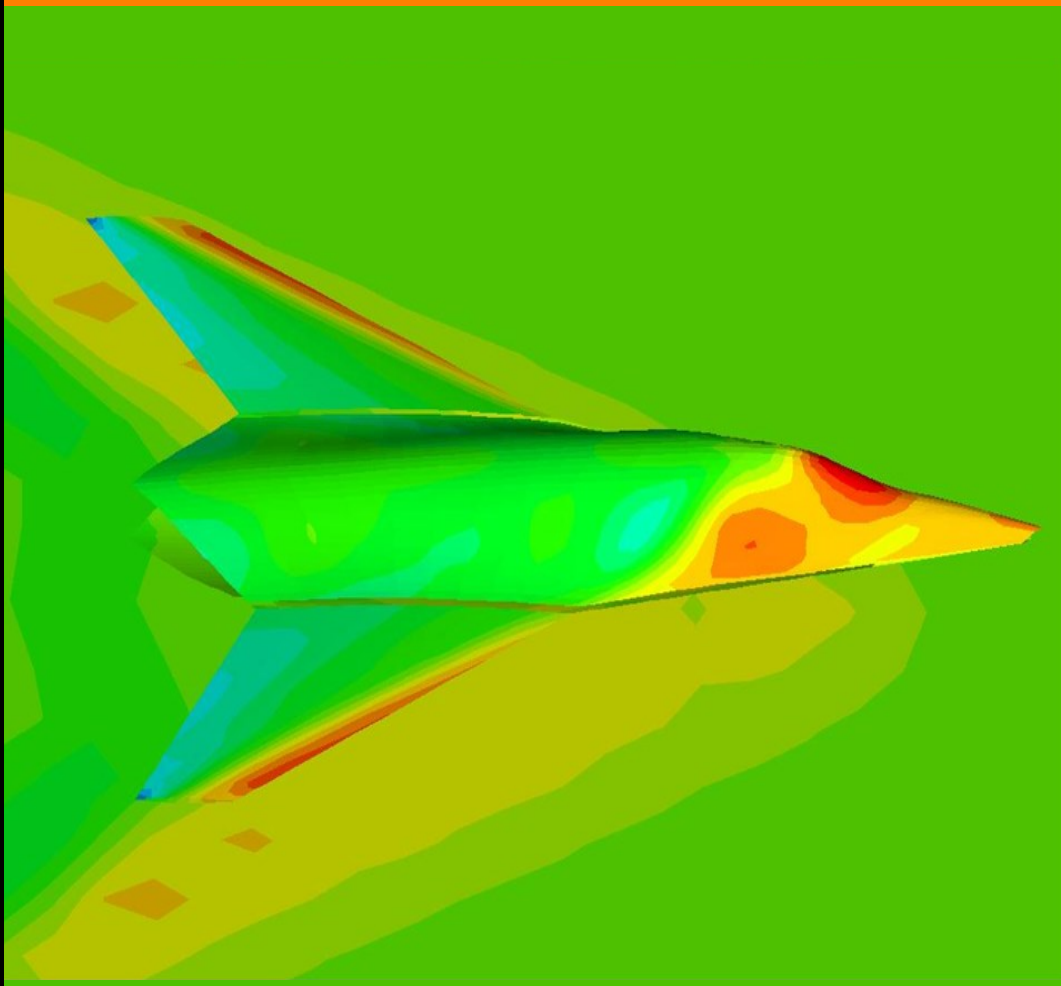
About ZONAIR™

Engineering Software for Aerodynamics and Flight Loads



ZONA TECHNOLOGY INC℠

TABLE OF CONTENTS

The ZONAIR Software System/Architecture 3
Finite-Element Base High Order Paneling Scheme..... 4
NASTRAN Bulk Data Input for ZONAIR 5
High Fidelity Geometry (HFG) Module 6
Direct Adoption of Off-the-Shelf FEM Pre-Processor
for Panel Model Generation 7
Subsonic Aerodynamics 8
Supersonic Aerodynamics 8
Hypersonic Aerodynamics 9
Aft-Body Wake Effects 10
Multi-Body Interference..... 11
Wave Drag Prediction..... 11
Ground Effects 12
Aeroheating Analysis 13
Wake Relaxation..... 14

ZONAIR

A finite-element based Aerodynamic/Loads system utilizing a unified high-order sub/super/hypersonic panel methodology

ZONAIR is advanced engineering software used for computation of aircraft flight loads that include aeroelasticity and aerothermoelasticity effects. The resulting flight loads are used by structural engineers for performing detailed stress analysis of the aircraft structure. ZONAIR utilizes a unified high-order subsonic/supersonic/hypersonic panel methodology as the underlying aerodynamic force generator to efficiently create aerodynamic and loads databases for 6 degree-of-freedom simulation and critical loads identification. ZONAIR's unstructured surface panel scheme is compatible with the finite element method so that existing pre-processors, such as Patran and Femap, can be used to set up the aerodynamic model.

Additionally, ZONAIR employs a vortex roll-up scheme for high-angle-of-attack aerodynamics and includes ZAERO's advanced Trim module for flexible loads analysis and a Thermal Protection System for Optimization (TPSOPT) module for aerothermoelastic analysis.

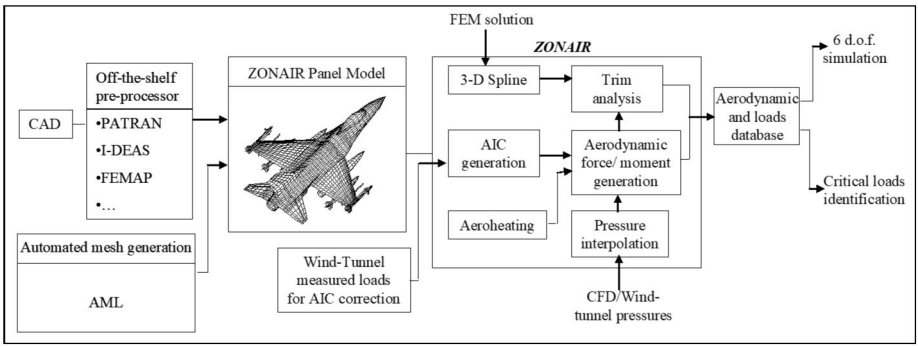
This brochure includes more information on ZONAIR’s features and architecture.

To License ZONAIR
Call: 480-945-9988 or
Email: licenses@zonatech.com

The ZONAIR Software System Architecture

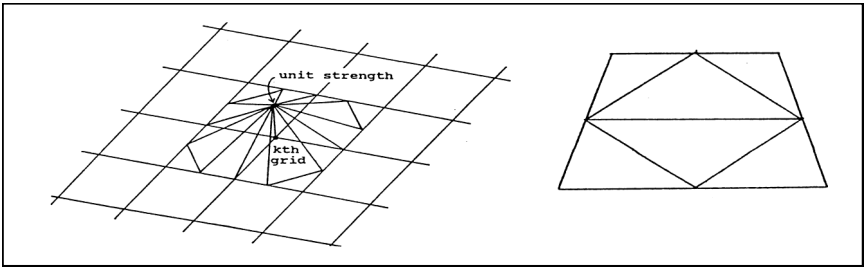
The Main Features of ZONAIR Include:

- Unified high-order subsonic/supersonic/hypersonic panel methodology as the underlying aerodynamic force generator.
- Unstructured surface panel scheme compatible to the finite element method.
- Provides all stability derivatives including control surfaces deflections without modifying the panel model.
- For a four thousand panel model, ZONAIR runs for roughly one hour for the first α, β, p, q, and r case at a given Mach number. However, additional α, β, p, q, and r cases for the same Mach number, will only take two to three minutes to complete.
- Direct adoption of off-the-shelf FEM pre- and post-processors for rapid panel model generation.
- Vortex roll-up scheme for high angle-of-attack aerodynamics.
- Performs a trim analysis and automatically maps the forces from ZONAIR panels to NASTRAN structural grids for subsequent stress analysis.
- Computes flexible loads due to structural flexibility and provides Elastic-to-Rigid ratios of all stability derivatives.
- Can import CFD solutions and map the pressure from CFD grids to ZONAIR panels.
- Based on the mapped CFD C_p as the rigid loads, ZONAIR can compute incremental flexible loads.
- AIC correction using wind-tunnel measured loads for accurate flexible loads generation

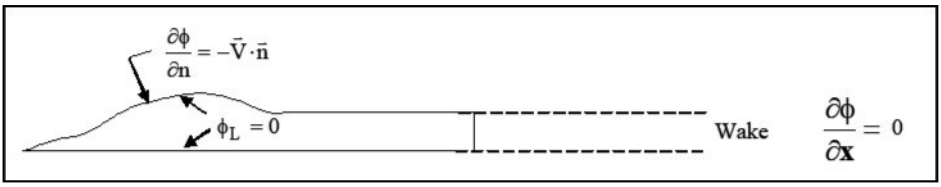


Finite-Element Based High Order Paneling Scheme

- In conjunction with the source singularity, piece wisely linear doublet is distributed over all panels which are surrounding this grid. In so doing, the continuity of doublet singularity is ensured.



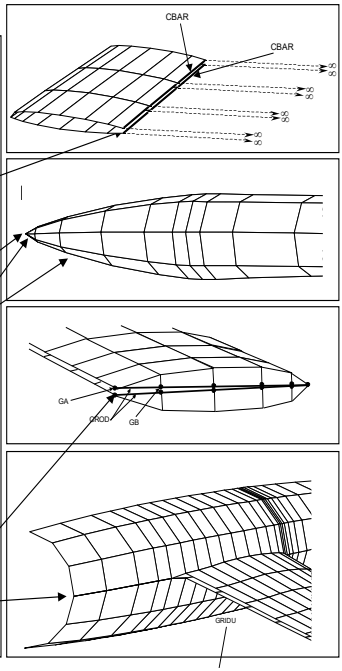
- Each quadrilateral panel is subdivided into six triangular panels for the continuity of panel geometry.
- Both Dirichlet boundary condition ($\phi_L = 0$) and Neumann boundary condition $\left(\frac{\partial \phi}{\partial n} = -\vec{V} \cdot \vec{n}\right)$ are imposed for solving the source and doublet strengths.
- Wake condition $\left(\frac{\partial \phi}{\partial x} = 0\right)$ is implicitly satisfied on the wake surface.
- In-flow of inlet and out-flow of nozzle effects can be included in the boundary condition.
- Transpiration boundary condition is used to model the control surface deflection, thereby no grid movement of the control surface deflection is required.
- Structural deformation can be also included in the boundary condition for the static aeroelastic analysis.



NASTRAN Bulk Data Input for ZONAIR

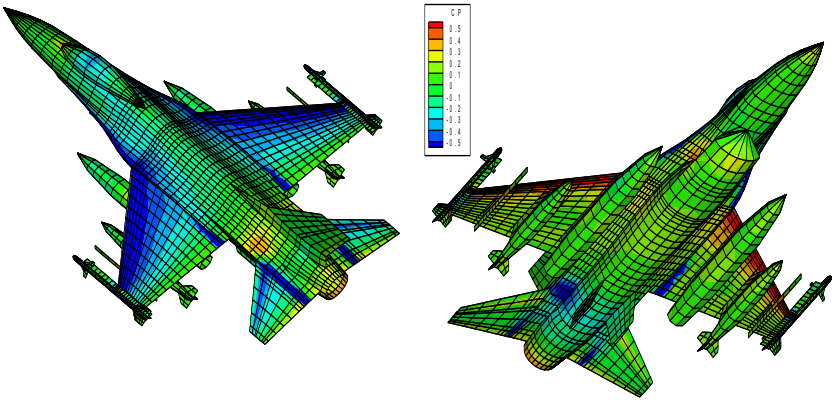
- Whole configuration is first discretized by grid points; the NASTRAN GRID cards.
- Grids points are connected by either quadrilateral panels, the NASTRAN CQUAD4 cards; or by triangular panels, the NASTRAN CTRIA3 cards.
- Wake surface modeling is not required. It is automatically generated by the wake lines; the NASTRAN CBAR cards, along the wing trailing edges.
- Tip vortex is modeled by the line vortex elements; the NASTAN CROD cards, along the wing tip.
- The effects of wake impingement on aft-body is modeled by the NASTRAN RBE2 cards.
- Multiple subcases for various flight conditions can be specified in the case control section within a single ZONAIR analysis.

```
TITLE= $naca 151f07 wing-body test case,the last model
ECHO = SORT
SUBCASE = 1
        AERO=1
SUBCASE = 2
        AERO=2
BEGIN BULK
$  Wake Modeling
CBAR          483       1     271     282
.................................
CBAR          484       1     273     283
$  Grid Point Locations
GRID            1            .000    .000    .000
.................................
GRID          586          29.313  12.000    .000
$  Triangular Panels
CTRIA3          1       1       1       2       3
.................................
CTRIA3          6       1       1       7       8
$  Quadrilateral Panels
CQUAD4          7       1       2       9      10       3
.................................
CQUAD4        558       1     193     200     201     271
$  Wing Tip Line Vortex
CROD          580       1     586     568
$  Wake-on-Body Impingement Behind Wing-Body Junction
RBE2         1001      51      52
              211     311     412     963     319
ENDDATA
```

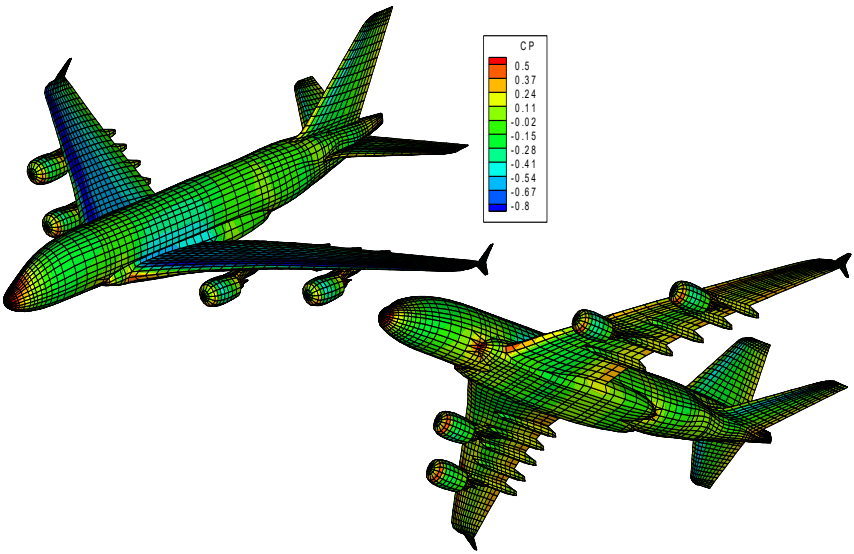


High Fidelity Geometry (HFG) Module

- M=0.6, AoA=10.0 deg., Half Model
- No. of Element: 1,602 (CTRIA3, CQUAD4) 446 (CAERO7)
- CPU time: 15min 46sec with Pentium XEON 2.4GHz

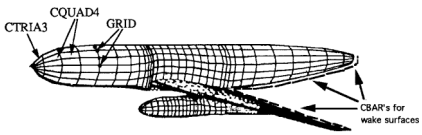
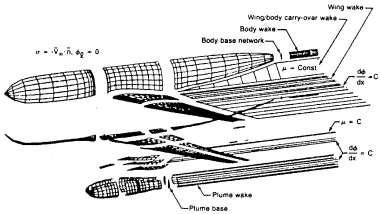


- M=0.8, AoA=2.0 deg., Half Model
- No. of Element: 3,528 (CTRIA3, CQUAD4) + 194 (CBAR, CROD)
- CPU time: 50min with Pentium XEON 2.4GHz

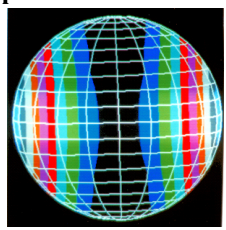
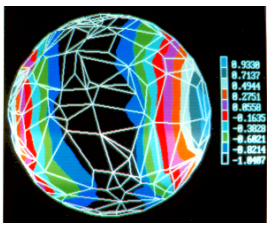


Direct Adoption of Off-the-Shelf FEM Pre-Processor for Panel Model Generation

Comparison of ZONAIR and PANAIR Paneling Schemes

ZONAIR *Unstructured Grids*	**PANAIR** *Structured Grids*
	
• Similar to structural FEM (MSC/ NASTRAN), the entire configuration is defined by "grids". CTRIA3's, CQUAD4's, CTRIA6's and CQUAD8's define the connectivity between grids. • Only the starting lines of the wake need to be defined (via CBAR elements). There are no input requirements for the surface wake. • PATRAN, FEMAP, I-DEAS, etc., can be employed directly for pre- and post-processing.	• The entire configuration is first divided into several "networks". Each network is further divided by m x n set of grids. Matching of doublet singularity between adjacent networks requires additional input. • The location of the wake surface must be explicitly modeled. • No commercially off-shelf software can be used directly for pre- and –post processing

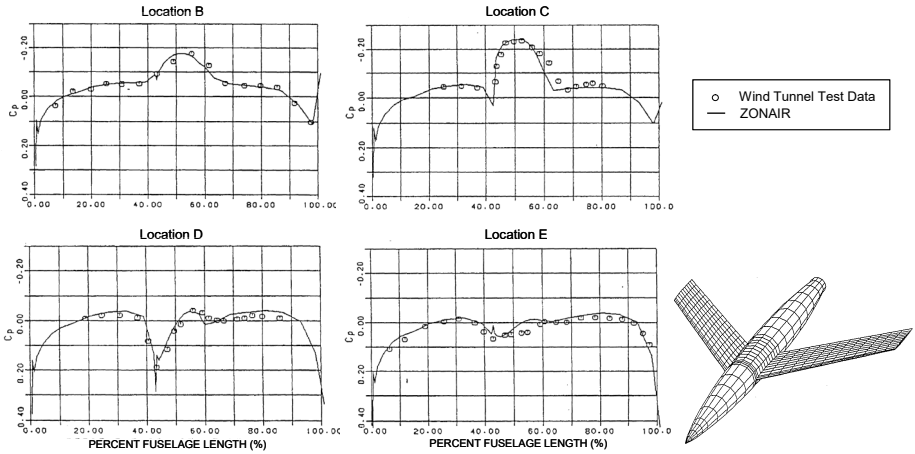
Regular and Random Paneling of a Sphere at M=0.0 and α = 0.0 deg

C_p on Regular Panels	**C_p on Random Panels**
	

Subsonic Aerodynamics

NACA RM L51F07 Wing-Body Configuration at M = 0.6, α = 4°

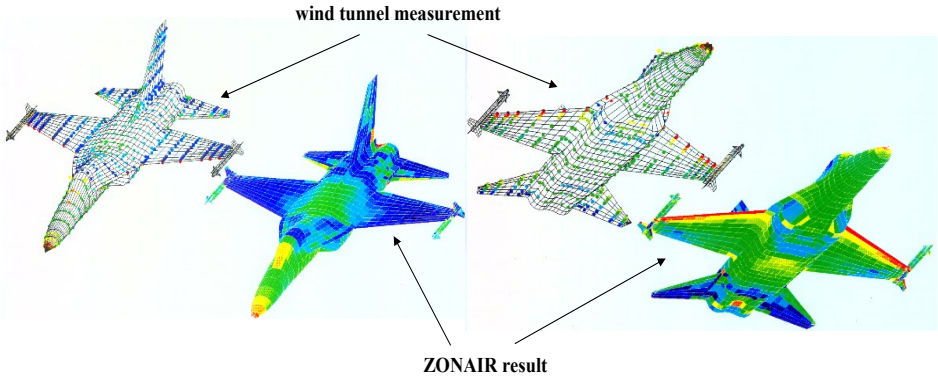
- Pressures along the body show strong wing-body interference.
- Good correlation with the wind-tunnel measurements.



Supersonic Aerodynamics

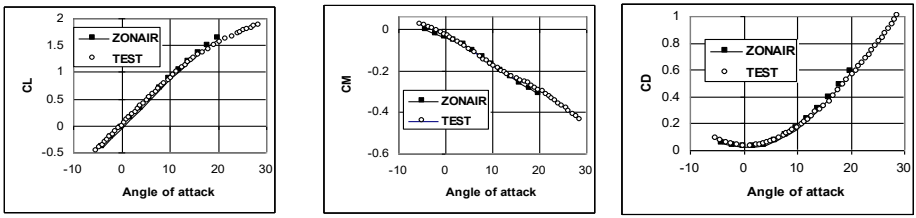
Pressure Distribution on Generic Advanced Fighter at M = 1.2, α = 4.1°

- Whole aircraft with tip missile configuration shows the capability of ZONAIR for accurate supersonic aerodynamics on complex geometry.
- CPU time is only 10 minutes on a 2.4 Ghz PC computer.

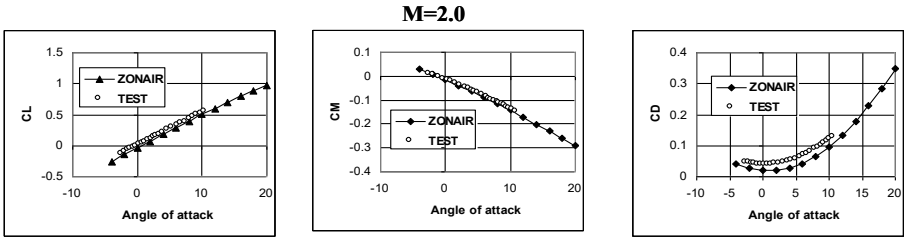


Comparison Between ZONAIR Force and Moment Coefficients and Wind-Tunnel Measurements on Generic Advanced Fighter

M=1.2



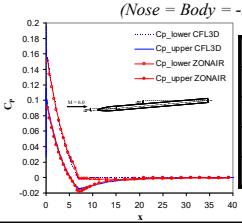
M=2.0



Hypersonic Aerodynamics

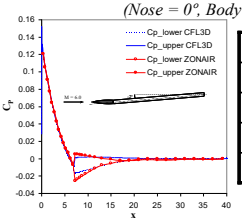
- Equivalent Mach number transformation to circumvent the super-inclined panel problem.
- Local pulsating body analogy for flow rotationality effects.
- Good agreement between ZONAIR and CFL3D on the CKEM body at various bent-nose angles at M = 6.0

Undeflected Case, Body & Nose at the same AOA (Nose = Body = -2°, at M = 6.0)



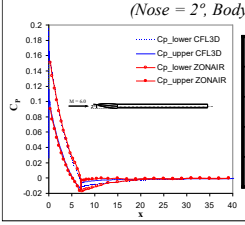
	CFL3D	ZONAIR
C_L	-0.118	-0.1125
C_m	-0.0549	-0.05588
C_D	0.0465	0.050
C_h	-0.00612	-0.00668

Positive 2° Deflection between Body & Nose (Nose = 0°, Body = -2°, at M = 6.0)



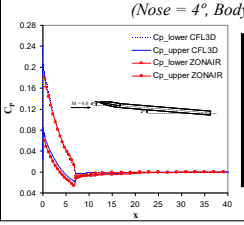
	CFL3D	ZONAIR
C_L	-0.076	-0.0712
C_m	-0.02552	-0.02776
C_D	0.0553	0.049
C_h	3.76e-7	0

Positive 2° Deflection between Body & Nose (Nose = 2°, Body = 0°, at M = 6.0)



	CFL3D	ZONAIR
C_L	0.0437	0.0408
C_m	0.0292	0.02806
C_D	0.0492	0.0493
C_h	0.00612	0.00668

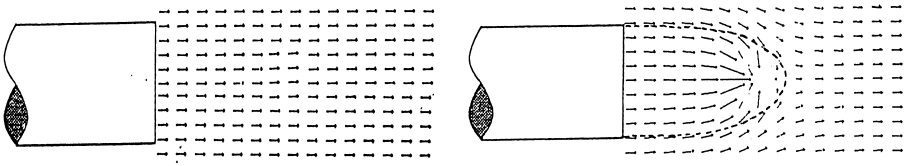
Positive 2° Deflection between Body & Nose (Nose = 4°, Body = 2°, at M = 6.0)



	CFL3D	ZONAIR
C_L	0.1637	0.1517
C_m	0.0857	0.08388
C_D	0.0537	0.057
C_h	0.0123	0.0133

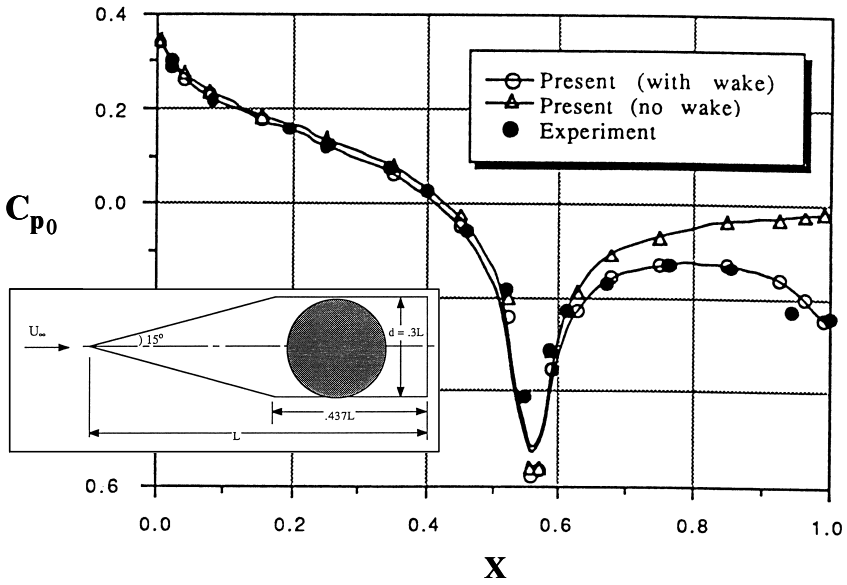
Aft-Body Wake Effects

- ZONAIR is capable of modeling the flow separation after truncated-end bodies by placing a point source singularity in the body wake region.
- By specifying the base pressure (C_{P_b}) as an additional input, the strength of this point source singularity along with all unknowns on panels can be solved altogether.



(a) without wake model **(b) with wake model**

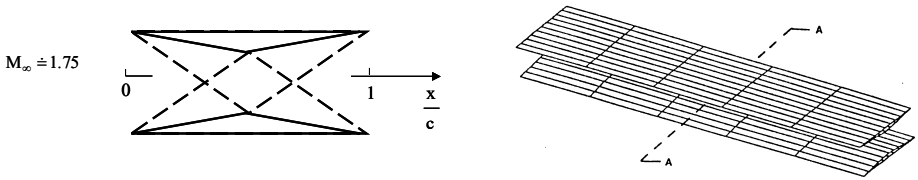
Computed Wake Shape for a LMSC Rattayya's Blunt Body at α = 0º and M∞ = 0 (view of the meridian plane)



Comparison of Surface Pressure Distributions for a Cone-Cylinder Body (L/d = 3.3) at α = 0° and M∞= 0.0 and C_{Pb} = -2.4

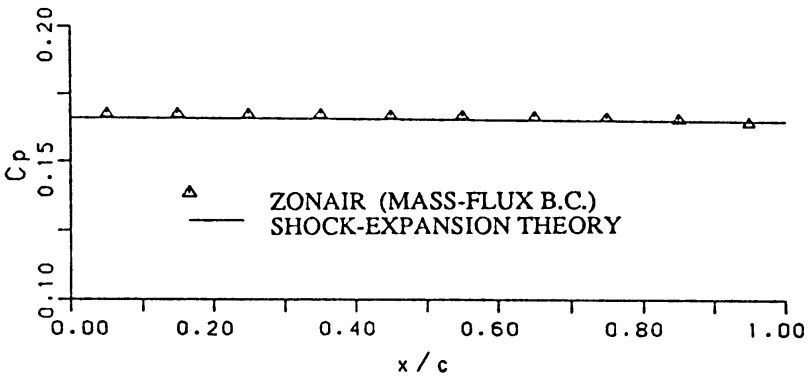
Multi-Body Interference

- Busemann Biplane at a design Mach number (M = 1.75 and α = 0º) where the shock-expansion theory predicts the nullification of wave drag due to the perfect cancellation of Mach waves.



Busemann Biplane at M = 1.75 and α = 0°

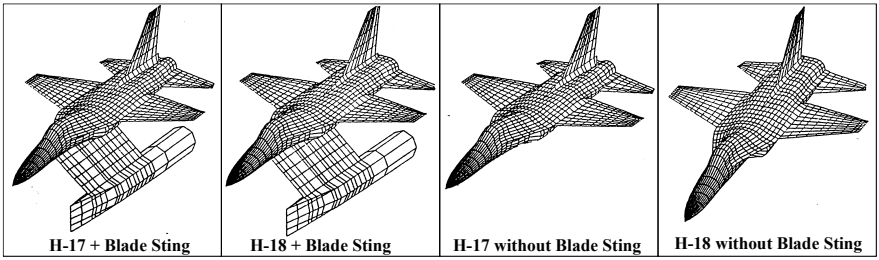
- Excellent agreement between ZONAIR and shock-expansion theory.



Cp on Busemann Biplane at M = 1.75 and α = 0°

Wave Drag Predictions

- The objective of the wind tunnel test is to determine the wave drag reduction of the GAF with a modified after body section (denoted as H-18) from the baseline GAF (denoted by H-17).
- Both wind tunnel models use an underbody “blade sting” fro supplying the jet flow and have sealed inlets. The difference in measured drag between these two models is assumed to be caused by the afterbody modification.
- The purpose of this ZONAIR analysis is to validate this assumption by establishing four ZONAIR models; H-17 + blade sting, H-18 + blade sting, H-17 without blade sting, H-18 without blade sting.



- Good agreement between ZONAIR and measured wave drag indicates that the blade sting effects on incremental wave drag measurements are small.

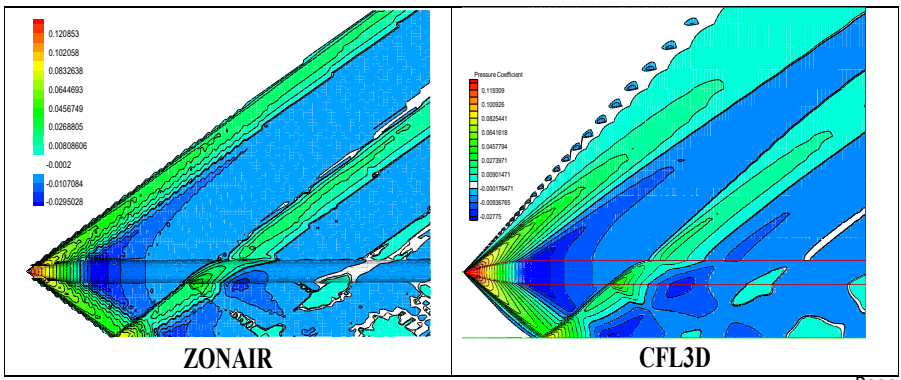
Blade Sting Effects on Wave Drag of GAF

M = 1.2	ZONAIR Wave Drag Predictions	Measured Drag
(H-17 + blade sting) – (H-18 + blade sting)	33 counts	31 counts
(H-17 without blade sting) – (H-18 without blade sting)	34 counts	N/A

Ground Effects

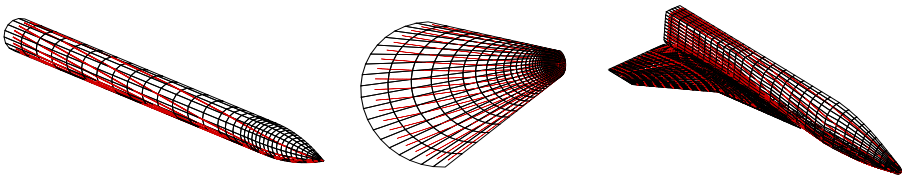
Compact Kinetic Energy Missile (CKEM)
Flying 5 Inches Above the Ground at M=2.0

- Mirror-image approach where the ground is treated as a mid-plane between two mirror-image bodies.
- ZONAIR can compute flow field solutions for the visualization of the detailed flow field solutions.
- Good agreement of the pressure distribution on the body surface and in the flow field can be seen. For this case, ZONAIR takes about 10 minutes of CPU time on a 550 MHz PC computer, whereas CFL3D takes about 10 hours.



Aeroheating Analysis

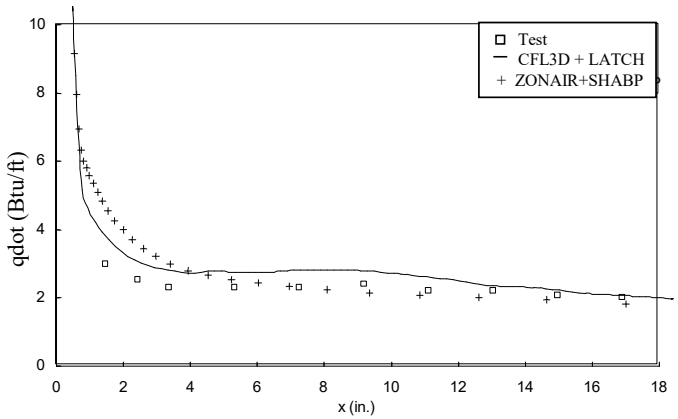
- A finite-element-based streamline module called ZSTREAM that adopts the inviscid surface velocities generated by ZONAIR as input to yield high quality streamline solutions.

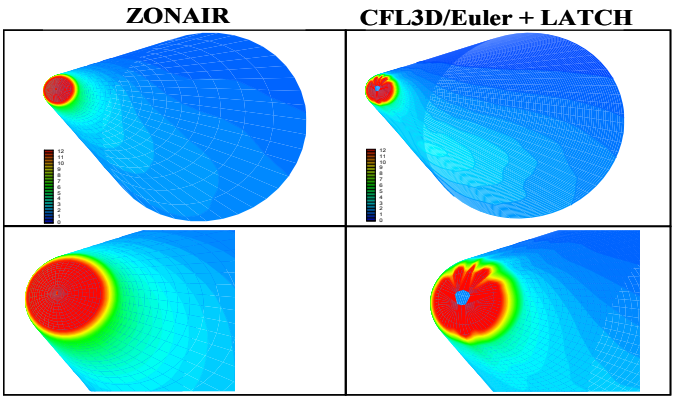


(a) (b) (c)

Streamline Results of (a) CKEM at M = 6.0 and α = 2°, (b) 15° Blunt Cone at M = 10.6 and α = 5°, (c) X-34 at M = 6 and α = 9°

- Once the streamlines are obtained, the aeroheating analysis can be performed along each streamline using a simple two-dimensional boundary layer method.
- The two-dimensional hypersonic boundary layer method is developed based on the similarity solutions of compressible (laminar/turbulent) boundary layer methodology of Eckert/Boeing and the White-Christoph methods.



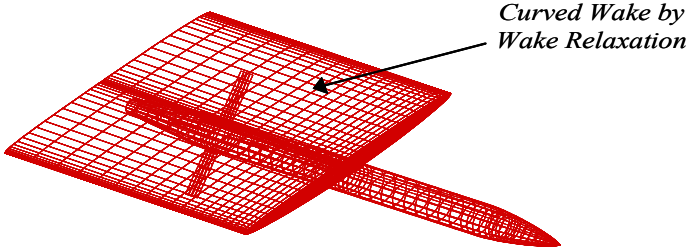


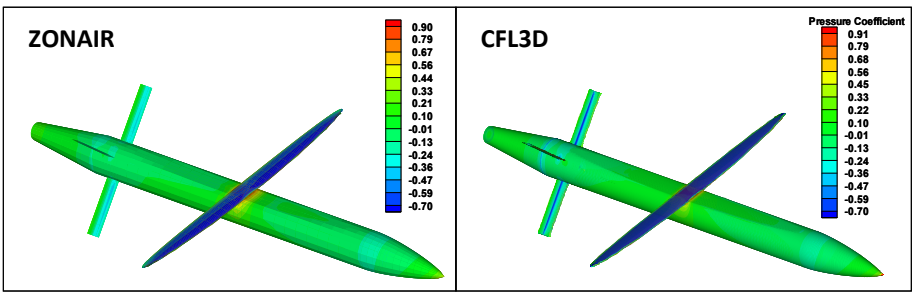
Laminar Heat Transfer Rates (Btu/ft2 –s) on 15° Blunt Cone at M∞ = 10.6, α = 5°, p∞ = 2.66 lb/ft2, T∞ = 89.971°R, Tw = 540 °R

Wave Relaxation

Gun-launched projectile with oblique wing at M = 0.6, α = 4º

- Flat wake generated from wing cuts into body which creates singularities in computations.
- Wake relaxation generates curved wake surface that removes the problem.





ZONA TECHNOLOGY INC[SM]

9489 E. Ironwood Square Drive
Scottsdale, AZ 85258-4578
Phone: 480-945-9988 | Fax: 480-945-6588
Email: info@zonatech.com
www.zonatech.com