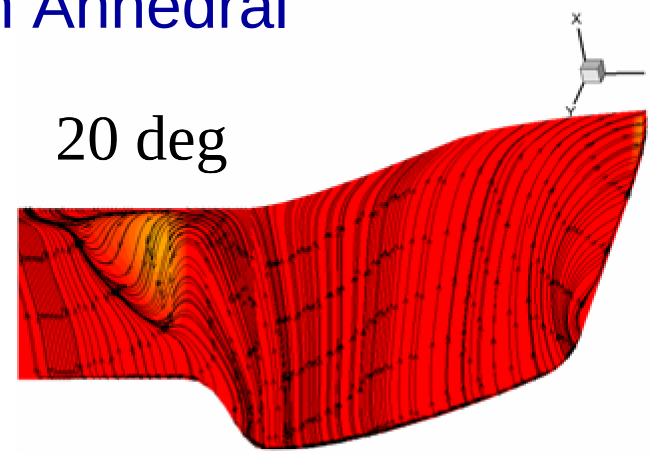


Subsonic conditions, M = 0.15, Re = 1.8 x 105, k-ω turbulence model

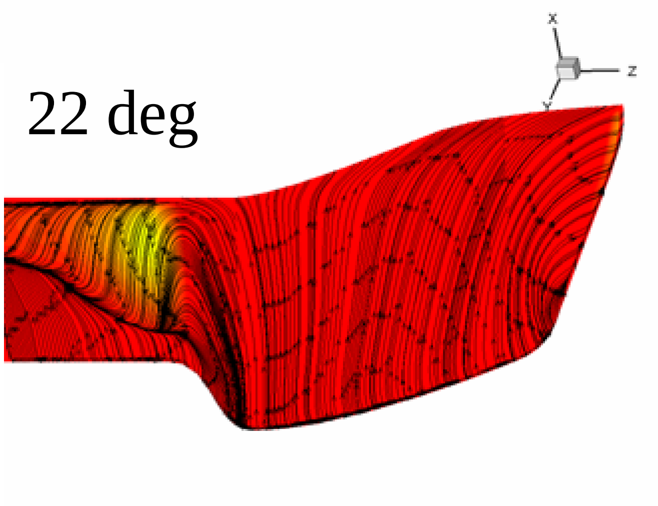
Flow Visualisation from CFD at High Angle of Attack

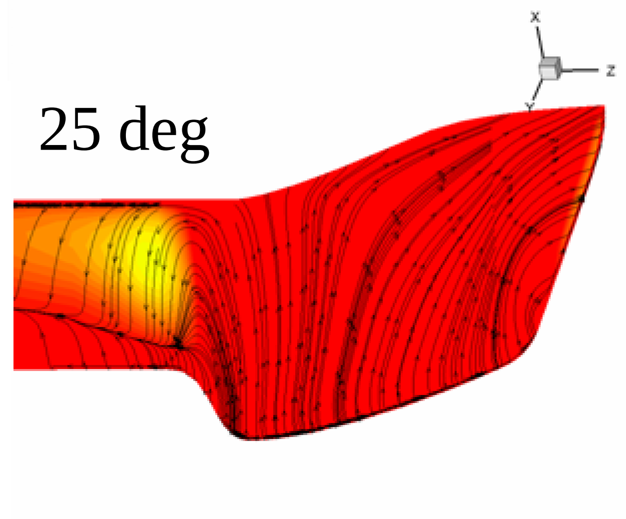
Ramping BERP-III Wing with Anhedral





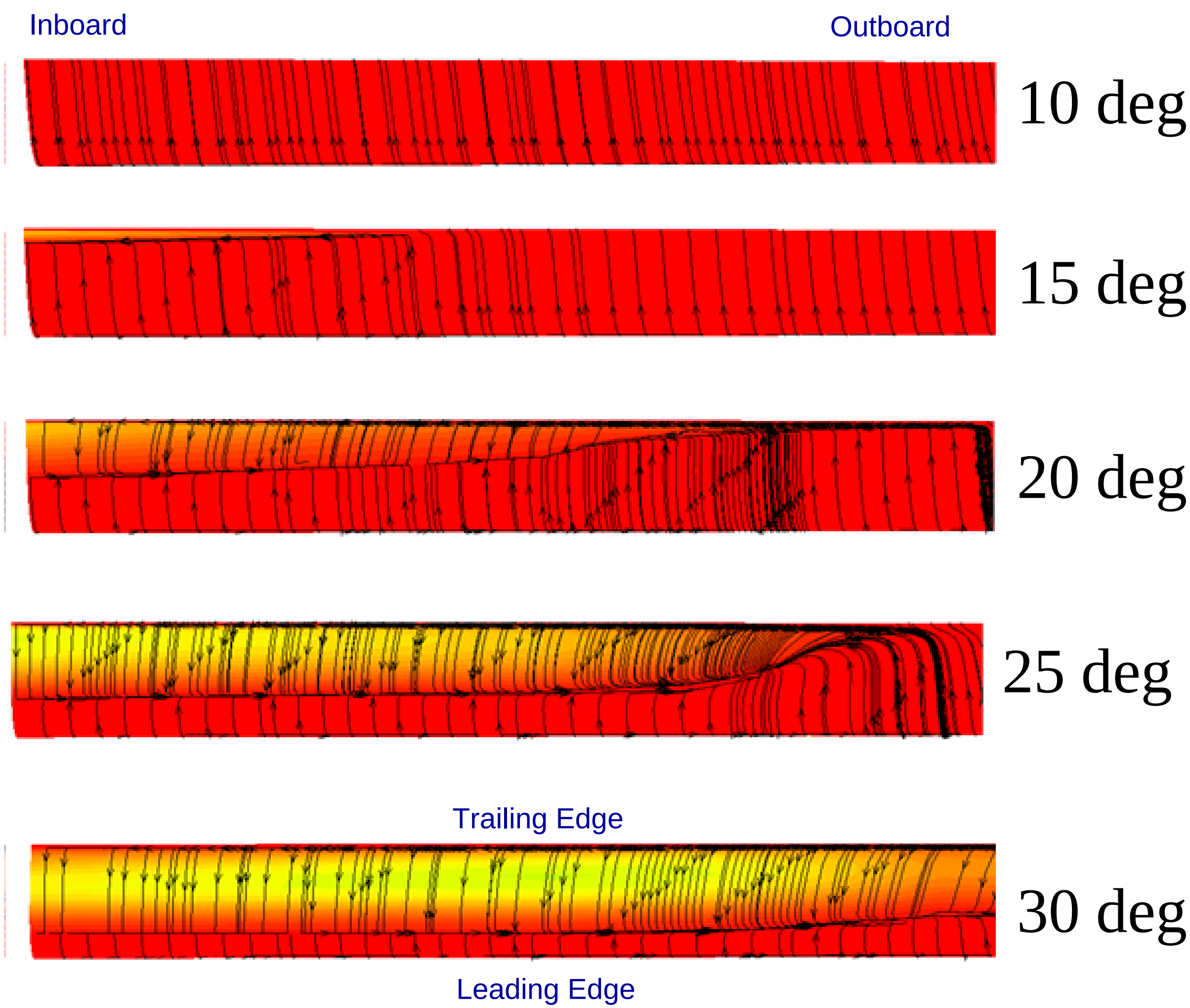
Re=0.64x10^{6}
M=0.2
k-ω turbulence model
350x10^{3} cells





yellow colour indicates
stalled area

INVESTIGATION OF BERP TIP AERODYNAMICS

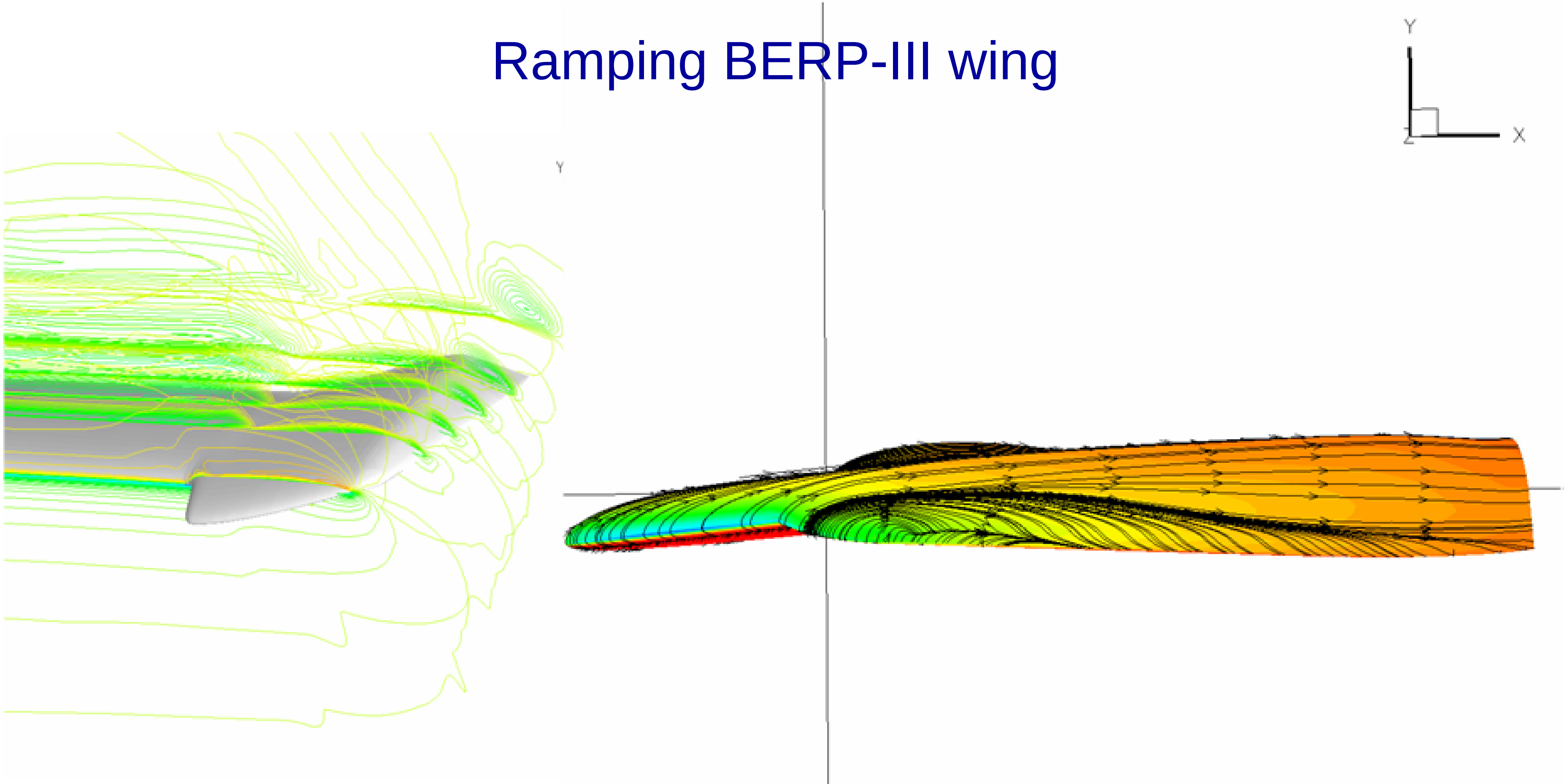


Ramping BERP III wing

$Re=0.64x10^6$
$M=0.2$
k-ω turbulence model
$350x10^3$ cells

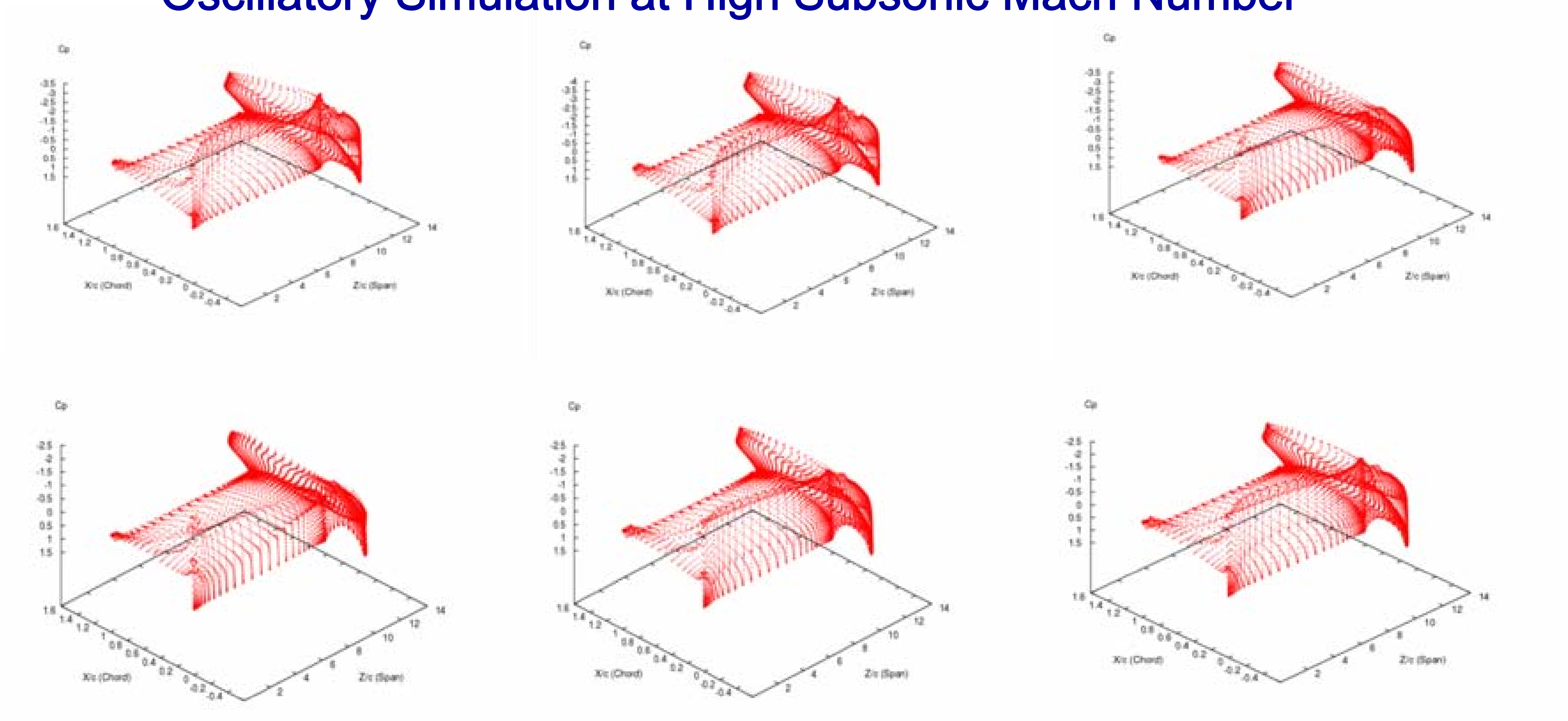
yellow colour indicates
stalled area

Ramping BERP-III wing



Re=0.64x10^6, M=0.2, k-ω turbulence model, 350x10^3 cells

Oscillatory Simulation at High Subsonic Mach Number



M=0.70, Re = 1.8×10^5, k-ω turbulence model

α_0 = 0° mean incidence, α_1 = 5° oscillation amplitude, f = 1 Hz oscillation frequency, Reduced frequency of ~ 0.1

Conclusions

CFD provides a powerful analysis method, and compares well to experiments – but some improvements are required – eg transition modelling
The experimental database for the BERP blade can be further exploited

CFD offers a way of transfering the insight gained from a 'simple' fixed wing test to the more complex rotor situation, and is able to embrace a wide range of conditions with the necessary detail and resolution

CFD simulation of a full 3D rotating multi-bladed helicopter is an exciting prospect and, at each step along the way, there are significant benefits to Industry by applying CFD in the design process.


PLAY SP
PART 2
Wool Tufts
Transition Fixed
3 to 23 deg. root incidence
20:54 15/01(WED)
-0:03:24