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TranAir: Recent Advances and Applications

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Abstract

TranAir is a computer code which solves the full-potential equation for transonic flow about very general and complex configurations. Piecewise flat surface panels are used to describe the surface geometry. This paneled definition is then embedded in an unstructured cartesian flow field grid. Finite elements are used in the discretization of the flow field grid in a manner which is fully conservative and 2^{nd}–order accurate. Since geometries may be defined with relative ease, and since the user is not involved in the generation of the flow field grid, computational results may be generated rather quickly for a wide range of geometries. For transonic cases in the cruise angle-of-attack range, TranAir has generated results which are in generally good agreement with both Euler results and wind tunnel data. A typical transonic case runs in 1–2 CPU hours on a Cray X-MP. For subcritical cases, the code runs in 15–30 CPU minutes, even for geometries in which several thousand surface panels are used in the definition. This ability to rapidly and accurately provide both subsonic and transonic predictions about very complex aircraft configurations gives TranAir the potential of being a very powerful and widely used design tool.

Acknowledgements

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TRANAIR: RECENT ADVANCES AND APPLICATIONS

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OUTLINE

- OBJECTIVE
- APPROACH
- RECENT ADVANCES
- APPLICATIONS
- OBSERVATIONS
- POSSIBLE FUTURE DIRECTIONS

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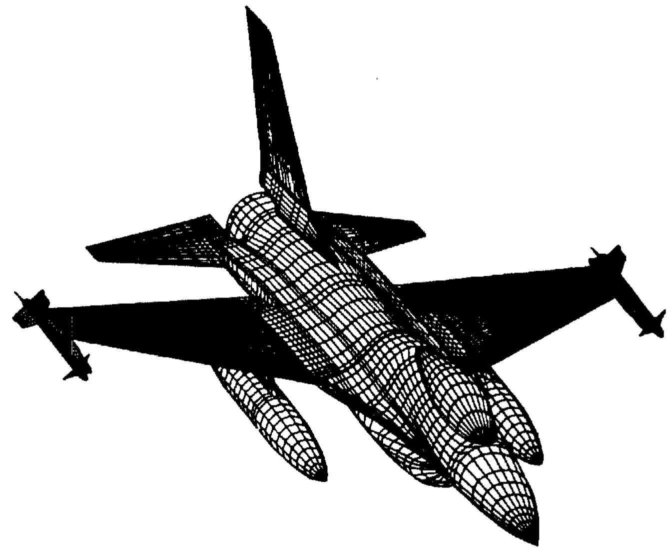
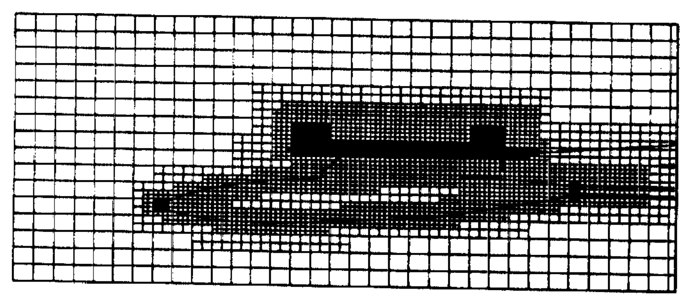
OBJECTIVE

TO DEVELOP AND VALIDATE A COMPUTATIONAL METHOD WHICH ELIMINATES THE USE OF SURFACE-CONFORMING GRIDS IN THE ANALYSIS OF COMPLEX AIRCRAFT CONFIGURATIONS IN THE TRANSONIC FLOW REGIME.

APPROACH

- GEOMETRY DEFINED BY SURFACE PANELS
- EMBEDDED IN UNIFORM CARTESIAN GRID
- LOCAL GRID REFINEMENT CAPABILITY BASED ON
  - LOCAL PANEL SIZE
  - USER INPUT
- SOLUTION PROCESS
  - GRID DISCRETIZED W/FINITE ELEMENTS, CONSERVATIVE, 2ND ORDER
  - SET OF NONLINEAR ALGEBRAIC EQNS SIMULATE FULL-POTENTIAL
  - 1ST ORDER DISSIPATION FOR SHOCK CAPTURING
  - SET OF EQNS SOLVED BY ITERATIVE PROCESS





RECENT ADVANCES

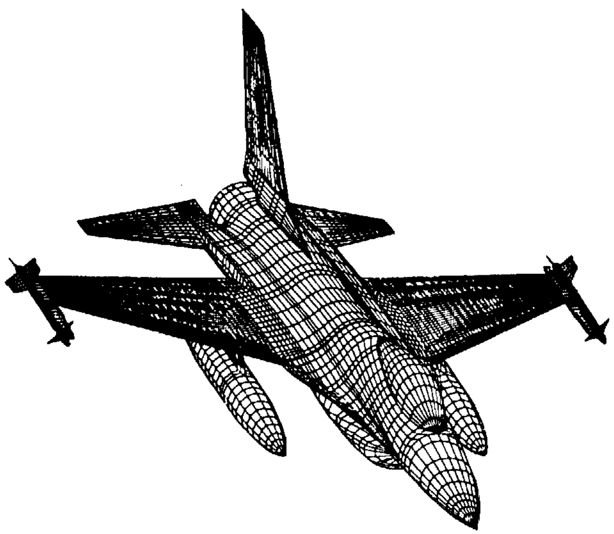
- LOCAL GRID REFINEMENT
  - CURRENTLY REQUIRES SUBSTANTIAL USER INPUT
  - SOLUTION ADAPTIVE REFINEMENT NEARLY COMPLETE
- IMPROVEMENTS IN SOLUTION PROCESS
  - DYNAMIC DROP TOLERANCE IN SPARSE MATRIX SOLVER
  - "SHOCK SMEARING" FOR CONVERGENCE IMPROVEMENTS
  - REGIONS OF DIFFERING T_T, P_T
  - MORE GENERAL BOUNDARY CONDITION OPTIONS
  - SUPERSONIC FREESTREAM
  - HIERARCHICAL MULTIGRID

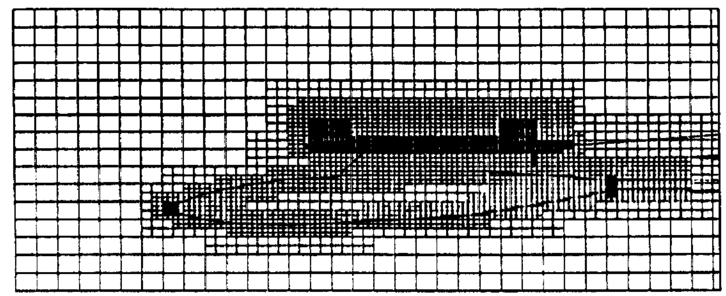
CURRENT EFFORTS

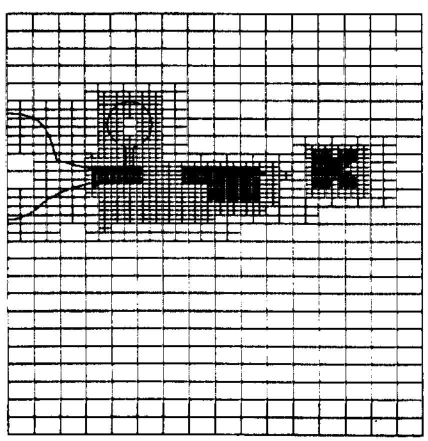
APPLICATIONS

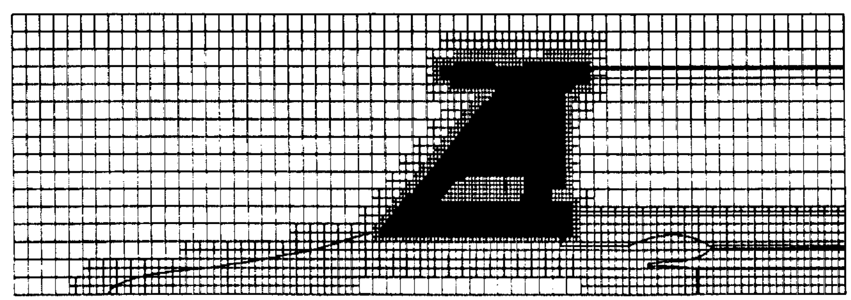
- F-16A W/TIP MISSILES, FUEL TANKS
- BOEING 747-200
- OBLIQUE WING RESEARCH AIRCRAFT
- GENERIC FIGHTER
- ONERA M6
- AXISYMMETRIC NACELLE
- ADVANCED TURBOPROP MODEL

F-16A W/TIP MISSILES, FUEL TANKS



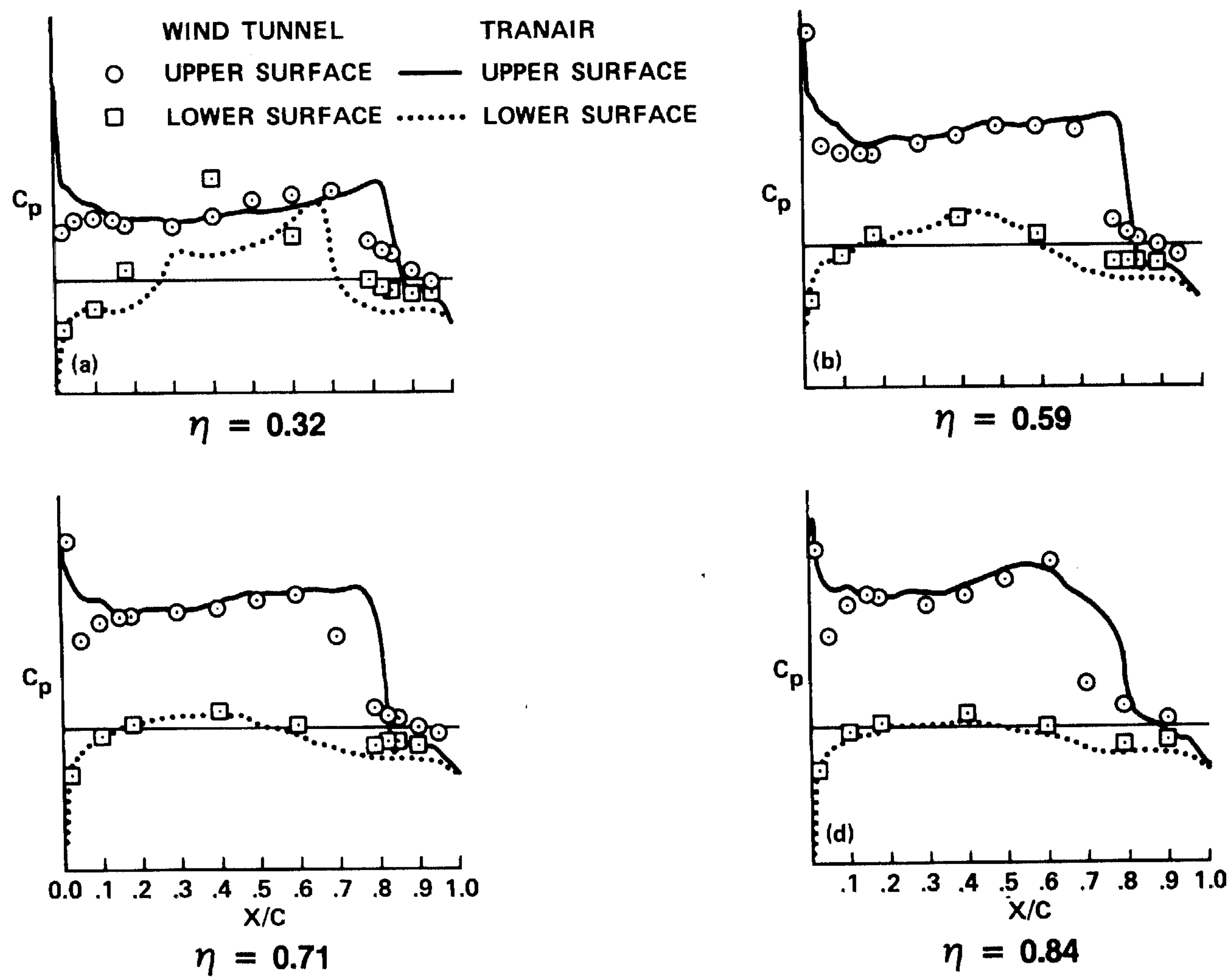






F-16A W/TIP MISSILES, FUEL TANKS

$M_\infty = 0.9, \alpha = 4°$



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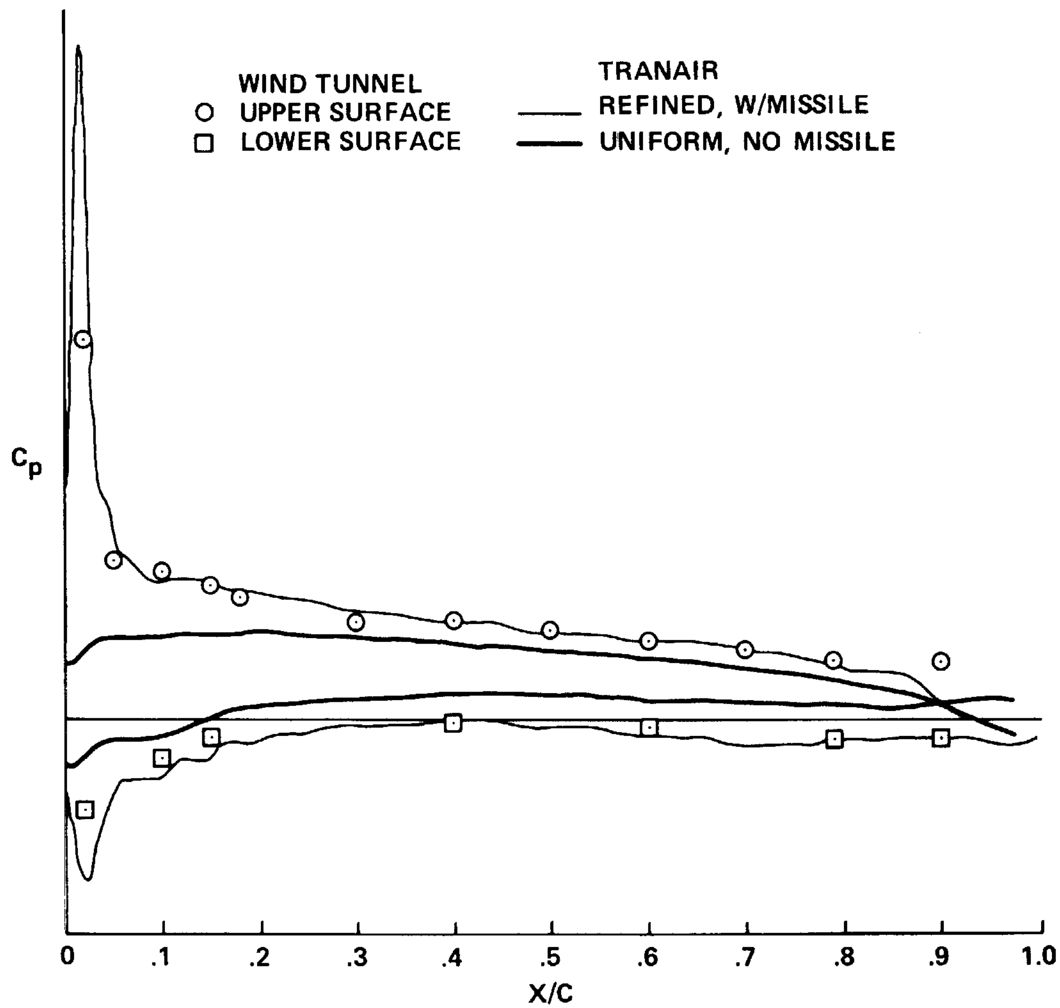
F-16A, TIP MISSILE EFFECT

$M_\infty = 0.6, \alpha = 4°, \eta \doteq 0.95°$



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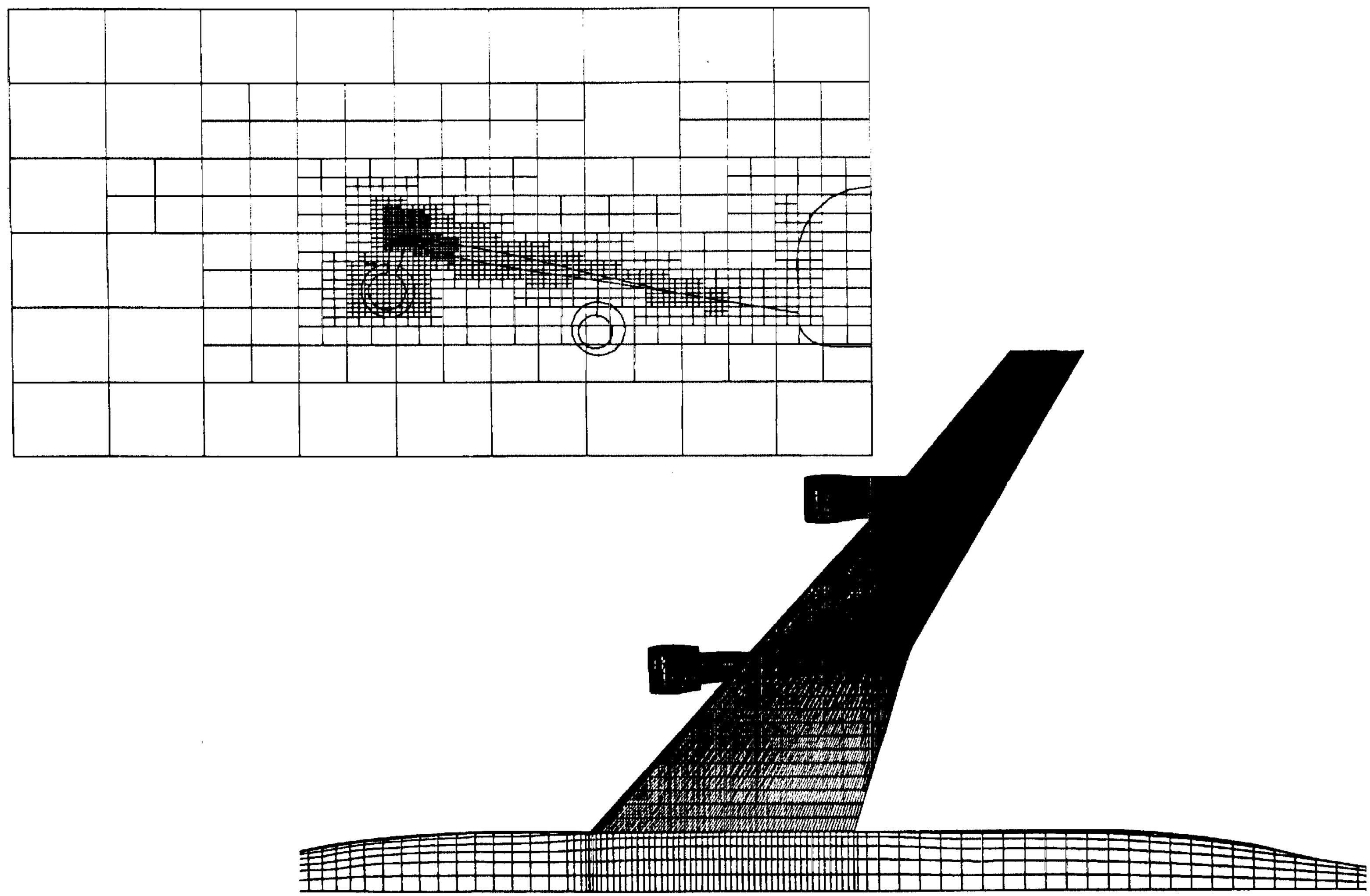
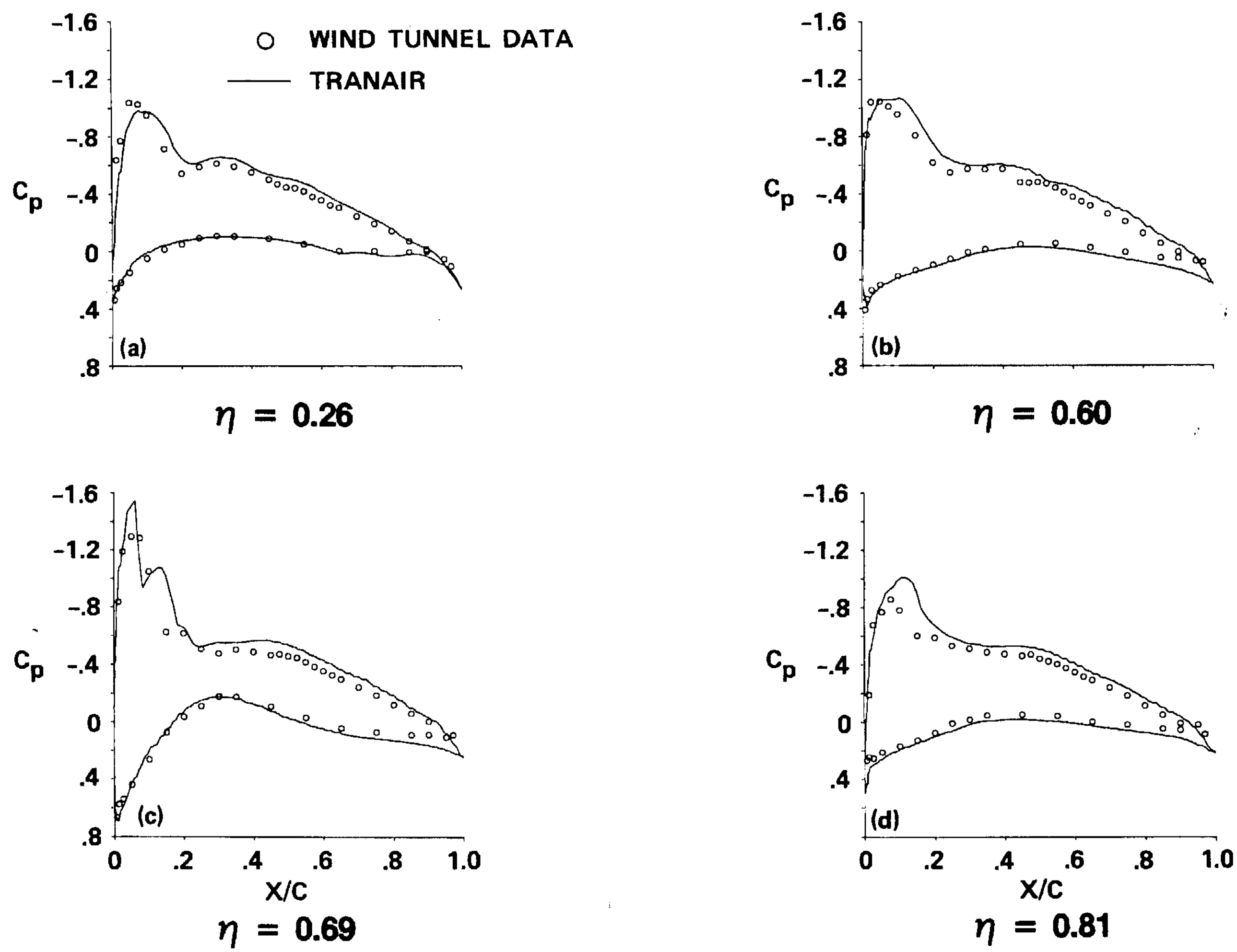
BOEING 747-200



BOEING 747-200

$M_\infty = 0.8, \alpha = 2.7°$



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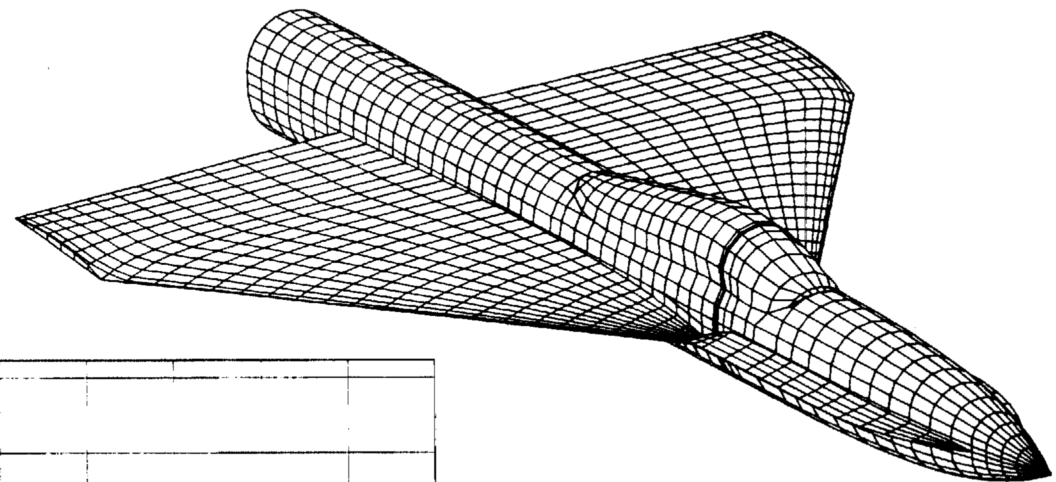
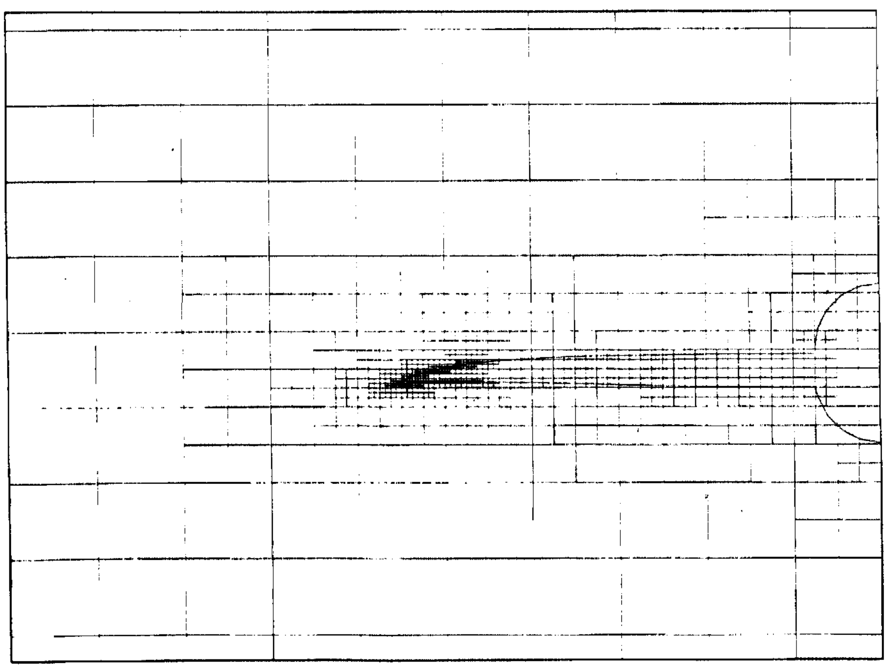
GENERIC FIGHTER





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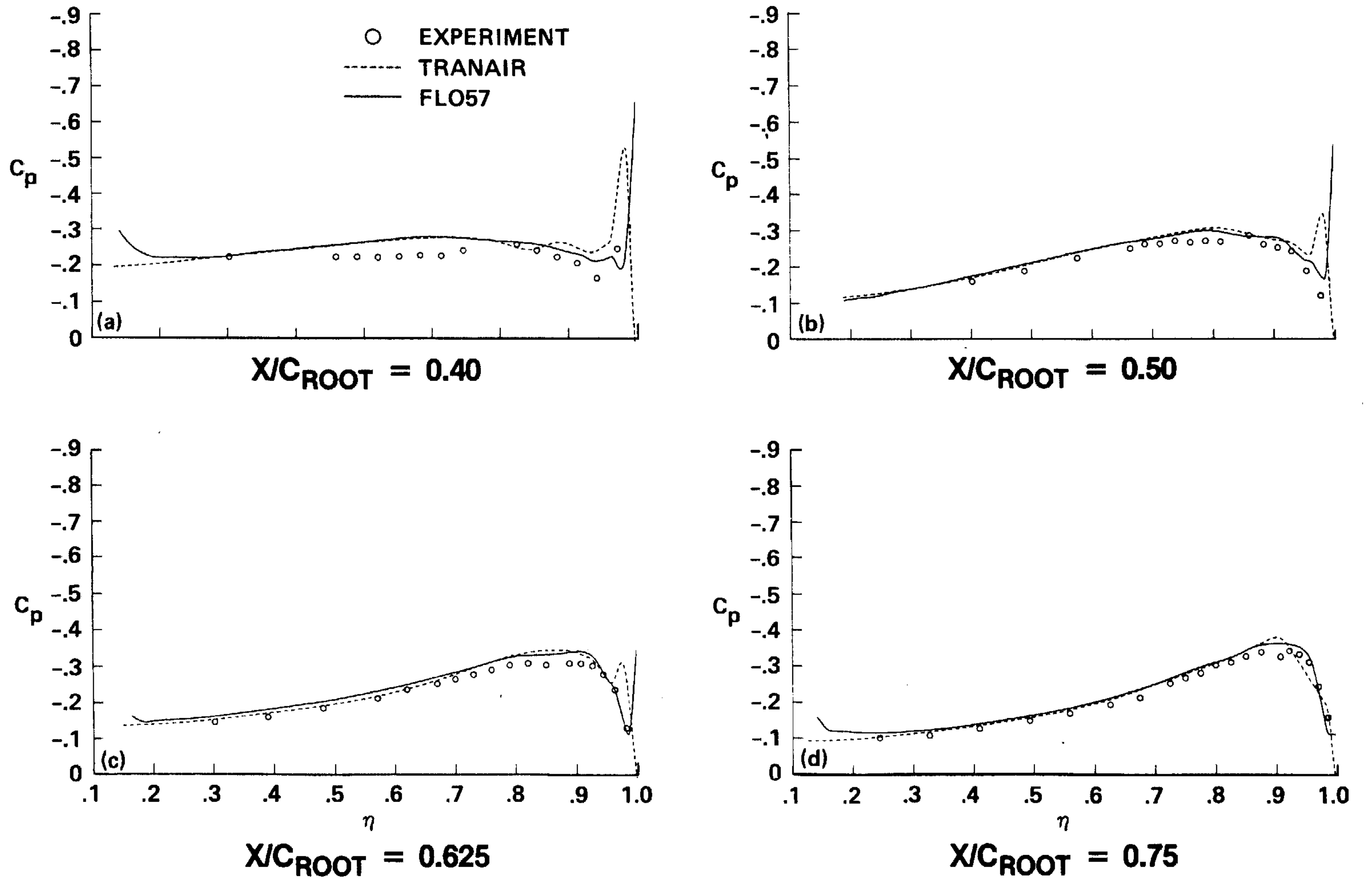
GENERIC FIGHTER

$M_\infty = 0.8$, $\alpha = 5°$, WING/BODY



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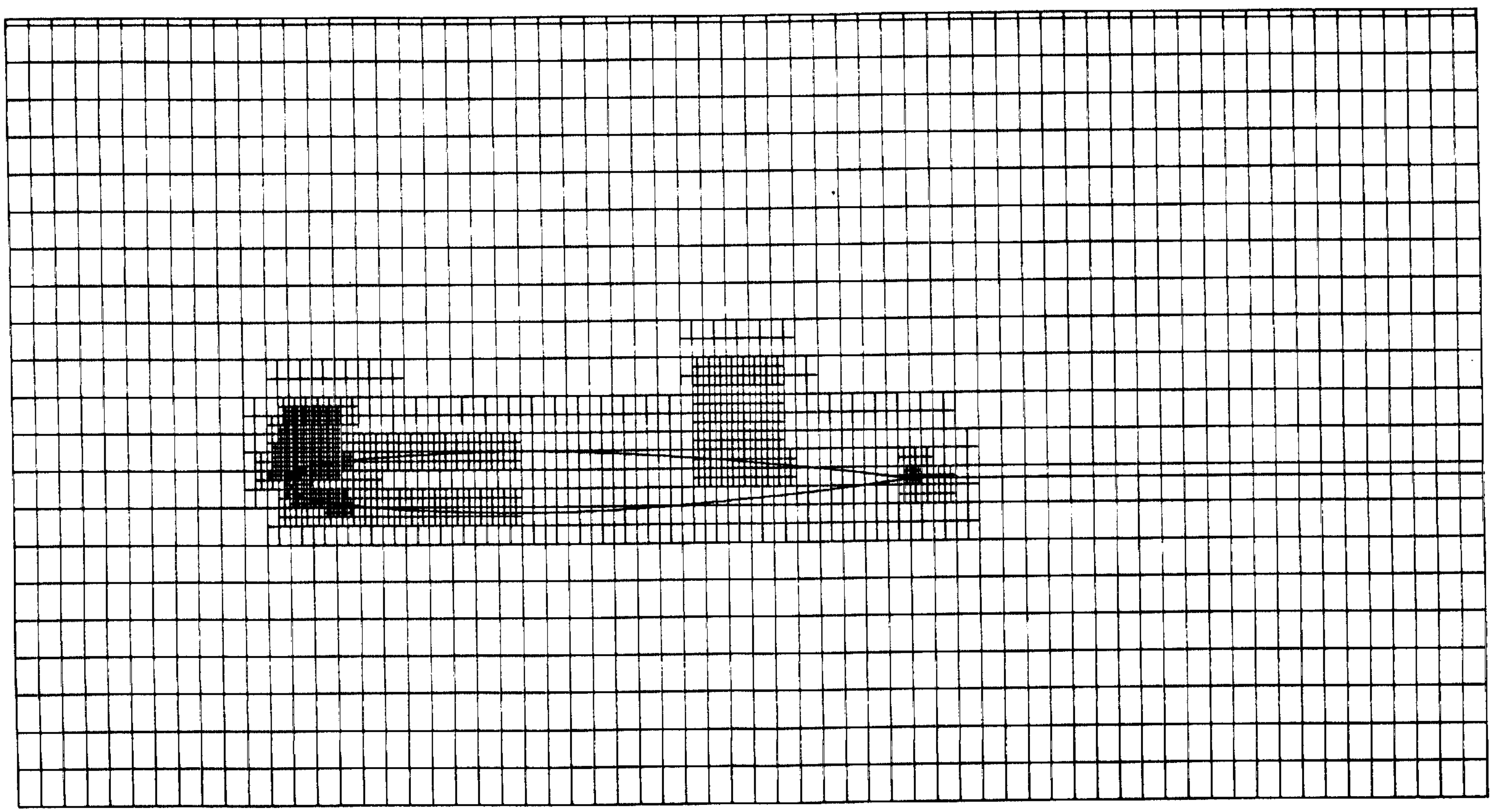
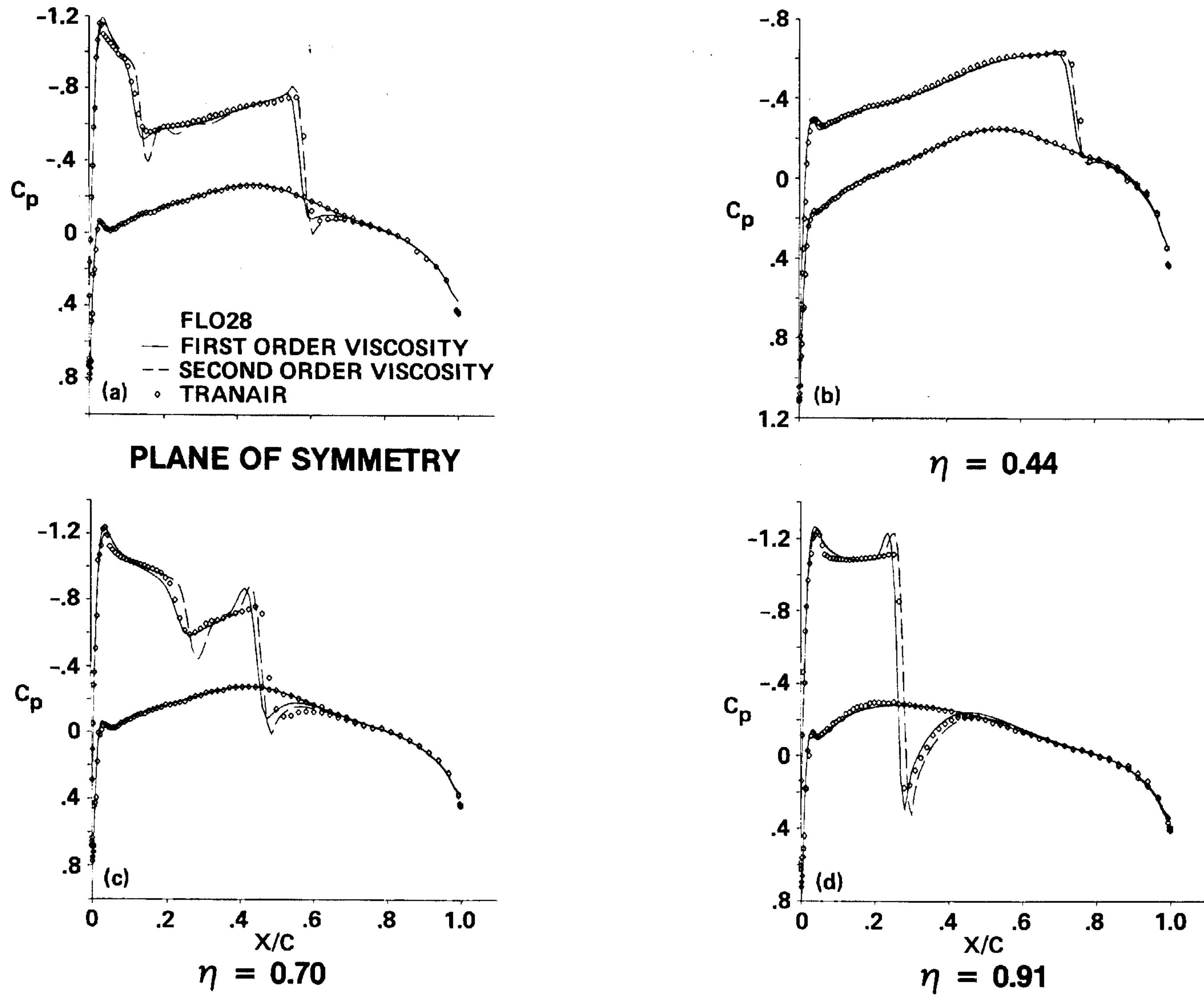
ONERA M6

REFINED GRID AT ROOT SECTION



ONERA M6 WING

$M_\infty = 0.84, \alpha = 3.06°$



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OBSERVATIONS

- SHOWS PROMISE OF BEING EXCELLENT DESIGN TOOL
  - EXPECTED TO REPLACE PANAIR FOR ANALYSIS OF COMPLEX CONFIGURATIONS
  - LINEAR CASES TAKE 15-30 CPU MINUTES ON CRAY X-MP
  - NONLINEAR CASES TAKE 1-2 CPU HOURS ON X-MP
  - FOR CASES W/LIMITED VORTICAL FLOW, GOOD AGREEMENT W/FLO57
  - INITIAL Y-MP RUNS INDICATE 25-40% IMPROVEMENT IN CPU TIME
- AREAS FOR IMPROVEMENT
  - FURTHER MODS COULD REDUCE CPU TIME BY A FACTOR OF 2
  - BOUNDARY LAYER COUPLING FOR MORE ACCURATE SHOCK LOCATION
  - ADDITION OF "WAKE CAPTURING" TERM FOR VORTICAL FLOW TRACKING

POSSIBLE FUTURE DIRECTIONS

- MODIFIED FULL-POTENTIAL
  - SOURCE TERM ADDED TO FULL-POTENTIAL EQN FOR WAKE TRACKING
  - VISCOUS COUPLING
- EULER EQUATIONS
  - MAINTAIN CURRENT GEOMETRY, GRID FORMAT
  - SOLUTION ADAPTIVE REFINEMENT FOR ACCURATE VORTEX CAPTURING
- NAVIER-STOKES??
  - PROBABLY REQUIRES “PSEUDO-GRID” FOR BOUNDARY LAYER SOLUTION

SESSION VI

ROTORCRAFT

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