Stage Separation CFD Tool Development and Evaluation

9/11/01

Alan Droege

NASA-MSFC

Reynaldo Gomez

NASA-JSC

and Ten-See Wang

NASA-MSFC

Stage Separation CFD Tool Development and Evaluation

- Background
- Flow Solver Descriptions
- Initial Results
- Lessons Learned
- Future Work

A. Droege, R. Gomez, and T-S Wang

Background

- Second generation reusable launch vehicle (2nd gen. RLV)
  - Space shuttle was the 1st gen. RLV.
  - 2nd gen. RLV concepts - two stages to orbit
  - Risk reduction tasks in FY01 through FY05. Architecture downselect in FY03, full scale development decision in FY06.
- Stage Separation of two lifting/winged bodies - issues
  - Possible recontact after separation, plume impingement, or other unforeseen separation behavior
  - Therefore, aerodynamic and plume data is needed for separation and control system designs.
- Some CFD tools are available and others are being developed. They need to be benchmarked for this type of problem.

Background (continued)

- Purpose of this task - CFD tool demonstration and validation for second generation RLV stage separation
- Little work has been done in CFD for side by side separation of large lifting/winged bodies
- CFD is needed to expand experimental databases and to cover flow regimes not covered in testing
- Data for multiple configurations is needed to screen 2nd gen. RLV designs in the early design phases - CFD will be faster than test

Langley Glide Back Booster
Bimese Configuration

- LGBB concept developed by the Vehicle Analysis Branch of Langley Research Center
- Bimese configuration uses OML of two LGBBs belly to belly without canards
- Bimese configuration chosen for aerodynamic tool development because it is a representative 2nd gen. configuration but is not a "real" configuration.

Flow Solver Descriptions

- Cart3D
- Overflow/Overflow-D
- Unic

A. Droege, R. Gomez, and T-S Wang

Cart3D

- Cartesian mesh, Euler solver
- Advantages: Automated meshing, highly parallel, rapid turnaround
- Disadvantages: inviscid, single species, no automatic 6-DOF capability
- Under development: automatic adaption, propulsive flow boundary conditions, viscous capabilities
- Potential 2nd gen. RLV application: early development phases

Overflow/Overflow-D

- Body fitted mesh near body, Cartesian mesh in far field, Chimera, Navier-Stokes solver
- Advantages: Parallel, viscous, moving body, large user base, some grid adaption, multi-species
- Disadvantages: no automatic grid generation, no chemistry
- Under development: Overflow and Overflow-D are being combined to get a code with Overflow's multigrid, grid sequencing, improved turbulence models, and Fortran 90 coding and Overflow-D's moving body 6-DOF, adaptive Cartesian background grid, and MPI capabilities.
- Potential 2nd gen. RLV application: all but the earliest development phases

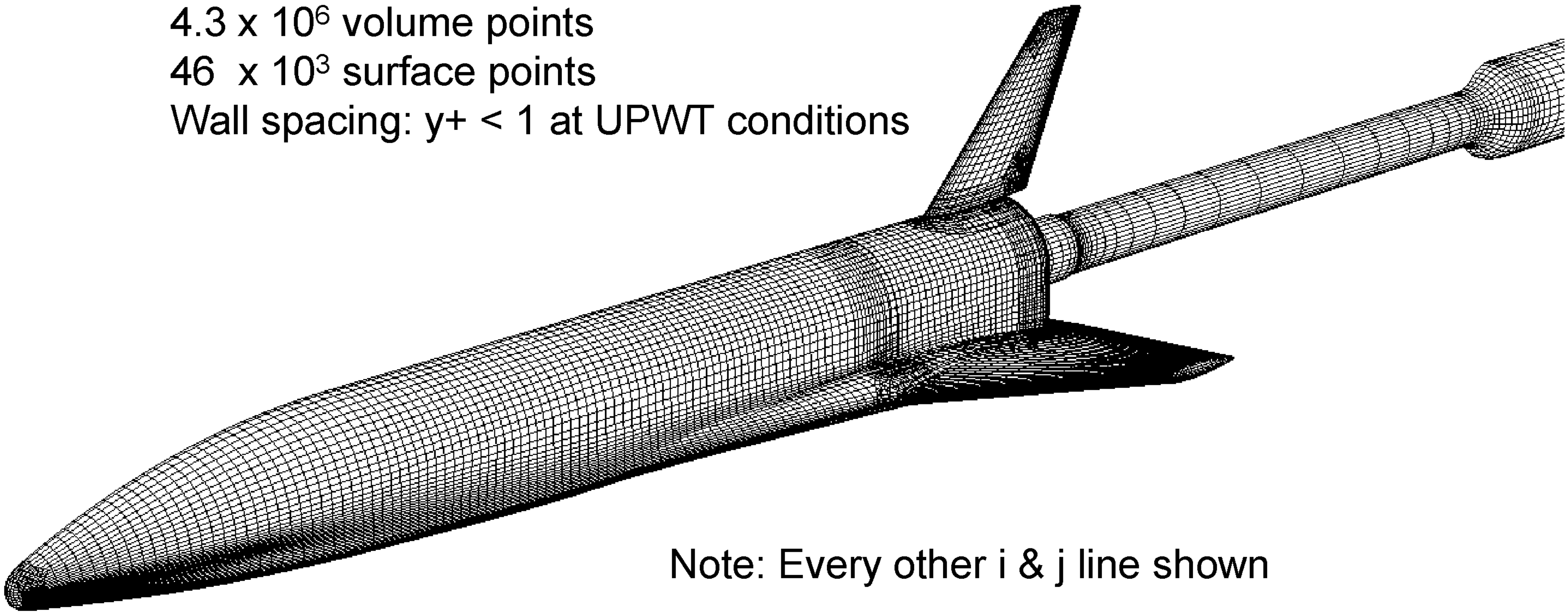
Unic

- Unstructured mesh, Navier-Stokes solver
- Advantages: Parallel, viscous, reacting flow chemistry, easy grid generation, mesh adaption, 6-DOF using assumed trajectory
- Disadvantages: code is still under development
- Under development: MPI, multi-body 6-DOF, mesh refinement
- Potential 2nd gen. RLV application: all development phases

Overflow grid system
Generated using Gridgen v13 + CGT

Single LGBB overset grid system

17 zones
4.3×10^6 volume points
46×10^3 surface points
Wall spacing: y+ < 1 at UPWT conditions



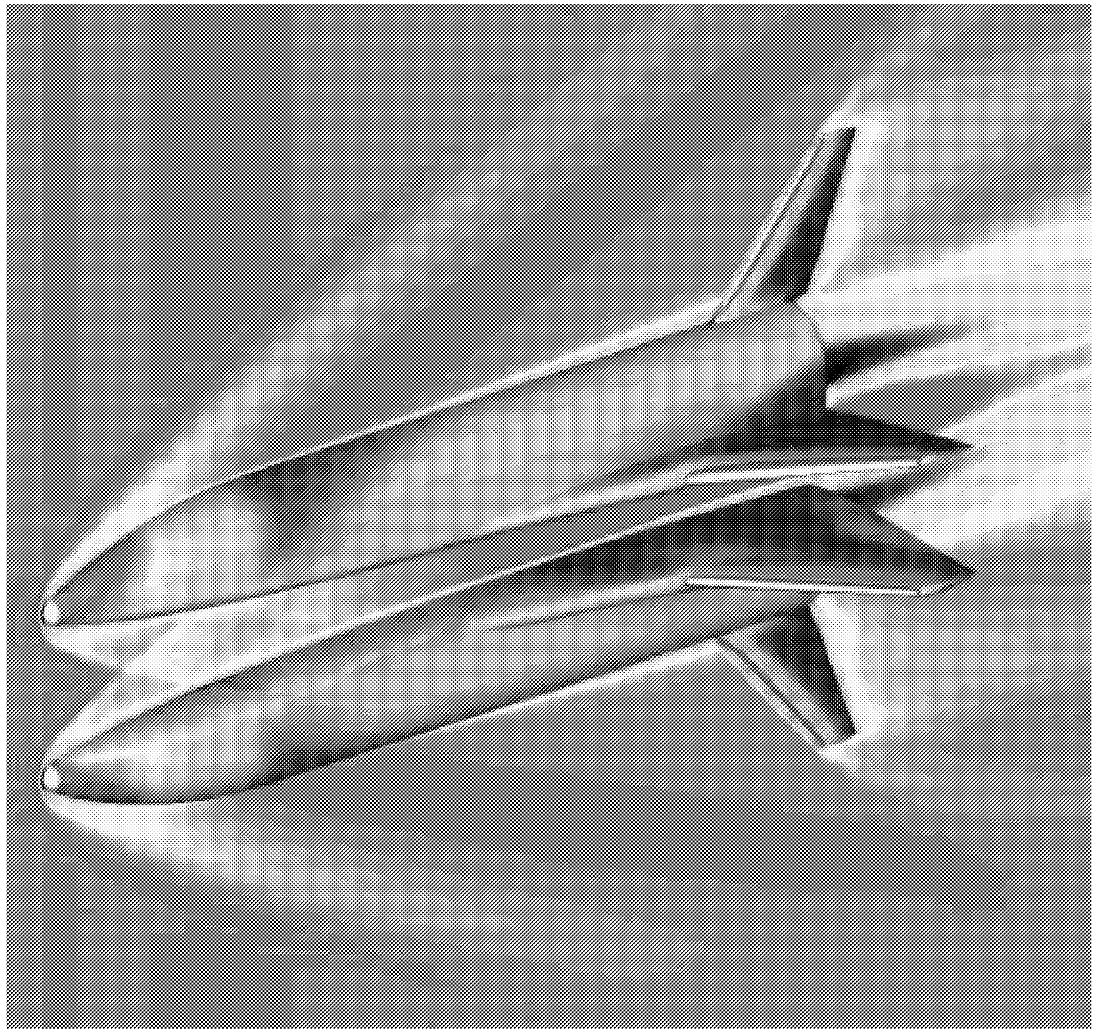
Note: Every other i & j line shown

A. Droege, R. Gomez, and T-S Wang

9/11/01

Overflow solution

Mach 3.0 UPWT
- 1.75% LGBB
- No wind tunnel stings
- 0.8” separation distance
- Cp on vehicle surface
- Mach number on y = 0 plane



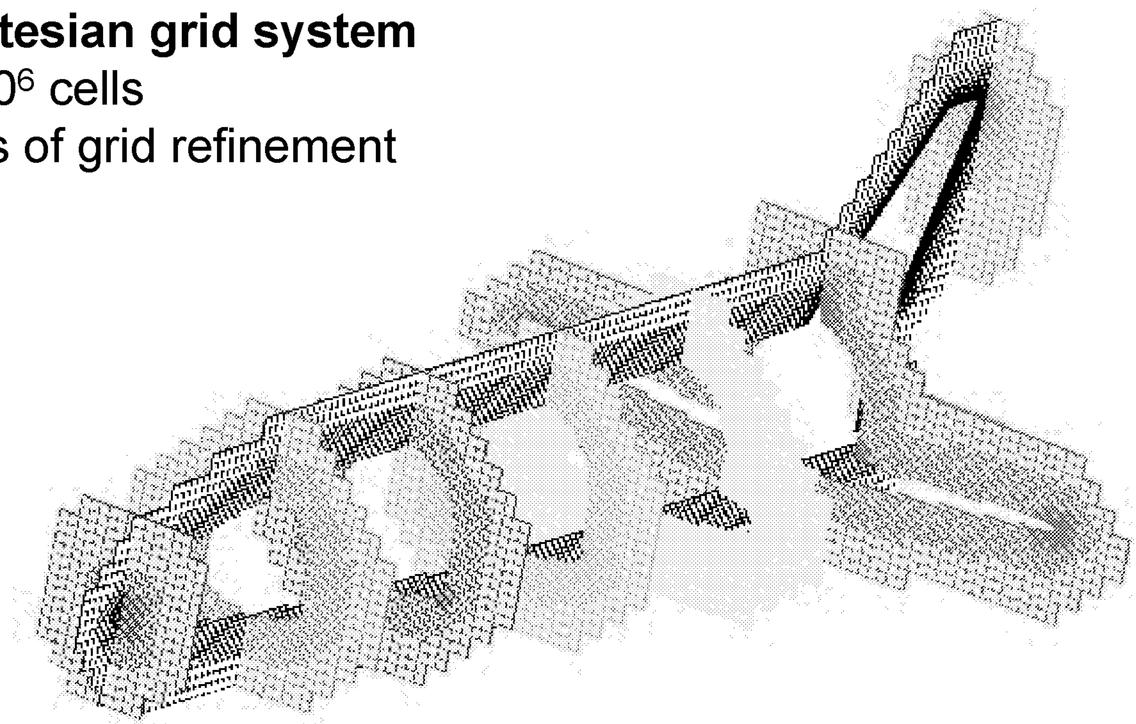
A. Droege, R. Gomez, and T-S Wang

Cart3D grid system

Sample LGBB Cartesian grid system

1.1 x 10^6 cells

7 levels of grid refinement

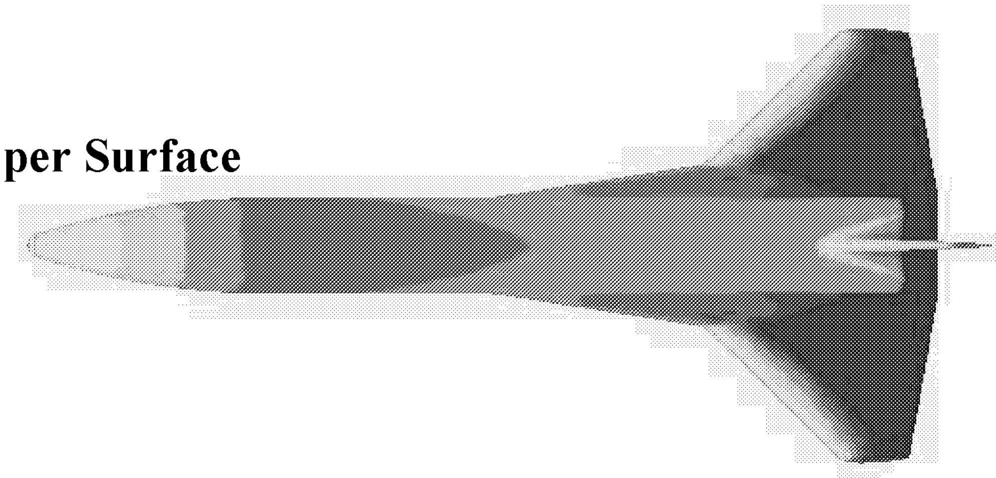


Note: 3 coarsest levels of refinement not shown

A. Droege, R. Gomez, and T-S Wang

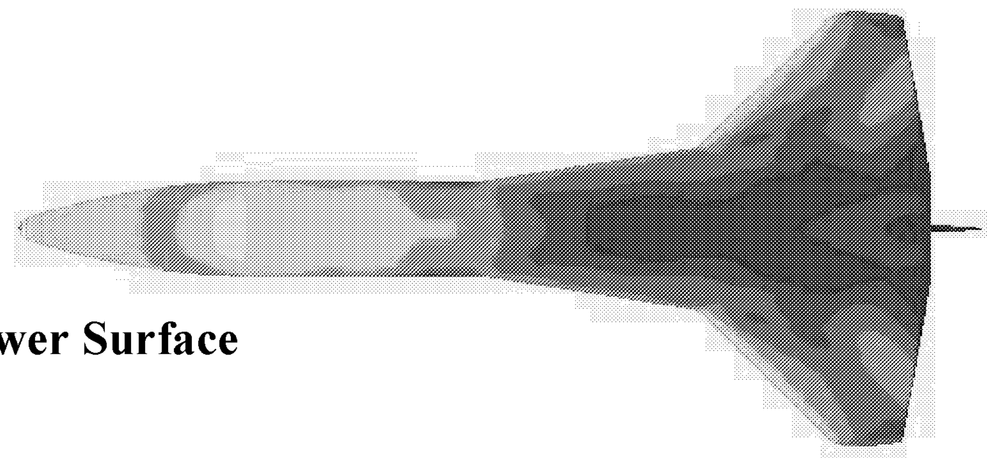
Cart3D solution

Upper Surface



Mach 3.0

1.75% LGBB
No wind tunnel stings
0.42” separation distance
Cp on vehicle surface



Lower Surface

A. Droege, R. Gomez, and T-S Wang

Lessons Learned

- Massively parallel computers and flow solvers have helped bring CFD into the realm of preliminary design tools for vehicle aerodynamics.
- Automated and semi-automated meshing tools in the hands of experienced users have yielded good meshes in a significantly reduced amount of time when compared to work done just a few years ago - Faster, Better, Cheaper.
- Automation of run set-up, convergence checking, and postprocessing is needed. It exists, but is not tightly coupled with the codes investigated in this study.
- Terabytes of storage needed for storage of all files associated with a single CFD aerodynamic database. Question: Is it cheaper to keep restart files or just rerun cases of interest later?

Future Work

- Cart3D
  - Work on new flow solver (add capabilities)
  - Exercise new flow solver and compare results to old flow solver
  - Compute more cases for comparisons
- Overflow
  - Completion of the integration of Overflow and Overflow-D
  - Exercise the combined flow solver
  - Compute more cases for comparisons

Future Work

- Unic
  - Code completion
  - Single and bimese benchmark calculations and comparisons
  - Plume/vehicle interaction simulations
- All
  - Do an apples-to-apples comparison (between CFD codes and between analytical and experimental results)
  - Investigate sting effects
  - Apply codes to downselected configurations
  - Use CFD tools to impact all phases of the 2nd gen. RLV design process