National Aeronautics and Space Administration

Supersonic Nozzle Design for Low-Noise \ High-Thrust at Takeoff

F. Frate, ASRC Aerospace
NASA Glenn Research Center

SC11 International Conference for High Performance Computing, Networking, Storage and Analysis
NASA Exhibit, November 14-17, 2011

www.nasa.gov

National Aeronautics and Space Administration

Supersonic Nozzle Design for Low-Noise \ High-Thrust at Takeoff

F. Frate, ASRC Aerospace
NASA Glenn Research Center

SC11 International Conference for High Performance Computing, Networking, Storage and Analysis
NASA Exhibit, November 14-17, 2011

Overview

Research Summary:

Investigating innovative nozzle concepts for commercial supersonic transports entering service around the 2018-2020 "N+2" timeframe

Goal:

Reduced NOISE at takeoff while maintaining high *THRUST*

Funded by:

Supersonics Project within NASA's Fundamental Aeronautics Program

Computational Methods and Procedures

Approach:

Reynolds-Averaged Navier-Stokes Computational Fluid Dynamics (RANS CFD) simulations support aerodynamic screening of new concepts and provide the necessary inputs for RANS-calibrated noise prediction codes.

CFD Tool:

The Wind-US RANS CFD code (structured and unstructured solvers)

Computational Platform:

The Pleiades supercomputer at NASA Advanced Supercomputing (NAS)

Role of High-End Computing Resources

The Pleiades supercomputer at NASA Advanced Supercomputing has been instrumental in providing a computing platform to run RANS CFD on multiple nozzle concept cases and conditions, so to get more timely insights during the conceptual design process.

Pleiades has ample compute power and memory for those larger grids constructed to resolve physical phenomena when validating to experimental results.

Access to large amounts of storage space combined with high-throughput networks has been essential for the most complex, grid-intensive cases.

Project Details

Predictions for baseline and more complex nozzles have been compared to experiment as part of the overall Wind-US RANS CFD code verification and validation efforts.

Analyses have helped screen and map out the design space for integration of various noise-suppression technologies into three-dimensional nozzles.

The technologies investigated thus far have included multi-chevrons, mixers, ejectors, beveled/aft-deck extensions, and rectangular nozzles with varying aspect ratio.

Current concepts being evaluated include rectangular nozzles with half-ejectors, single-chevrons, notches, wings and submerged nozzle configurations.

Results and Impact

Cases To Be Discussed (All Run On Pleiades) :

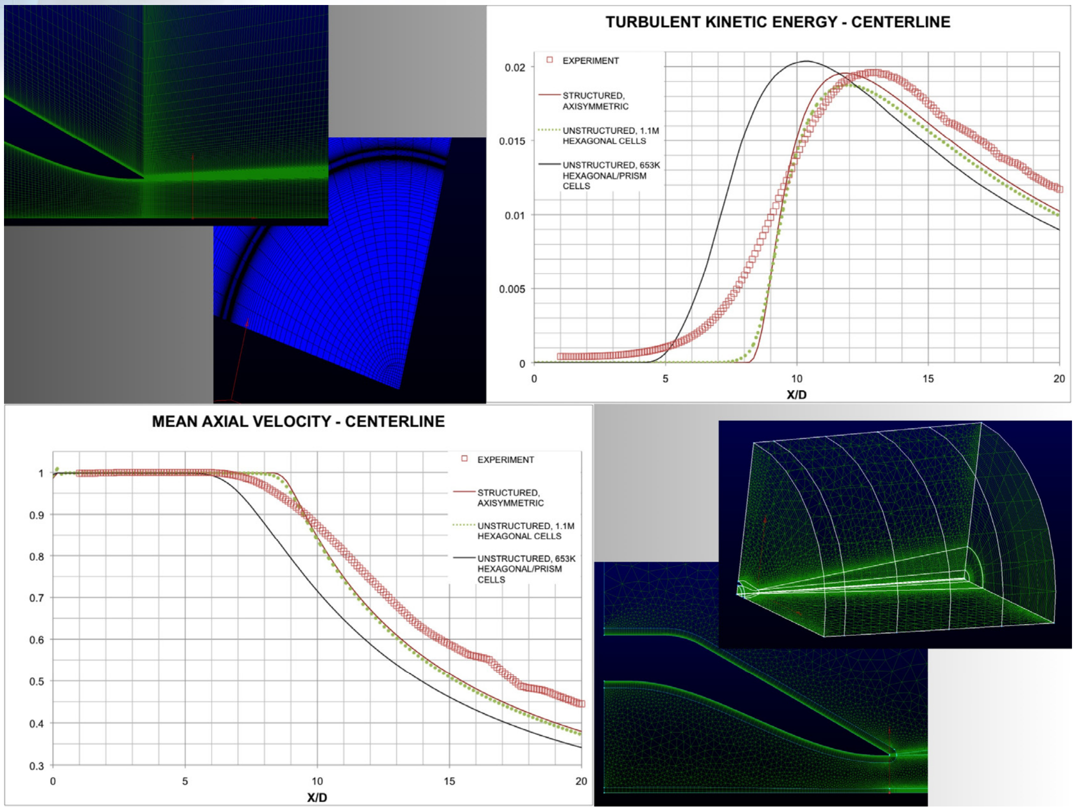
Validation of the updated Wind-US code's Structured and Unstructured Solvers

Structured Solver's Application to Highly Variable Cycle (HVC) Mixer-Ejector Nozzle

Structured Solver's Application to Extensible Rectangular Nozzle (ERN) Phase 1 Design

Current Application of the Unstructured Solver to the ERN Phase 2 Design Effort

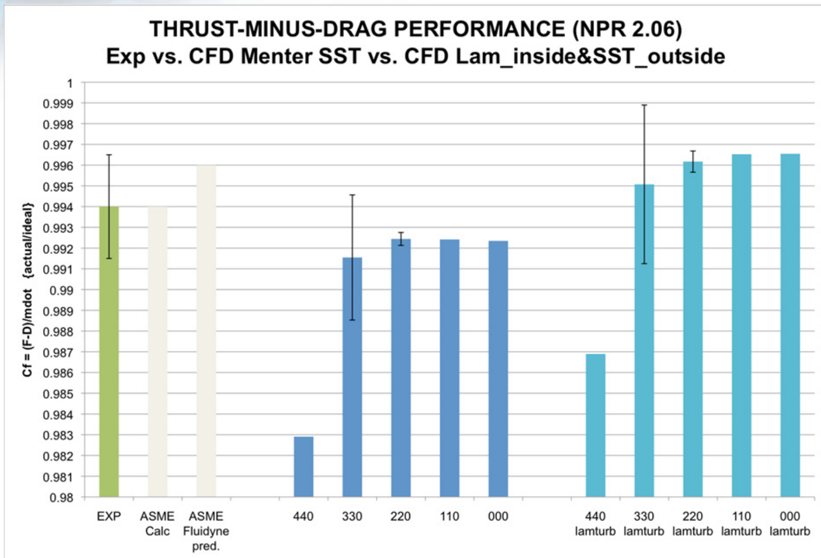
Wind-US Validation - Acoustic Research Nozzle

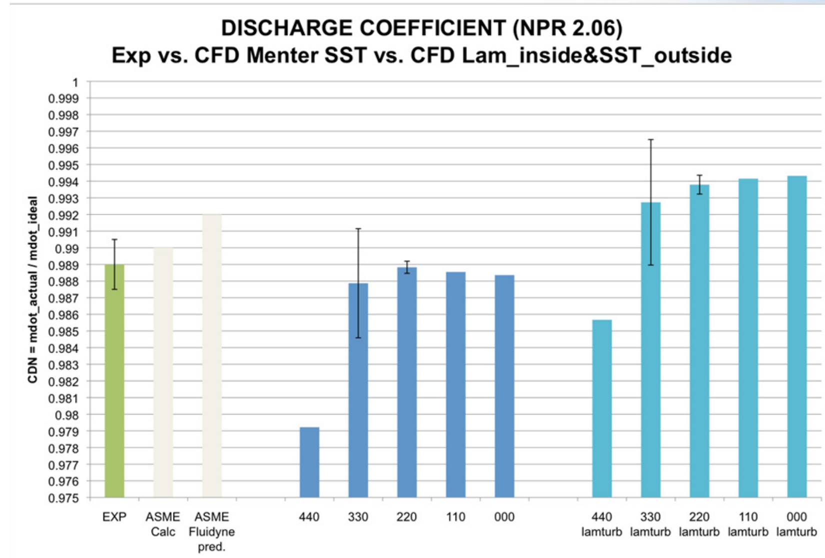


Predicted mean flow and turbulence parameters more accurately approach experimental test data following recent updates to the Wind-US code's structured and unstructured solvers.

The validated Wind-US unstructured solver provides a tool that will help increase engineering and computational efficiencies for more complex nozzle geometries

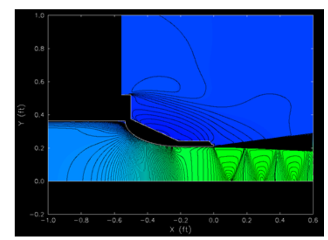
Wind-US *Thrust* Validation – ASME nozzle



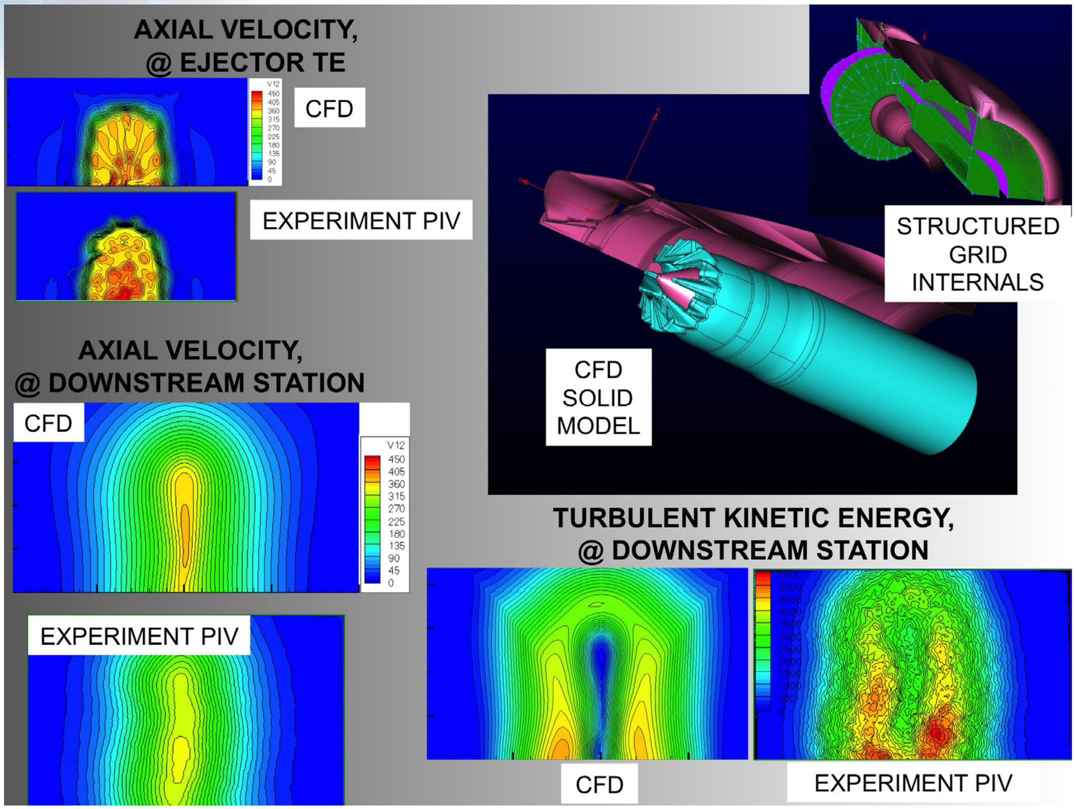


Structured CFD Results for the ASME nozzle from NASA TM-2010-216771

Grid independence studies shown above for various turbulence model assumptions


Fine Grid - Axial Velocity

Highly Variable Cycle (HVC) Mixer-Ejector Nozzle

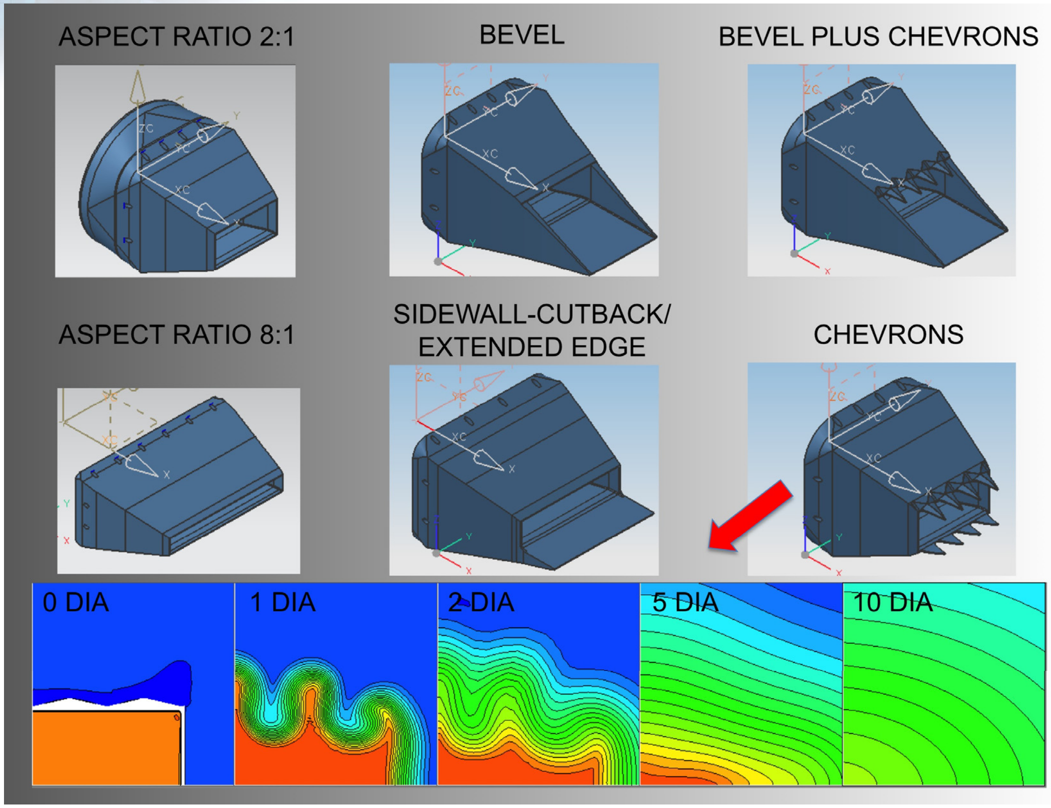


Complex nozzle geometries and the requirement for accuracy (trying to resolve key flow features) translates into very large grids.

The HVC <u>coarse</u> grid alone is 8.9 million grid points.

The structured approach can have inefficiencies during grid creation (on the order of one-month to create the initial HVC grid) and while managing the grid to convergence.

Sampling of ERN Phase 1 Concepts



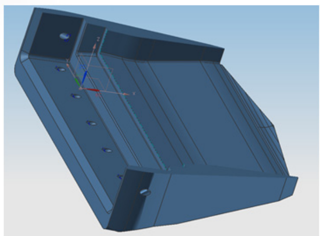
Screening complex nozzle geometries with CFD is a critical first step prior to fabrication of costly test hardware.

Wind-US structured analyses helped guide ERN Phase 1 design, though each grid would take on the order of one-week (or longer) to construct

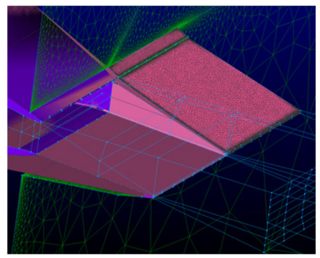
← Velocity contours at takeoff (Aspect Ratio 2:1 Chevron Nozzle)

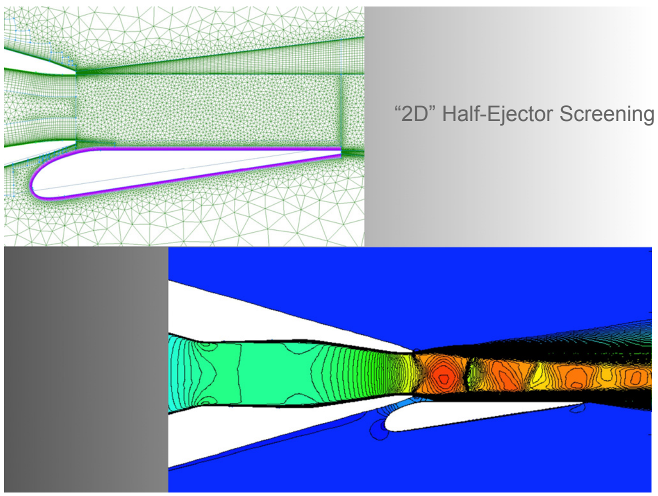
Current Efforts - ERN Phase 2 Screening

Single Chevron



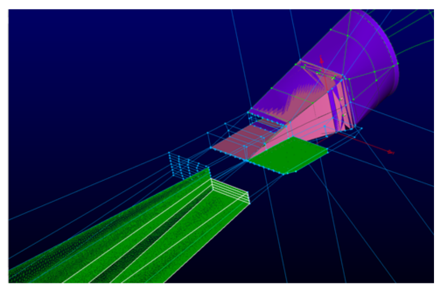
Submerged Bevel





“2D” Half-Ejector Screening

Winged Bevel



Screening of the various design parameters with the unstructured solver provides another degree of freedom.

On the order of days to construct rather than weeks

Grid adaptation (not currently in Wind-US) may be needed to allow benefits of unstructured approach to be fully realized.

Research Summary

Updates to the Wind-US code's structured and unstructured solvers resulted in closer agreement with test data, leading to better input for noise prediction.

Wind-US RANS CFD analyses have helped screen and map out the design space for integration of various noise-suppression technologies into complex nozzles.

Wind-US RANS CFD analyses have helped guide the Extensible Rectangular Nozzle design process to minimize flow non-uniformities over a range of conditions.

The validated unstructured solver within Wind-US provides another tool to increase engineering and computation efficiencies for complex nozzle geometries.

Conclusions / Comments

Screening complex nozzle geometries with CFD is a crucial first step prior to fabrication of costly test hardware.

Improved solver capabilities enable more accurate noise and thrust predictions.

Systems designers will use future databases populated with output from validated RANS CFD along with output from RANS-calibrated noise prediction codes when performing propulsion system trade studies of the noise-suppression technologies.

The Pleiades supercomputer at NAS has provided a fast, powerful platform during the screening process and has been essential for the most complex, grid-intensive cases.

Questions?

Franco Frate, ASRC Aerospace

RTE/Inlet And Nozzle Branch

NASA Glenn Research Center

21000 Brookpark Road

Cleveland, OH 44135

(216) 433-8450

Franco.C.Frate@nasa.gov

Visit More of NASA's SC11 Poster Exhibits!