HYPersonic CFD Applications at NASA Langley

Using CFL3D and CFL3DE

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CFL3D/CFL3DE

- Time-dependent conservation law form of compressible Euler and Navier-Stokes equations

- Upwind-biased spatial differencing (Flux Vector Splitting - FVS and Flux Difference Splitting - FDS)

- Thin-layer, finite-volume implementation with algebraic turbulence model

- Zonal grids - longitudinally patched (for hypersonic flows)

  - CFL3D
    - 3-factor implicit time advancement algorithm
    - Thin-layer viscous in 3 directions - two wall corner model

  - CFL3DE
    - Streamwise-relaxation crossflow-AF, space-marching Euler or PNS, first or second order
    - Perfect gas or equilibrium air
INDUSTRY USE STATUS OF CODES

  - Production code for NASP for McDonnell Aircraft Company
  - Some use at General Dynamics

● Other industry use
  - Boeing
  - Northrup
  - United Technologies Research Center

● University use
  - Iowa State University

● Other government use
  - Naval Surface Warfare Center
SR71 - GEOMETRY DEFINITION

FOUR ZONES:

51X51X23
71X51X8
71X51X7
91X51X4

\[ M_{\infty} = 3.0 \quad \alpha = 0^\circ \]

\[ \rho_{\infty} = 0.088 \text{kg/m}^3 \quad p_{\infty} = 5460 \text{N/m}^2 \]
HYPersonic LIFTING BODY

AOA = 0
M = 19.2
Re = 30000/in
PRESSURE COMPARISONS

M = 12.55
Re = 2.7 million/ft.
Zero degrees angle of attack

Upper Surface Centerline

Lower Surface Centerline

Fuselage Station (inches)

Open symbols - upper surface
Closed symbols - lower surface
HEAT TRANSFER COMPARISONS

$M = 12.55$
$Re = 2.7$ million/ft.
Zero degrees angle of attack

![Graphs of heat transfer comparisons for upper and lower surface centerlines.](image)

Open symbols - upper surface
Closed symbols - lower surface
AERODYNAMIC COEFFICIENTS COMPARISON MCDONNELL BLENDED WING BODY CFD AND EXPERIMENT

\( M = 12.4, \alpha = 6^\circ, \text{Re}/\text{L} = 930,000/\text{ft} \)

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TEMPERATURE

GENERIC OPTION #2 : 2-D INLET MODEL

COMPUTATIONAL METHODS BRANCH NASA LANGLEY

CONTOUR LEVELS

12.500  MACH
0.00 DEG  ALPHA
9.40x10**4  Re
1.0  TIME
95x30x51  GRID
**MACH NUMBER**

30 deg sweep, Mach 3.5 inlet

Computational Methods Branch NASA Langley

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Grid 1

Grid 2

Grid 3
FUTURE PLANS RELATED TO THE NATIONAL AERO-SPACE PLANE PROGRAM

- Continue to expand the envelope of capabilities for the code to include calculations of an entire NASP-like configuration
- Improved zonal capabilities for inlets with sweep and combustors
- Addition of non-equilibrium chemistry for combustor and nozzle/afterbody calculations
- All capabilities scheduled for production code by 1/90 (NASP Technology Maturation Program)