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Status of CFD for LaRC's HSR High-Lift Program

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OUTLINE

Objectives of CFD Applications

Approach

Dominant Flow Mechanisms

Candidate Codes

Analysis Results and Experimental Comparisons

Emerging Unstructured Grid Technology

Plans

OBJECTIVES OF CFD APPLICATIONS

- Increased insight into flow physics and fluid mechanisms "driving" the flowfield

- Complement to ground based experiments
  - Improved testing efficiency
  - Aid in parametric interpolation and extrapolation

- Used for design and analysis of high-lift concepts

APPROACH

- Identify candidate computational methods
- Calibrate/validate candidate codes using available experimental data
  - Cruise configuration
  - High-lift concepts
- Determine areas/regions of applicability, resource requirements, etc. for candidate codes.
- Develop new technologies (algorithms, grid generation, etc.) where gaps are identified.

DOMINANT FLOW MECHANISMS

- Vortex formation
  - Large radius separation (forebodies)
  - Small radius separation (wing leading-edges)
- Vortex interaction
- Boundary layer separation and confluent boundary layers
- Ground effects
- Engine/airframe integration

CANDIDATE "PRODUCTION" ANALYSIS CODES

CFL3D

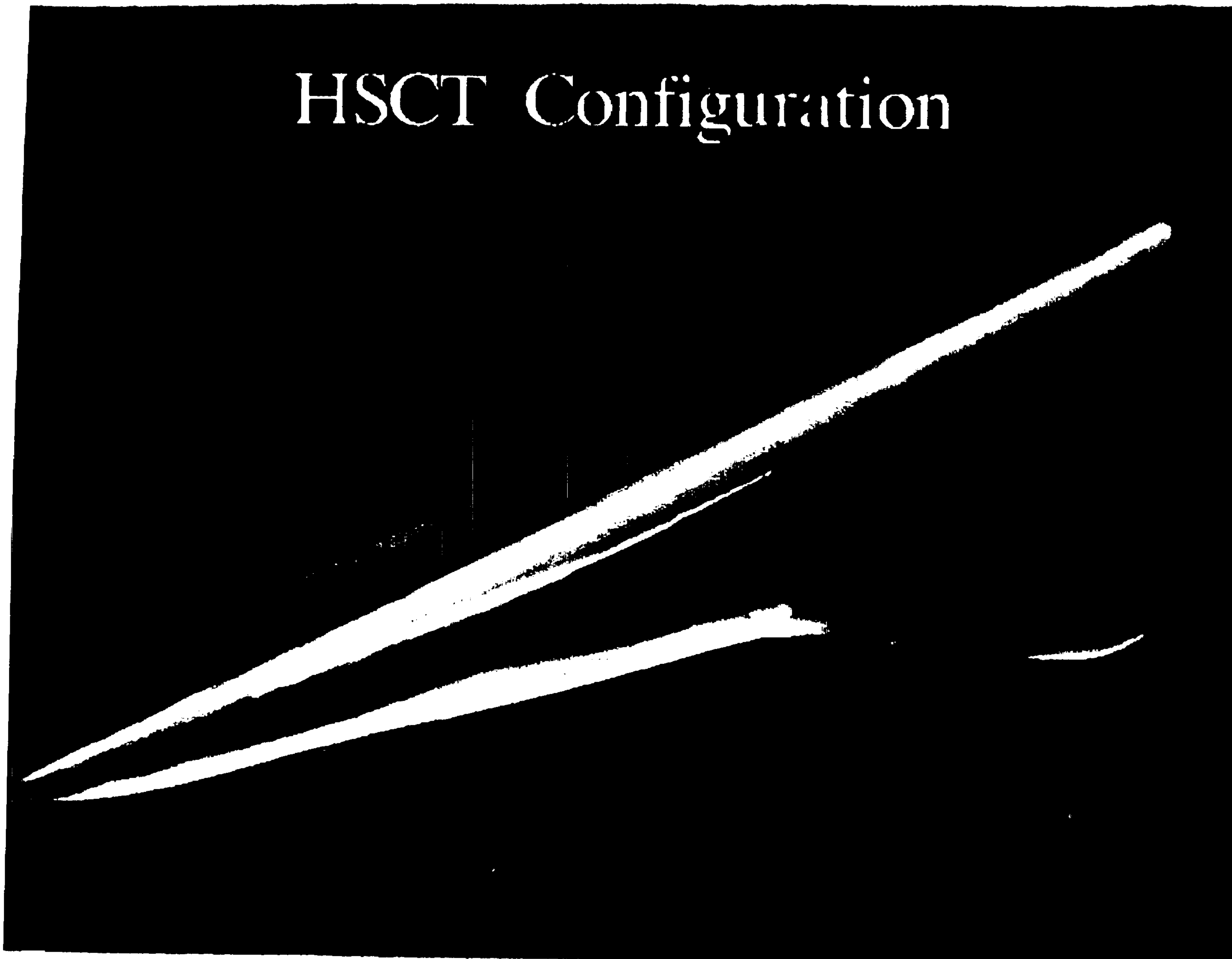
- Upwind-biased differencing
- Multi-block gridding with generalized patching
- Multi-grid
- Balwin-Lomax algebraic turbulence model

TLNS3D

- Central differencing
- Single block grid
- Multi-grid
- Balwin-Lomax algebraic and Johnson-King turbulence models

FMC1

- Incompressible
- Total variation diminishing
- Single block grid
- Shock fitting
- Balwin-Lomax (and extensions) turbulence model


HSCT Configuration

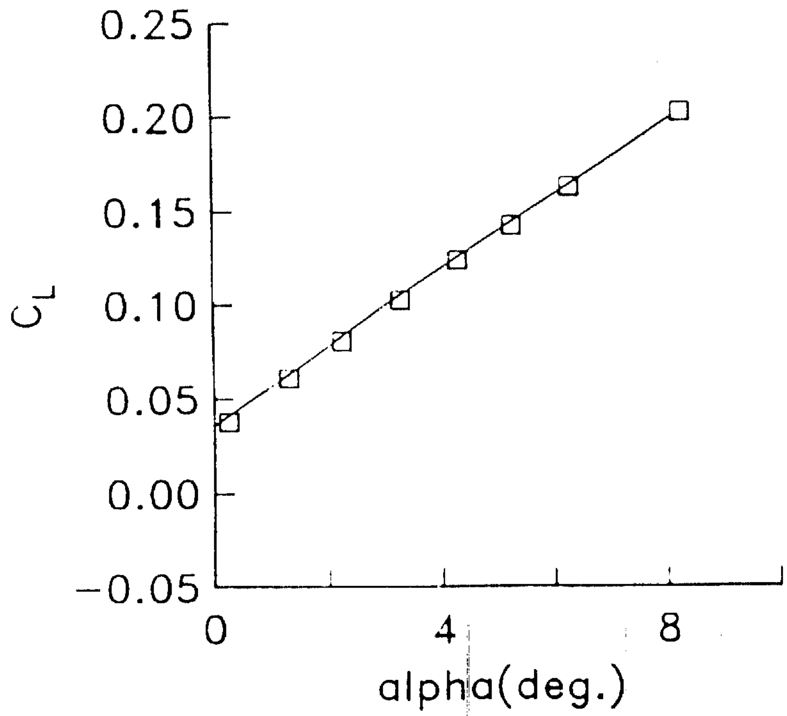
COMPARISON OF FORCE–COEFFICIENTS FOR HSCT

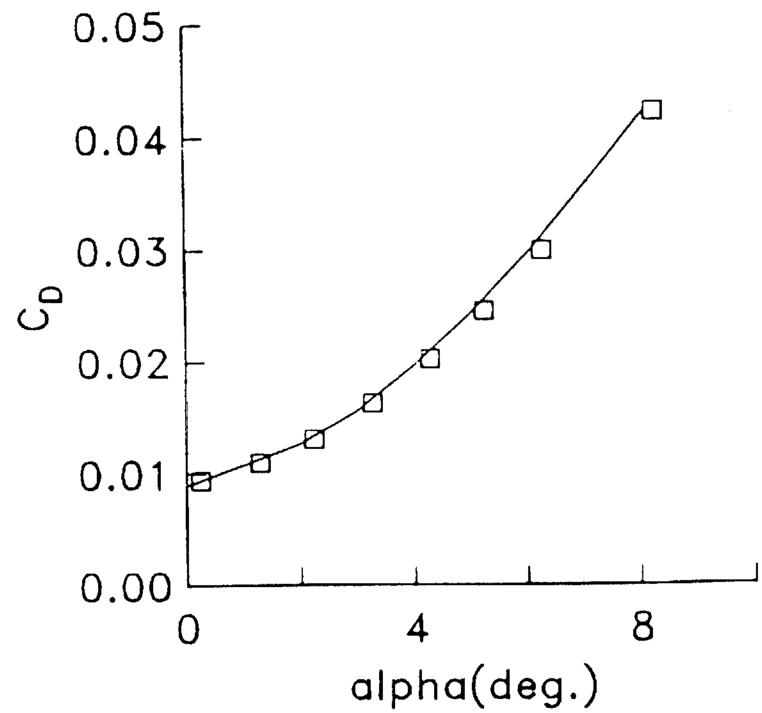
$(M_\infty = 3.0,\ Re_l = 6.3 \times 10^6)$

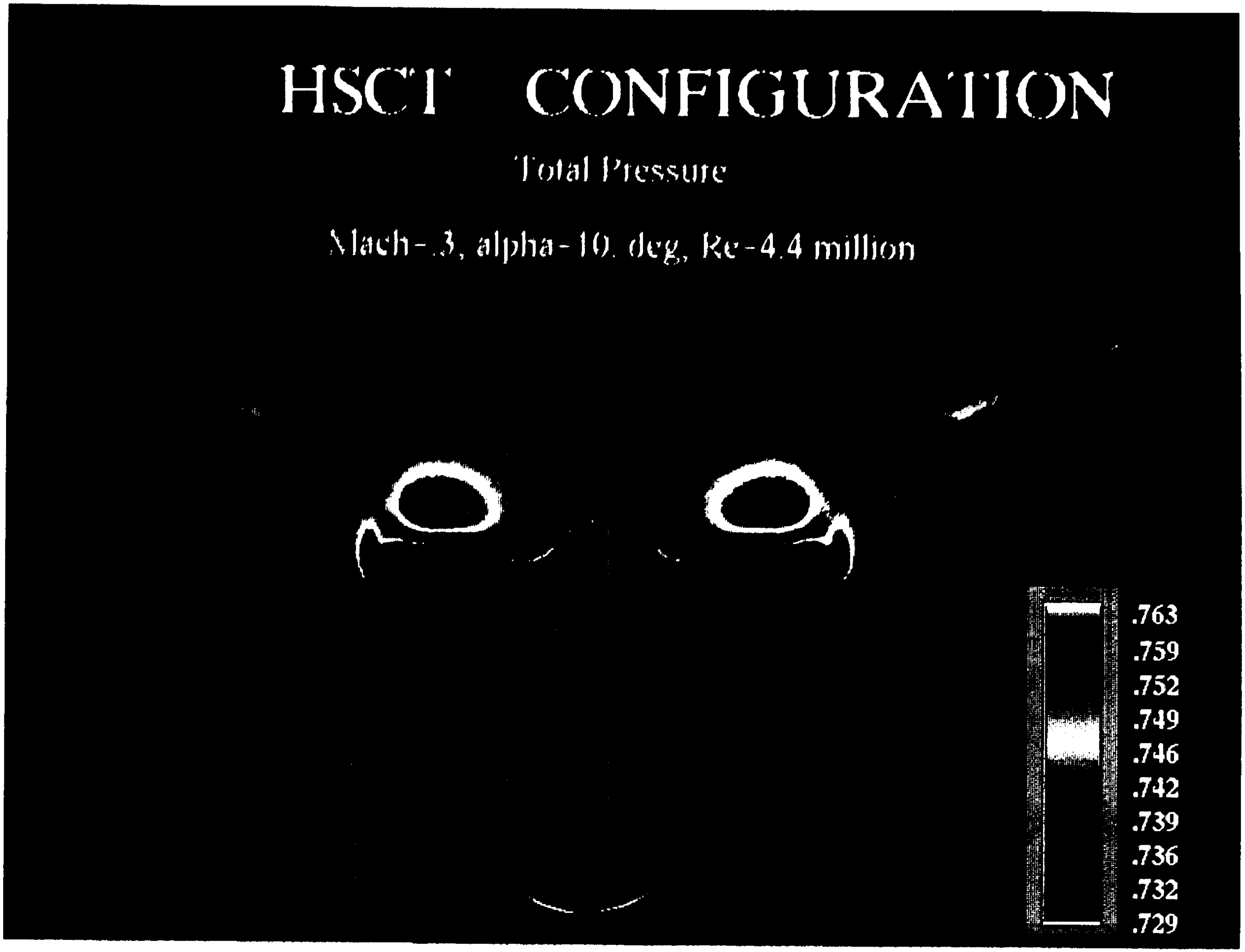
(a) Lift coefficient

(b) Drag coefficient

□ Experimental data —— Present Results



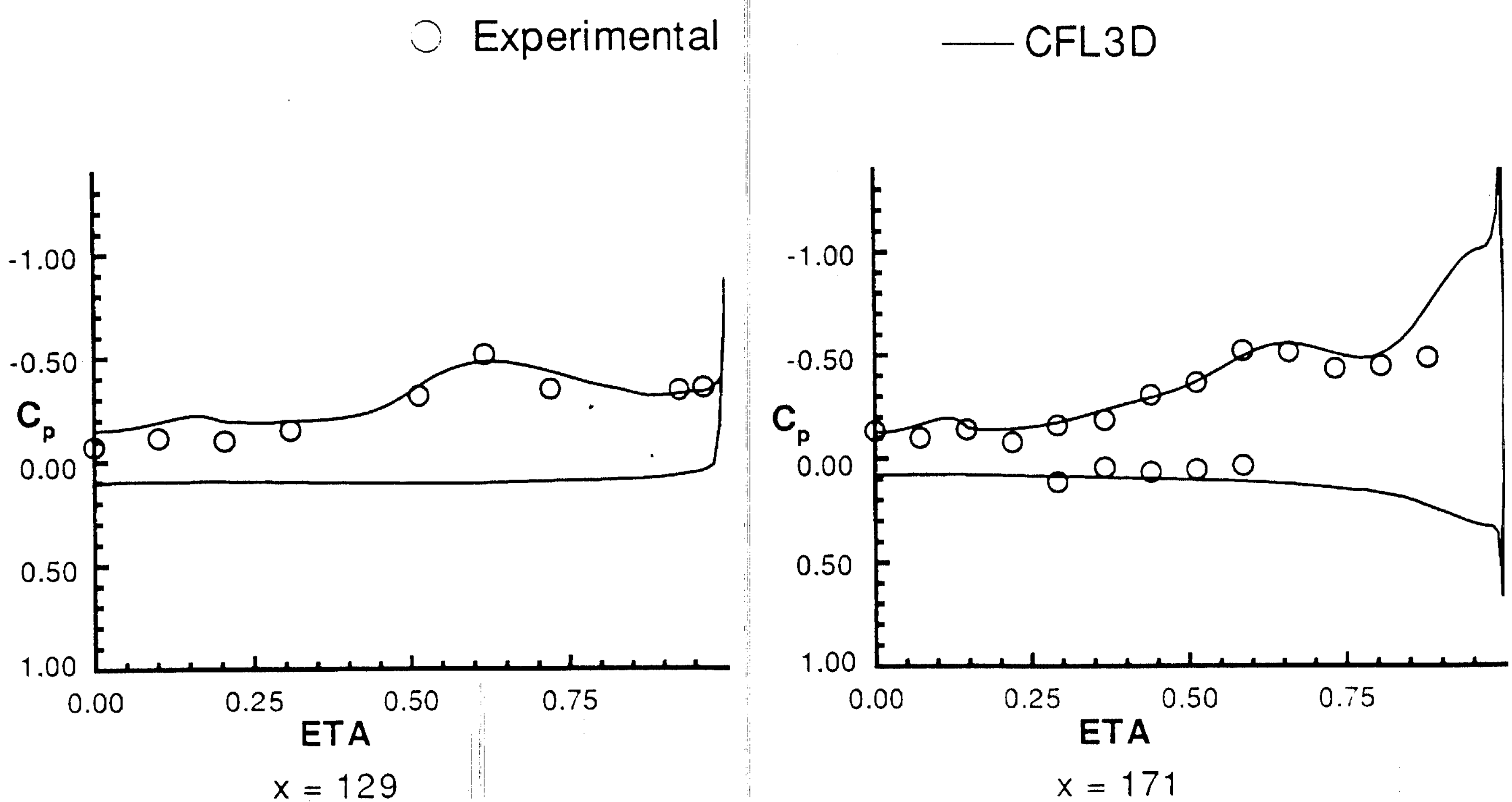



HSCT CONFIGURATION
Total Pressure
Mach-.3, alpha-10. deg, Re-4.4 million
.763
.759
.752
.749
.746
.742
.739
.736
.732
.729

HSCT CONFIGURATION

Surface Pressure Distributions

(M_∞=.3, α=10.0°, Re_L=4.4x10^6)



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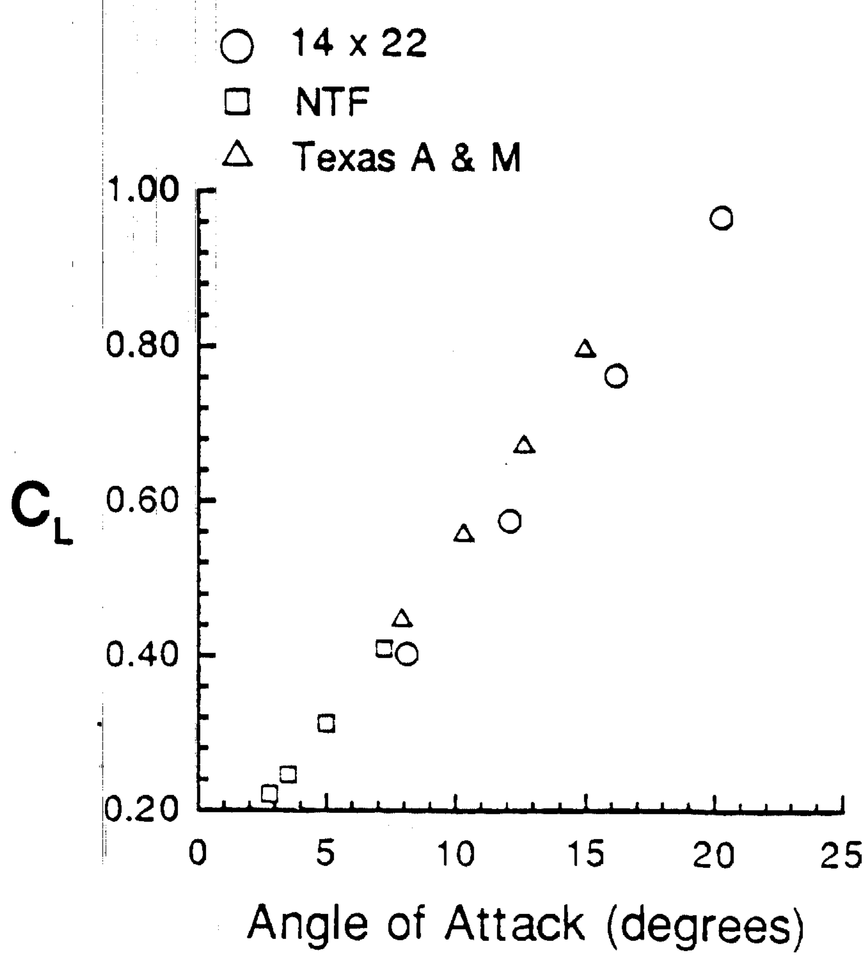
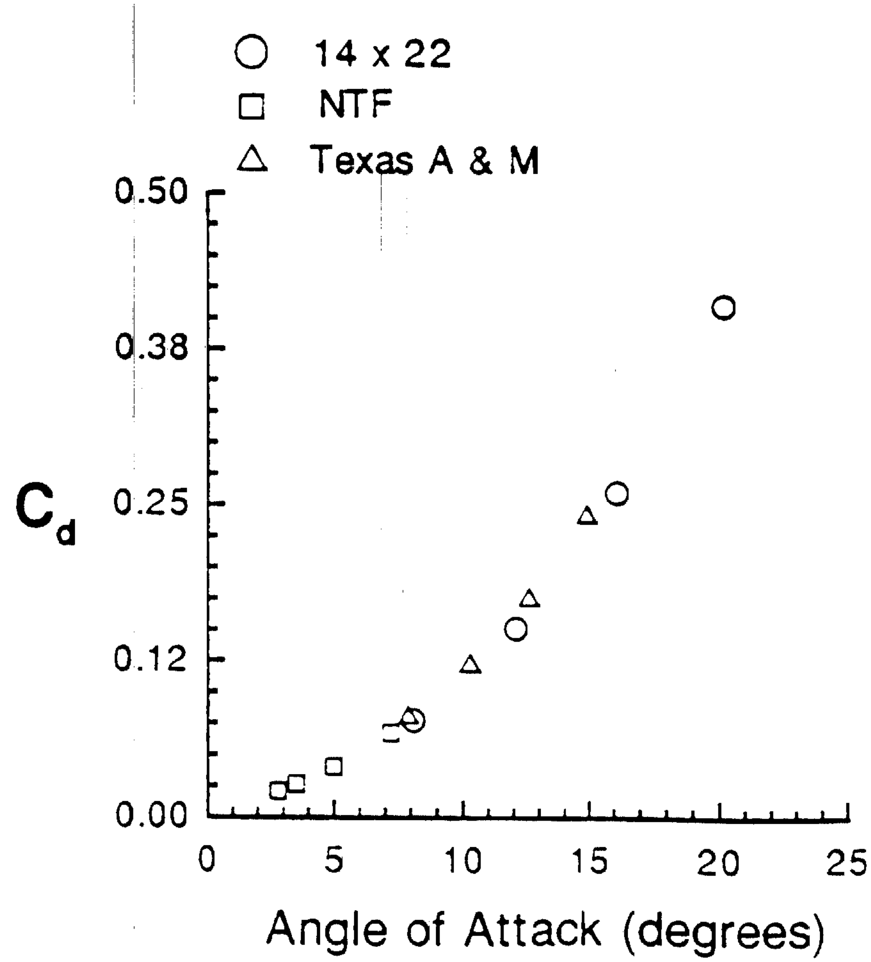
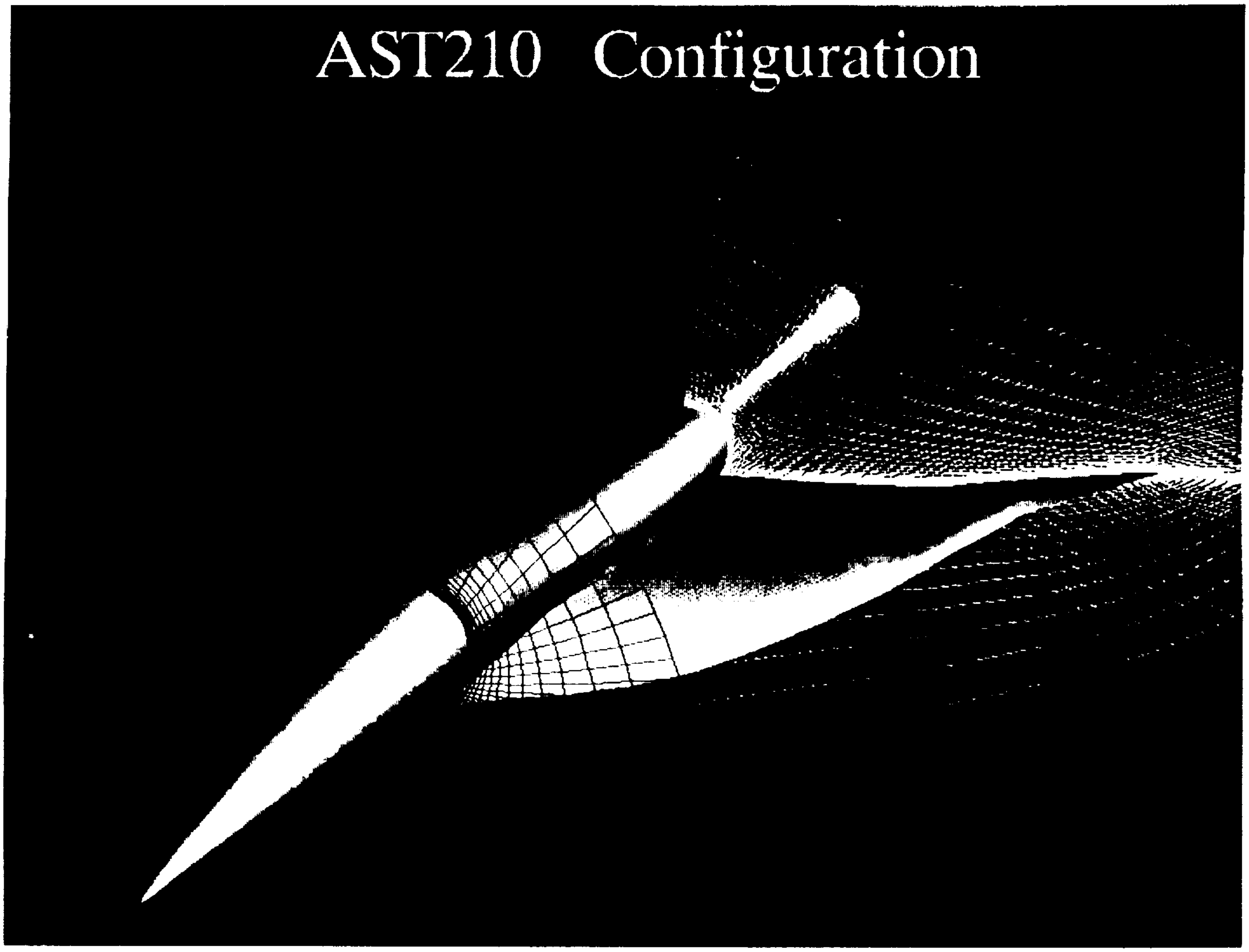
AST210 Configuration

Force Comparisons

Mach=.22



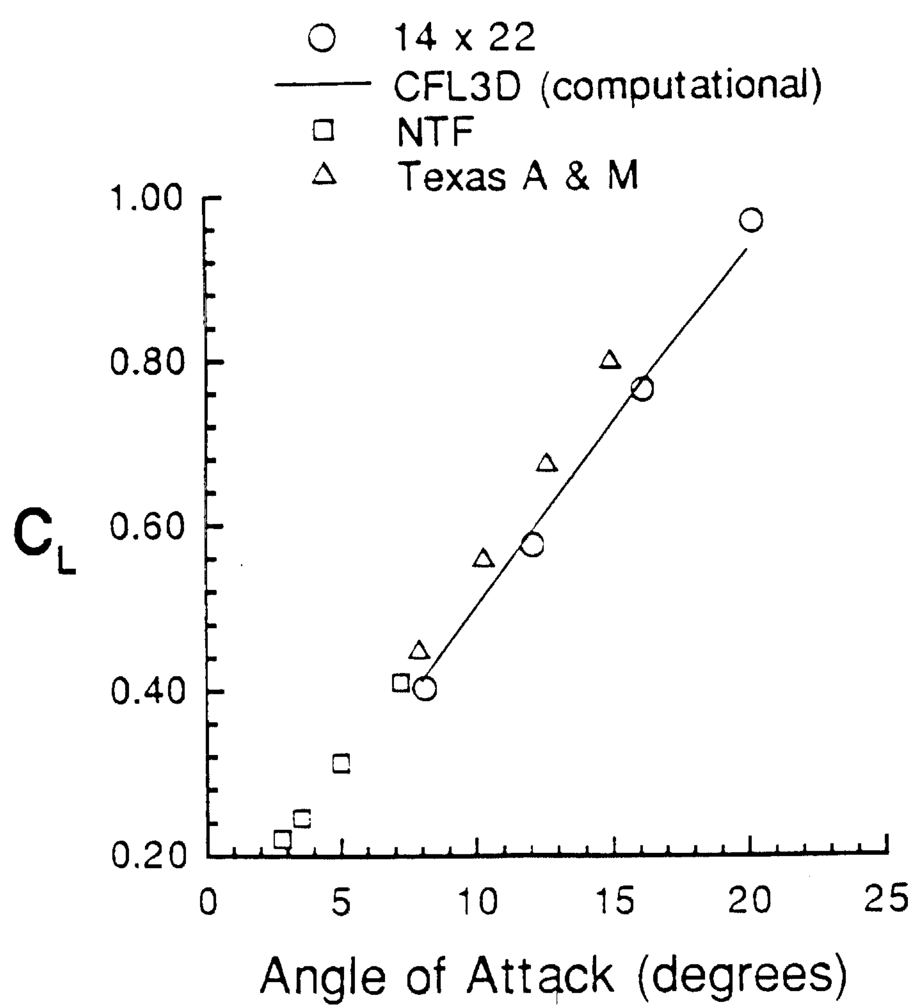


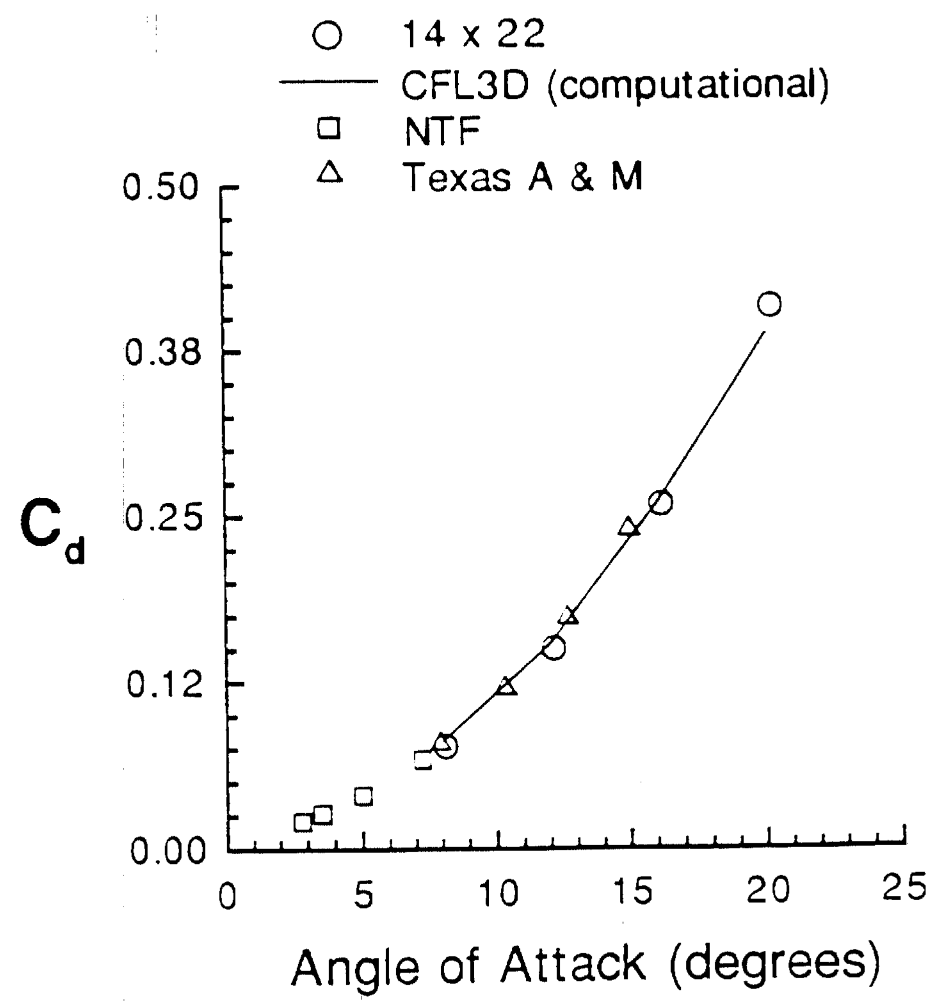

AST210 Configuration

AST210 Configuration

Force Comparisons

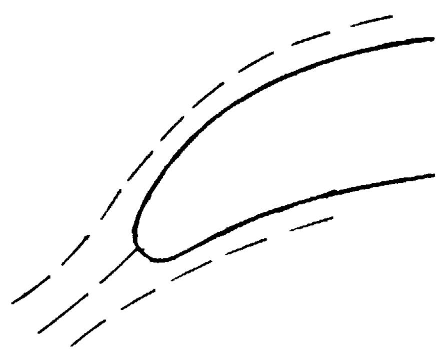
Mach=.22





LEADING-EDGE FLAP DESIGN FOR HIGHLY-SWEPT, THIN WINGS

Vortex Supression



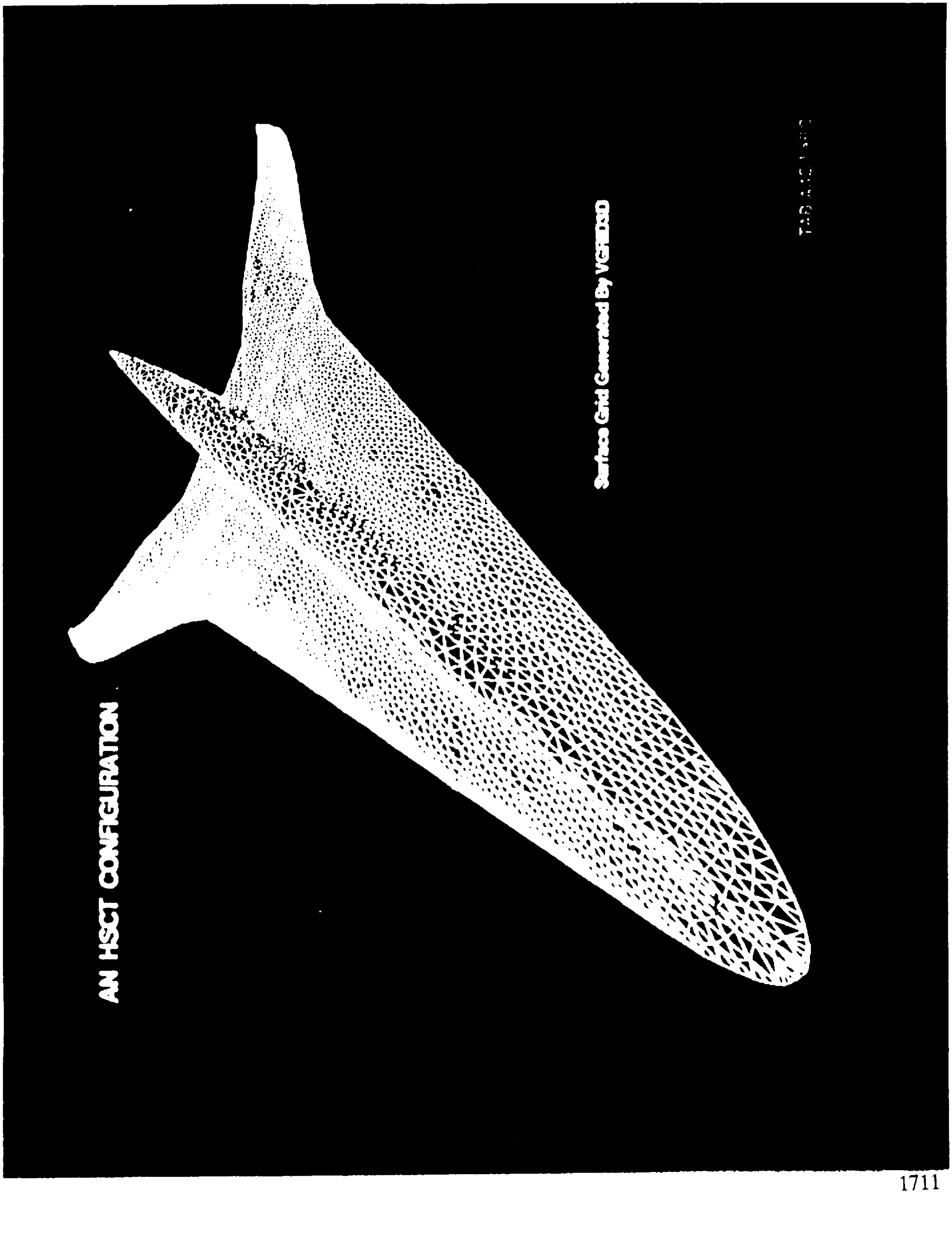
Attached Flow Flap

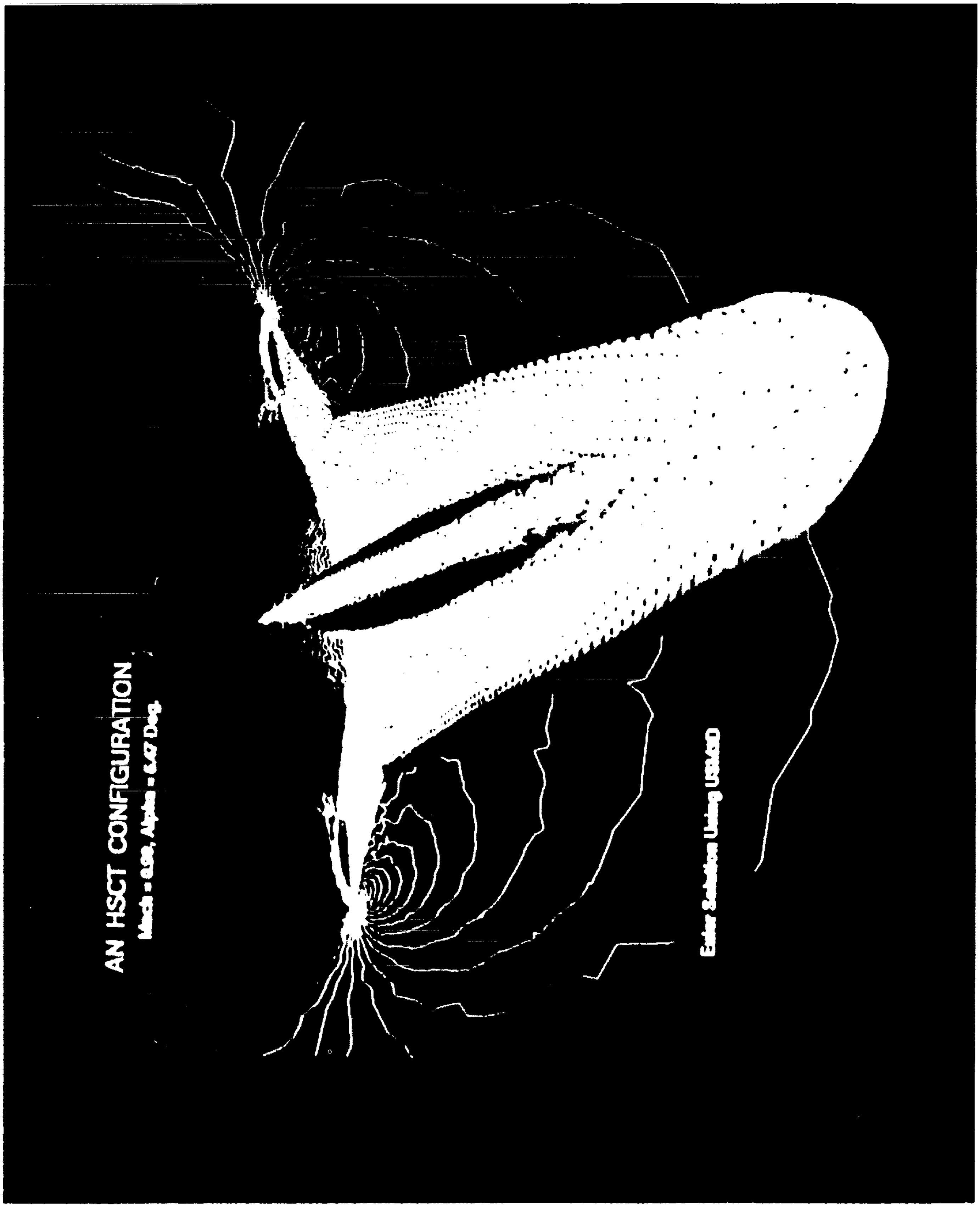
Vortex Control

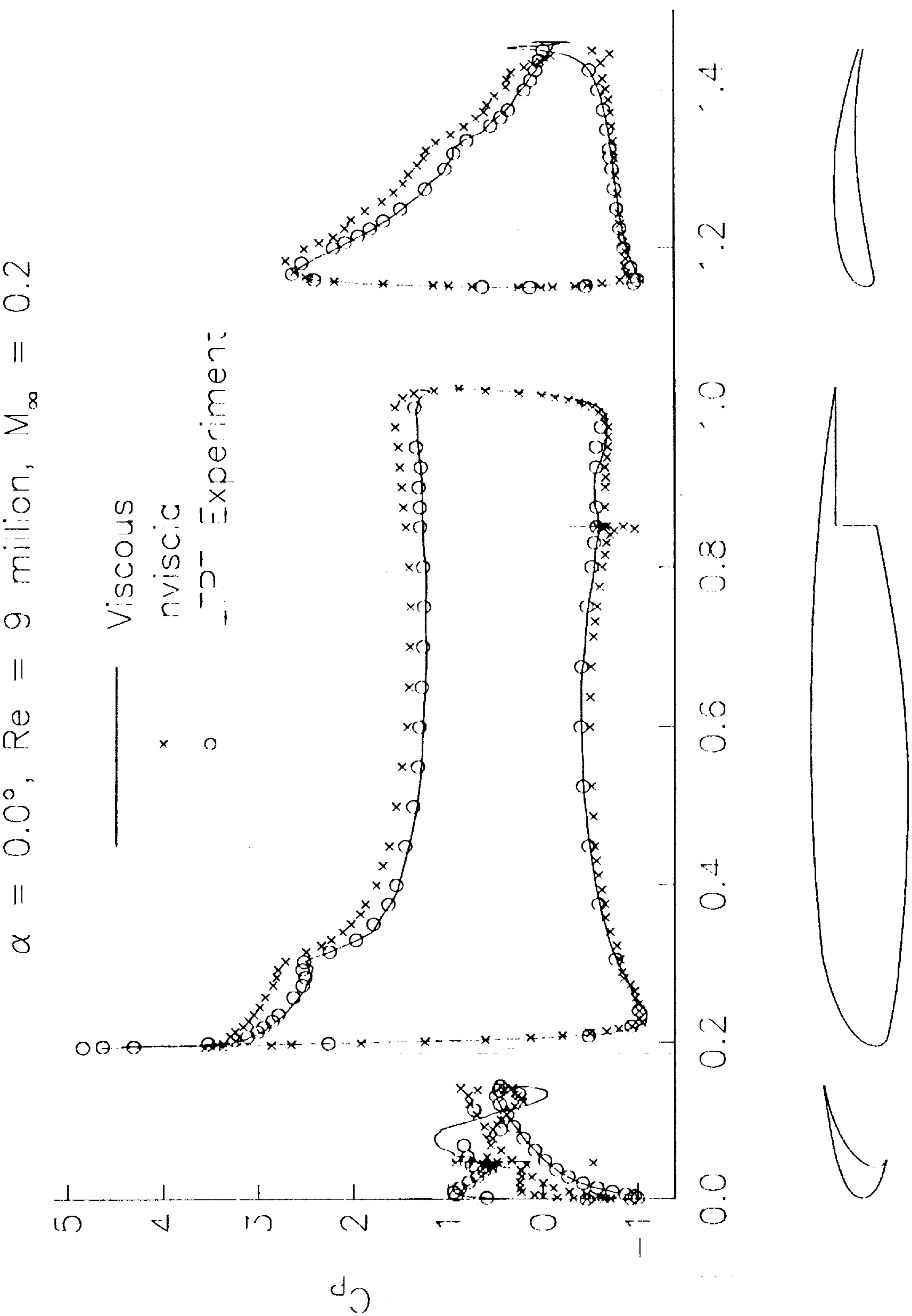
Vortex Flap

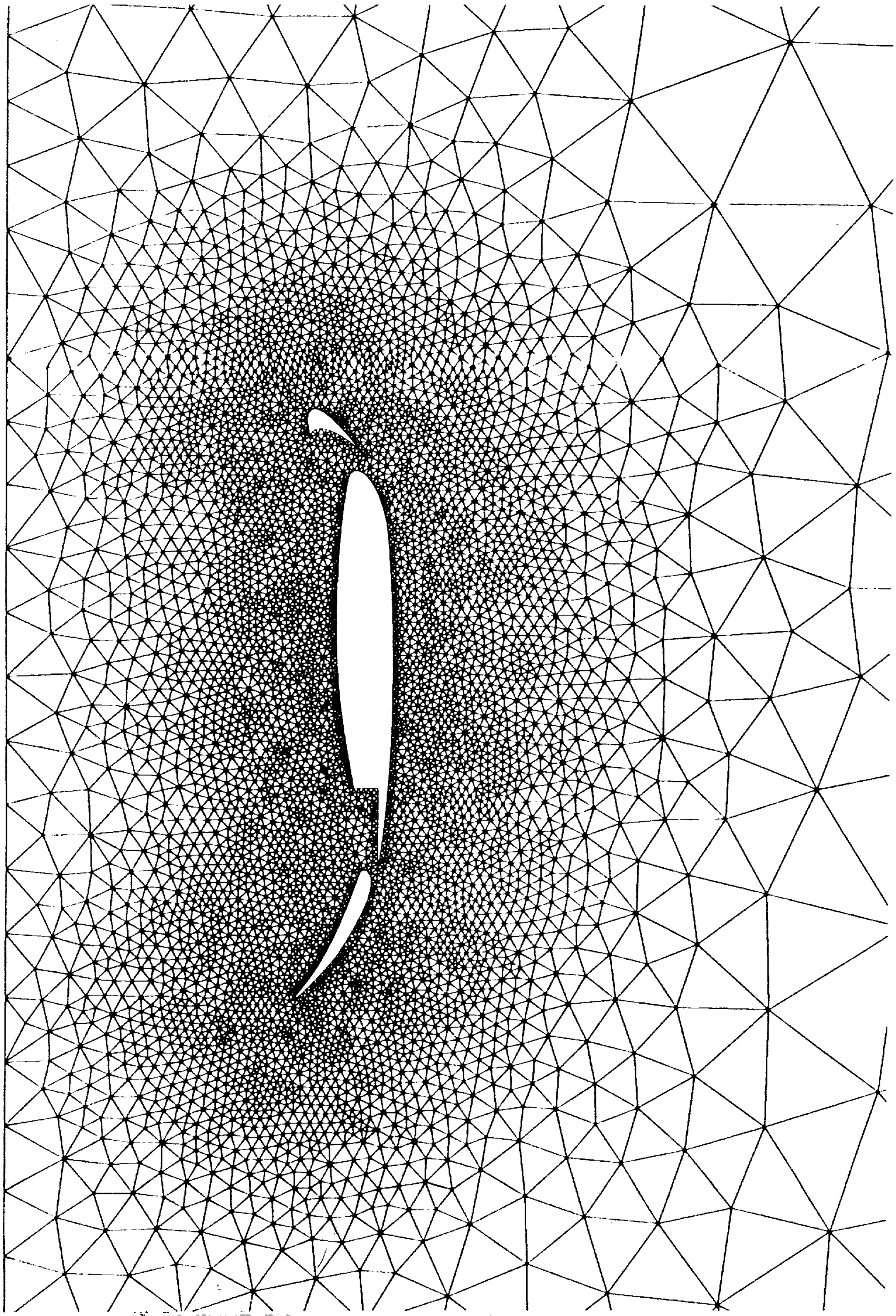
EMERGING GRID TECHNOLOGIES

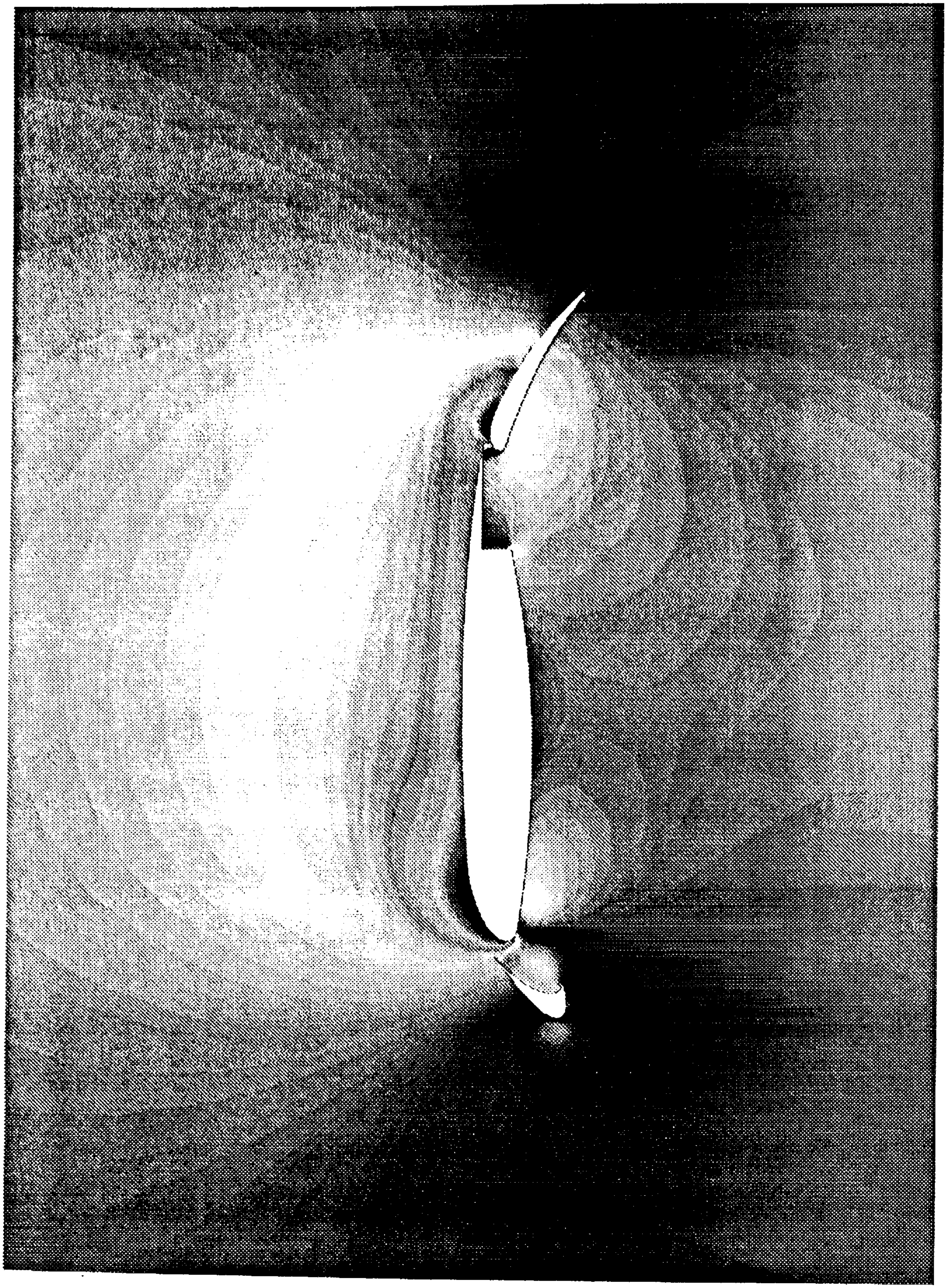
- Chimera
- Unstructured
- Solution adapting


AN HSCT CONFIGURATION
Surface Grid Generated By


AN HSCT CONFIGURATION
Euler Solution Using USM3D


α = 0.0°, Re = 9 million, M∞ = 0.2
Viscous
nviscic
Experiment
Cp
5
4
3
2
1
0
-1
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4





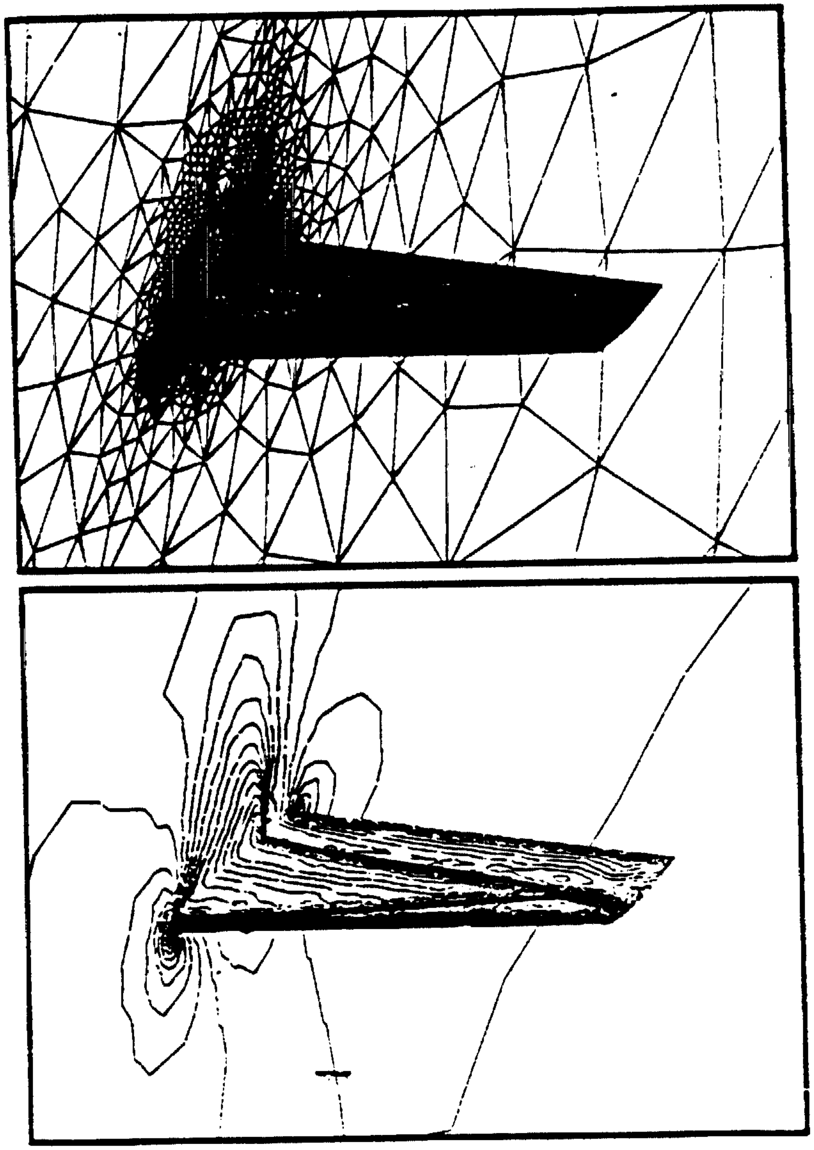


Figure 1: Adaptively Generated Mesh and Computed Mach Contours for Flow Over an ONERA M6 Wing
(Number of Grid Points = 173,412 Number of Tetrahedra = 1,013,718)
(Mach = 0.84, Incidence = 3.06 degrees)

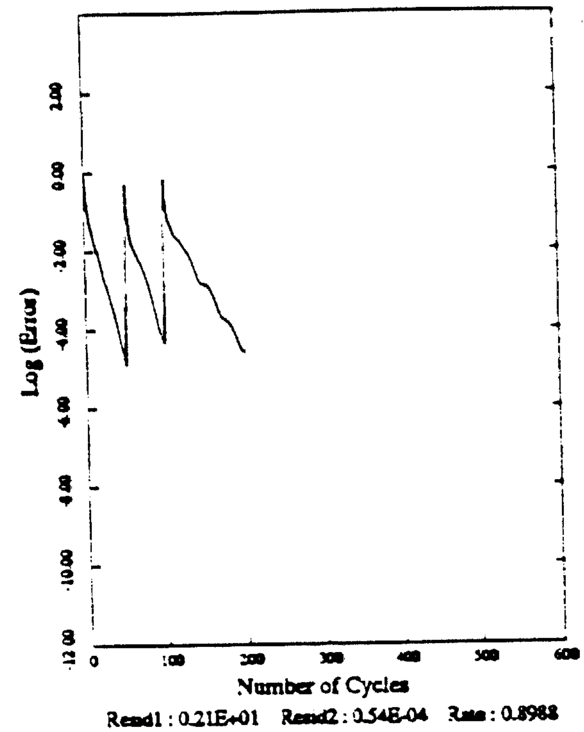


Figure 2: Multigrid Convergence History on the 3 Finest Grids of the Adaptively Generated Multigrid Sequence

CFD PLANS

- Develop unstructured-grid (USG) solver for Euler solutions for highly-swept wing with separated leading-edge flow (9/91)
- Develop capability to generate unstructured grids suitable for N-S calulations on HSCT high-lift systems (6/92)
- Develop USG solver for laminar/turbulent Navier-Stokes equations (9/92)
- Computational assessment of code high-lift predictive capability (9/93)
- Validation of enhanced computational methodology (9/94)
- Complete revisions of USG code as required by feedback from industry users (9/95)

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