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3D EULER SOLUTIONS USING AUTOMATED CARTESIAN GRID GENERATION

JOHN E. MELTON
NASA AMES RESEARCH CENTER

FRANCIS Y. ENOMOTO
NASA AMES RESEARCH CENTER

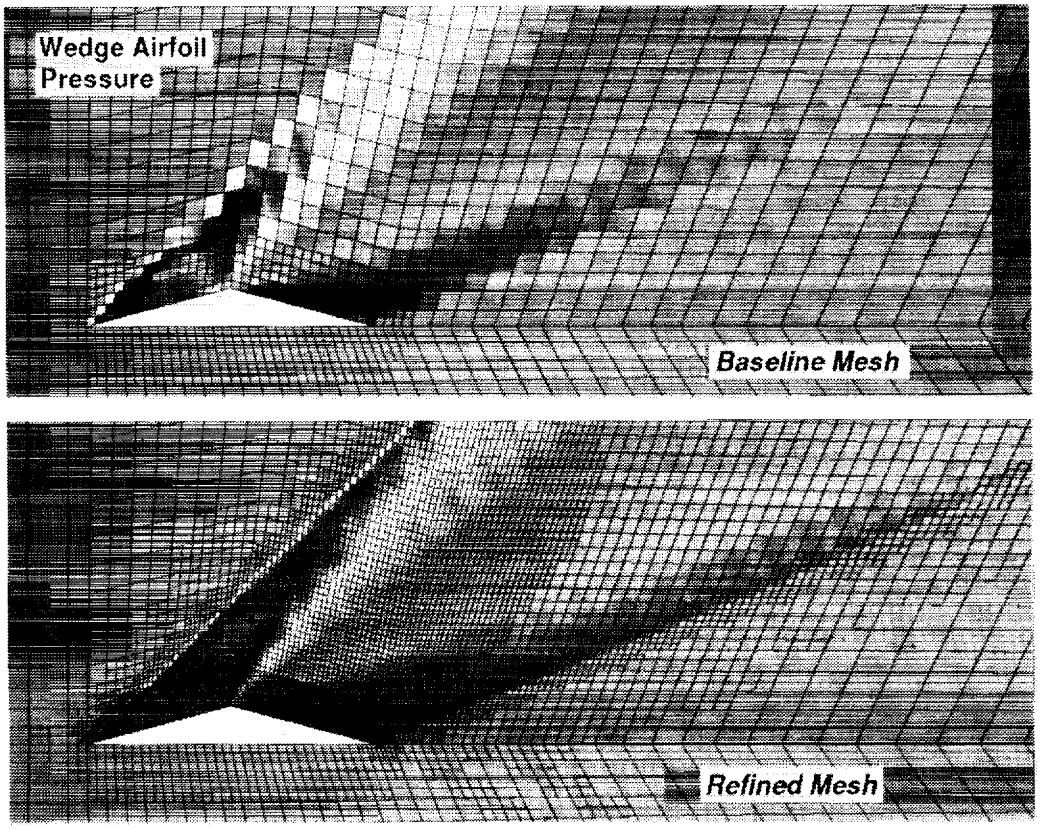
MARSHA J. BERGER
NEW YORK UNIVERSITY

Agenda

- History
- Cartesian Overview
- Technique Comparisons
- 3D Cartesian Grid Generation Strategy
- Survey of simple test cases
- Current research and future plans
- Summary

History

- Lessons from ATP grid generation
- AIAA 91-0637 with Thomas and Cappuccio
  - Unstructured, refined, hexahedral body-fitted grid
  - Euler FV RK4 Jameson flow solver algorithm (FLO57)
- TIGER = Topologically Independent, Euler Refinement
- GIRAFFE = Grid Interactive Refinement and Flow Field Examination



CFD and the Design Cycle

Compute ***better*** solutions ***faster*** and ***cheaper***

Analysis Issues

Resolution adequate for detailed design
- refinement appropriate for each Mach, α, β

Flexibility
- Multi-block
- Unstructured

Geometry Issues

- Turnaround **inside** the design cycle
- Use of CAD/CAM and automated geometry handling wherever possible

Three Important Questions

Are CFDers doomed to eternal grid generation?

Why shouldn't CFD be like structural FEA?

↓

How can we automate the geometry manipulation and grid generation processes?

Cartesian Grid Strategy

- South, Clarke, Salas, Hassan, Berger, LeVeque, Powell, Epstein, Morinishi, TRANAIR
- Make the computer do the work
  - ***Interactivity ≠ Automation***
  - Divorce surface grid from field grid
  - Use computational geometry algorithms to extract surface/cell intersection information
  - Use NURBs (Non-Uniform Rational B-Splines) to maintain a single, accurate, database
- Use grid refinement for "efficient" resolution
  - Unstructured grid (block or cell)
  - Flowfield and geometry-based refinement

Technique Comparisons

Task	Structured Body-fitted	Cartesian
Grid generation	tedious and boring time-consuming requires surface grid good tools are available	automated NURB accuracy no surface grid research software
Flux and BCs	"simple" and familiar	"complicated"
Connectivity overhead	minimal	~60 words/cell
Grid refinement/ adaptation	not automated difficult	automated for both geometry and flowfield
Flow solver	highly vectorizable	vectorizable

TIGER Surface Geometry

Entity	Advantages	Disadvantages
Triangles	"Simple" intersections LaWGS / FEM / PANAIR Compute - inexpensive	Poor refinement accuracy Creation Loss of surface information
NURBS	Direct from CAD Complete accuracy Complete information NASA/IGES standard	"Nonlinear" intersections - tolerance specifications - polynomial root-finding Topology determination Unfamiliarity Compute - expensive

2-Step Cartesian Grid Generation Algorithm

1 - Create initial equi-spaced Cartesian grid

→ Flag cells that intersect with surface
Refine along with a number of neighbors
Repeat to create desired resolution

2 - Compute cell geometric information

- face areas
- body surface normals
- cell volumes
- face and volume centroids

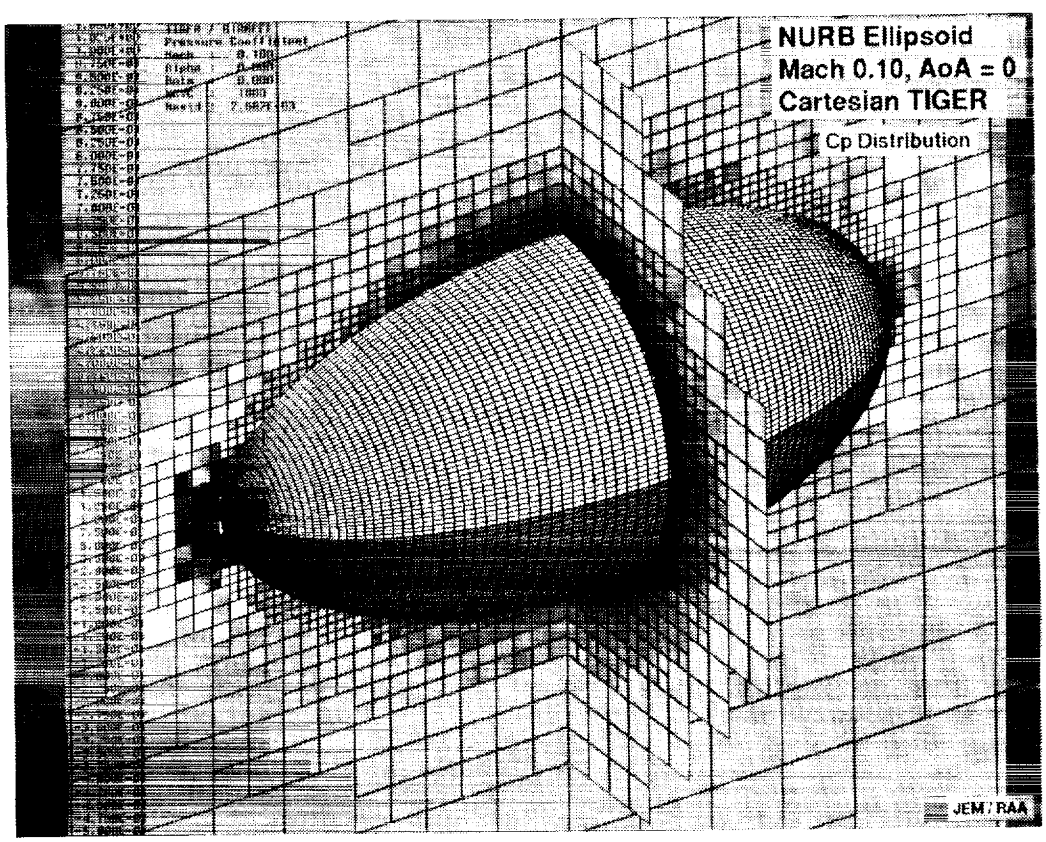
Current TIGER Connectivity Data Structure

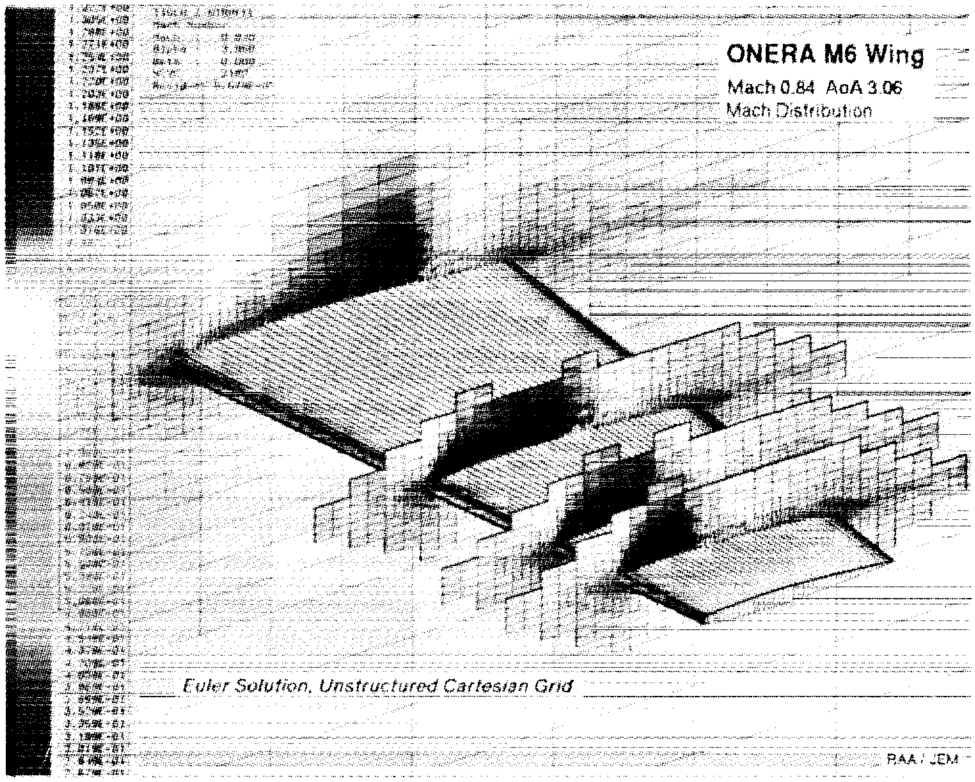
Item	Words per cell
Pointer to connecting cells	6 faces x 4 connections per face
Face BC flags	6 faces x 2 flags per face
Face area vectors	7 faces x 3 components per face
Cell Refinement Level	1
Cell BC flag	1
Cell volumes	1

Unstructured Cartesian Overhead ~ 60+ words per cell

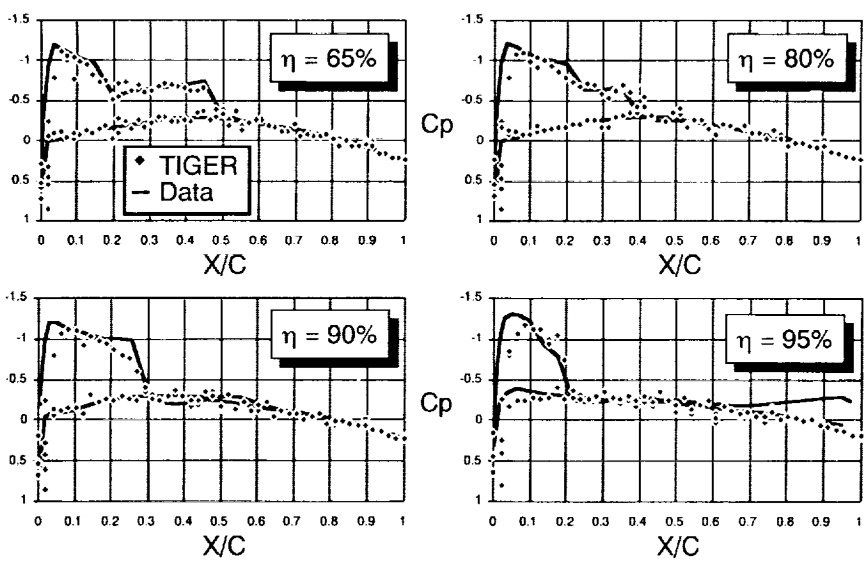
Survey of Test Cases

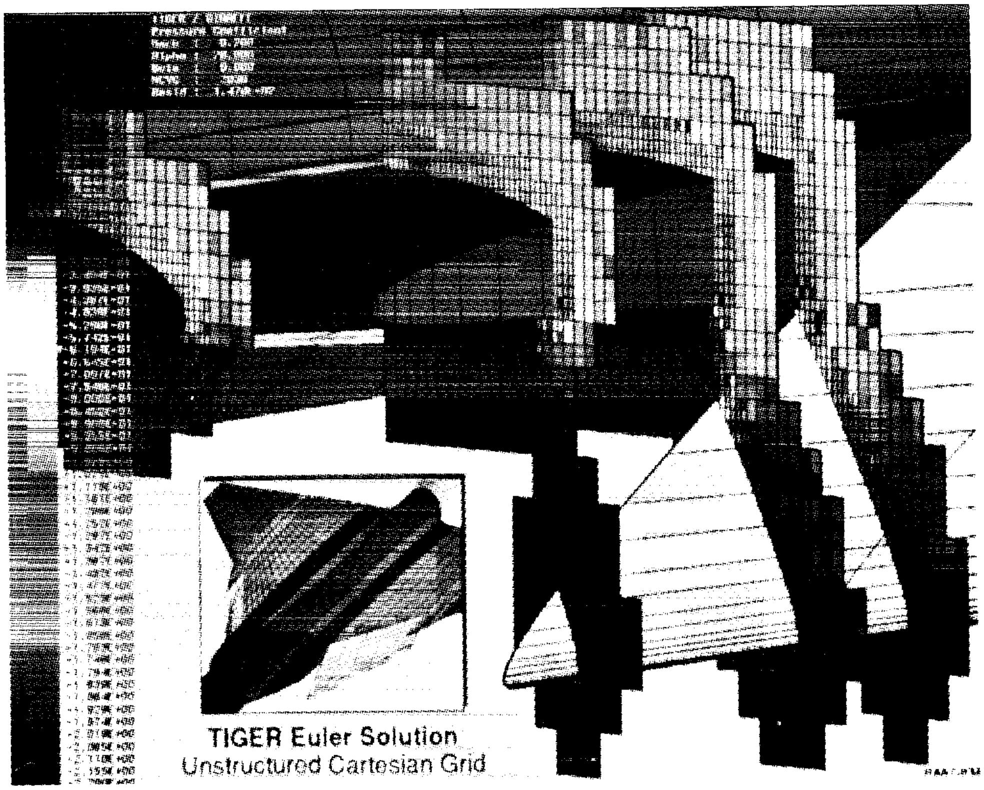
- Prolate Spheroid - NURB input
- ONERA M6 wing - Triangle input
- HSCT with LE flap - Triangle input





ONERA M6 Mach=0.84 α=3.06





HSCT Grid Generation Command Files

Step 1

```
1            1: use tiger.net data  2: use tiger.tri
1            1: flip y-z  0: don't flip
1            1: make new base grid  2: restart
-1  4000       : x-range
-1300  1700    : y-range
0  1201        : z-range
17  15  9      : dims
1            1: split surface cells  0: stop
6              : number of splitting passes
2              : number of buffer layers
1            1: reset symmetry plane cells  0: skip
1            1: compress the files  0: skip
```

Step 2

```
1     1: read from tiger.net  2: tiger.tri
1     1: flip y-z  0: don't flip
1     1: reset symmetry plane cells  0: skip
1     1: compress files  0: skip
```

Current Research and Future Plans

- Improved flux and dissipation modeling
- Improved boundary conditions
- "Intelligent" grid generation
- Flowfield refinements
- Validations

Summary

- Use of a single NURB geometry database for design and analysis has many advantages
  - allows for geometry manipulation with commercial CAD/CAM tools
  - provides analyst with complete and accurate surface information
  - provides consistent method for data transfer
- A mature unstructured Cartesian approach will have additional advantages
  - eliminate surface and volume gridding tasks via automation
  - provide local resolution appropriate for each flow condition
  - shrink CFD turnaround from months to hours
  - allow designers to concentrate on aerodynamic performance instead of computational geometry and numerical analysis
- Interactive techniques should be viewed as short term solutions, and not as long term CFD goals