Overflow Applications on Transonic Airplanes

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Agenda

- Introduction
- Process description; production environment
- Selected examples
- Conclusion

Introduction

- Overflow used extensively and very productively throughout Boeing
- This presentation focused on Everett PD, High Speed Aerodynamics in Commercial Airplanes
- Long range cruise condition
  - 1990's HSCT (M~2.4); 737NG (M~0.78)
  - 2000 Sonic Cruiser (M~0.95)
  - 2000's 787, 747, 777, 737 (M~0.78-0.86)
- Development of an in-house production N-S capability integral to the High Speed Aero process

Development of Overflow Process - Requirements

- HSCT, SC, early 7e7 work confirmed Overflow accuracy
- Production environment on airplane program required process development
  - Automation (for analysis speed and optimization)
  - Robustness
  - Consistency (geometry/grid/solution) from config to config, between airplanes, year to year
- Force calculations that fit into existing drag build-up methods

Development of Overflow Process - Strategy

- Focus on conventional configurations instead of general purpose process
- Developed constant set of pegasus, mixsur, overflow inputs
  - Number of blocks, names, topology, and key grid indices
- Solution strategy
  - Settled on preferred setup for accuracy and robustness, and use it without change for consistency

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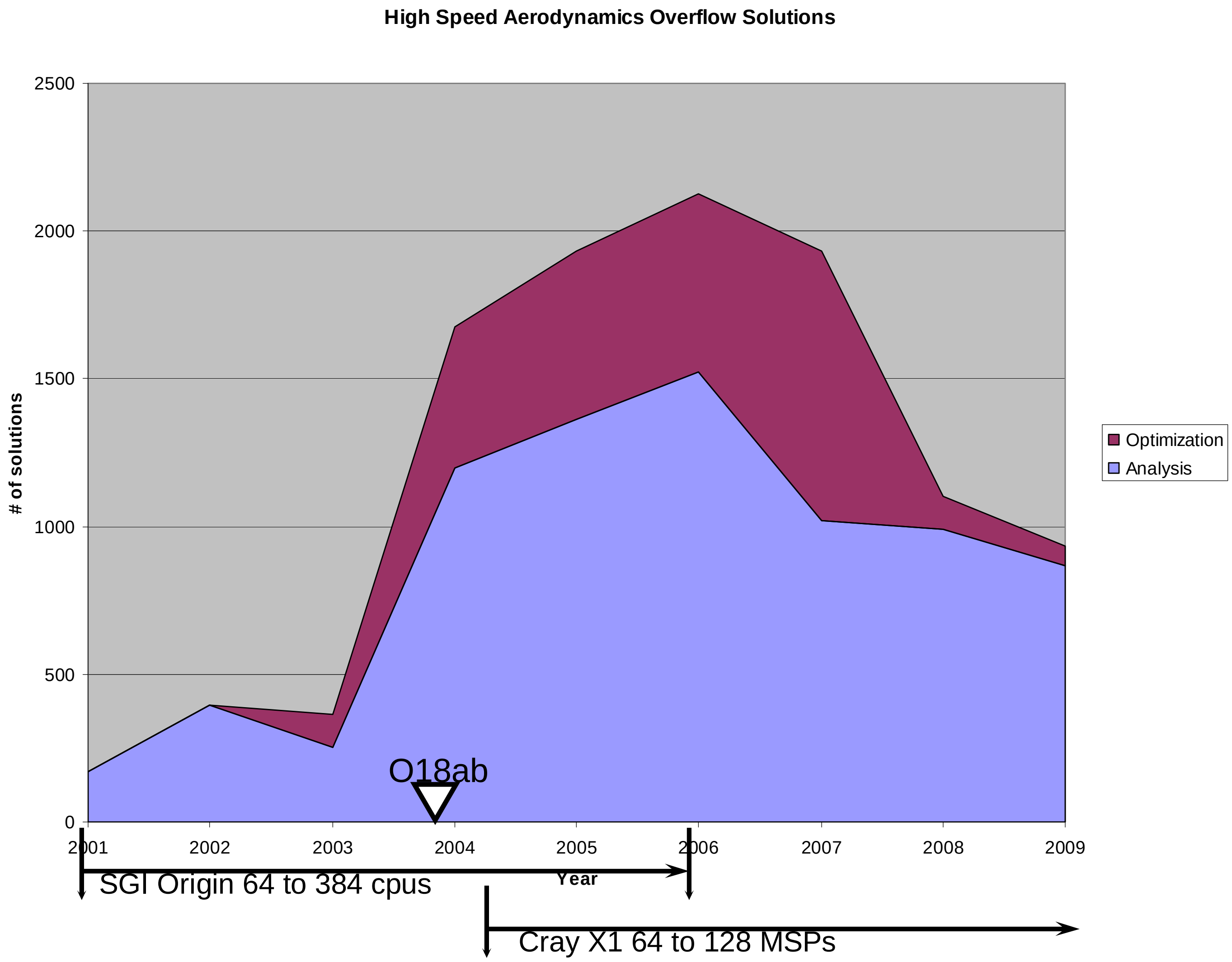
Overset Modeling Benefits

- Overset grids key to Overflow success in airplane development
- Many grid blocks built once; X_DIR becomes library
- Only modified component needs rebuilt grid block …
  - Nacelle/strut variations
  - Wing design and aeroelastic shape changes
  - Horizontal tail movement (for trim)
- … or, new components need new blocks added to an existing model with a proven robust solution strategy already in place.
  - Flap support fairings
  - Antenna and light fairings
  - Gaps
- … or, transfer grid model to other group for removal of component and replacement with increased model complexity

Process and Computer Improvements



High Speed Aero N-S Usage

- Enhancing performance estimates
  - Complementing full-potential, wind tunnel, flight test
- Detailed configuration analysis
  - Fairings/blisters, gaps, vg’s, etc.
  - Flow field Info (inlet/outlet, icing, noise)
  - Off-Cruise (loads)
- Junction flow design
  - Parametric design and numerical optimization
  - Wing/body intersection, etc.

Typical Grid Model

- Surface: grids from lofts (AGPS)
- Volume: hypgen, legrid
- Blanking/Interpolation: Peg5, Hcuts/2-Fringe/Level2/Manual-holes
- Model size (flight Re#)

	# of points	# of blocks	
• WBVH	25e6	30	
• SN	15e6	20	
• Total (1 eng)	40e6	50 blocks	(half-model)

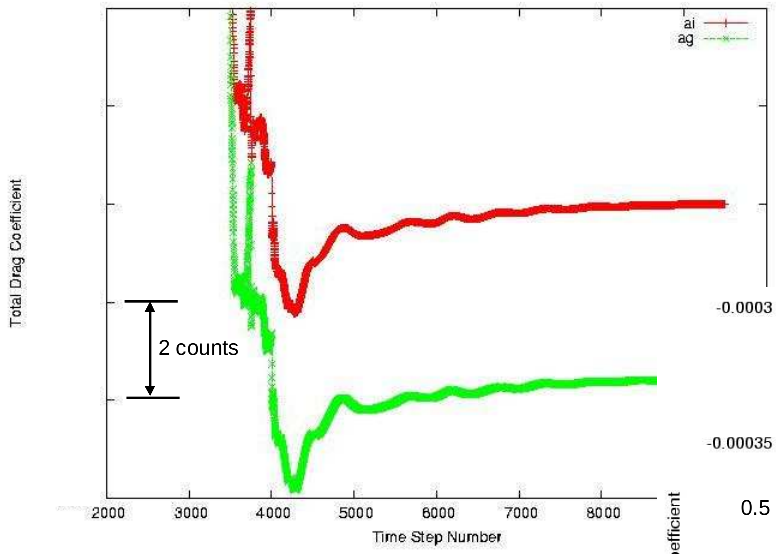
- SN(propaero) 50e6

Overflow Solutions

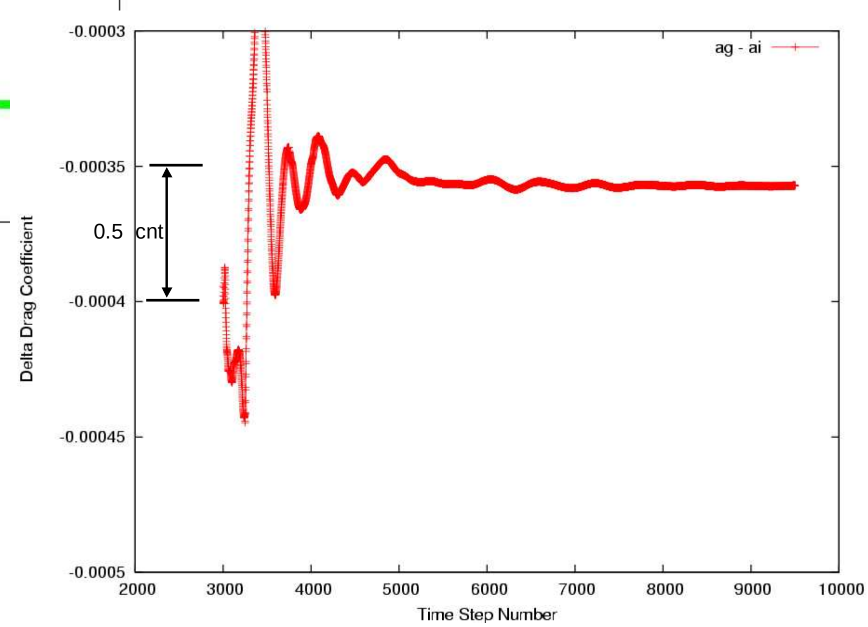
- Overflow 1.8ab MLP
  - ARC3D (ILHS=2), Central (IRHS=0), local time steps
  - SA turbulence model (pre-computed global wall distance)
    - Flight: all turbulent
    - WT: zero production laminar region to trip
  - Matrix dissipation; multigrid; VISCX=.T.
  - 7 phases, 9500 steps (1500/1500/6500); smoothing ramps
    - Occasionally use restarts during optimizations
  - CL & CM driver (alpha correction every 2 steps)
  - X1: 16 MSP's, 20 clock-hours

- Overflow 2.1ae MPI
  - ILHS=0 (BW !), 7000 steps
  - SARC, SST (NQT=205 !)
  - BC34, BC41, BC141 !

Typical [Delta] Drag Convergence



Drag increments often converge faster than total



Internal Environment, Mods, Tools

- Overflow/CGT/Pegasus software management using subversion
  - NASA updates easily merged with local changes
- Modularized installation: unique directory/module file for each combination of version, compiler, mpi, cpp flags, etc.
- Self-submitting pbs scripts: command line switches that define module to load

- Local mods
  - CGT: mixsur, overint
  - Pegasus5: topology logic, Level2
  - Overflow(18): CLdriver, InletMdot, polymixsur, Turb Model distance, Overtrip, Thrust-Drag Bookkeeping

- X_DIR directories shared among high speed aero overflow users
  - Script looks for grid.x local first, then to library X_DIR

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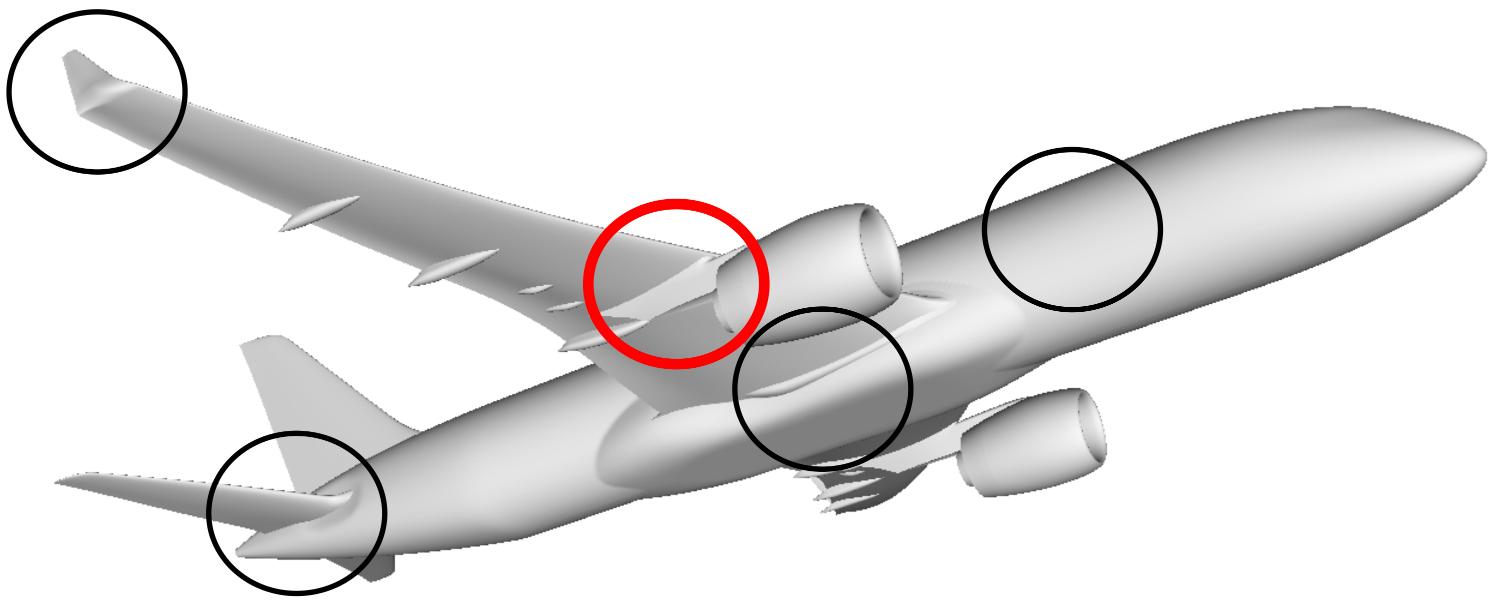
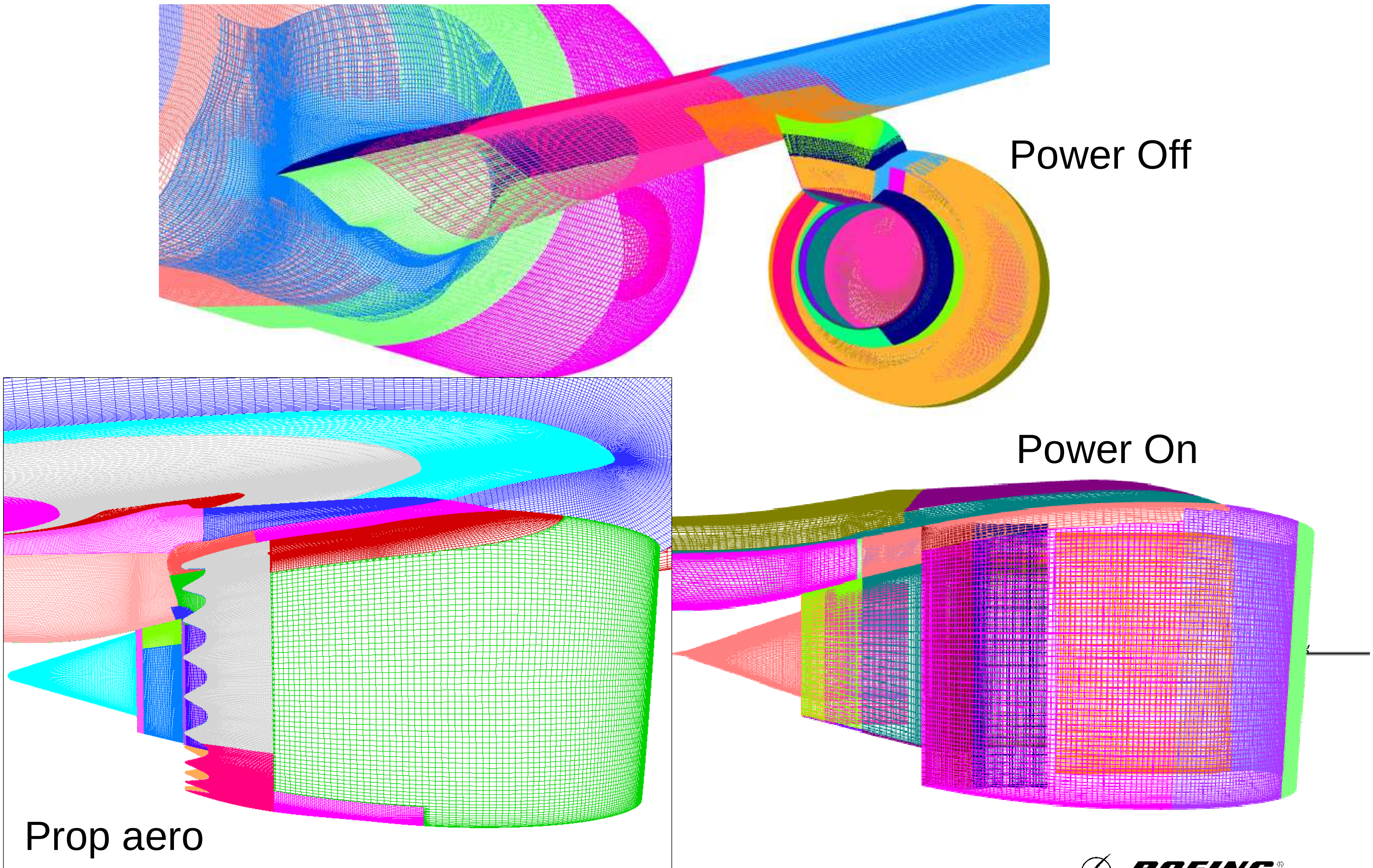
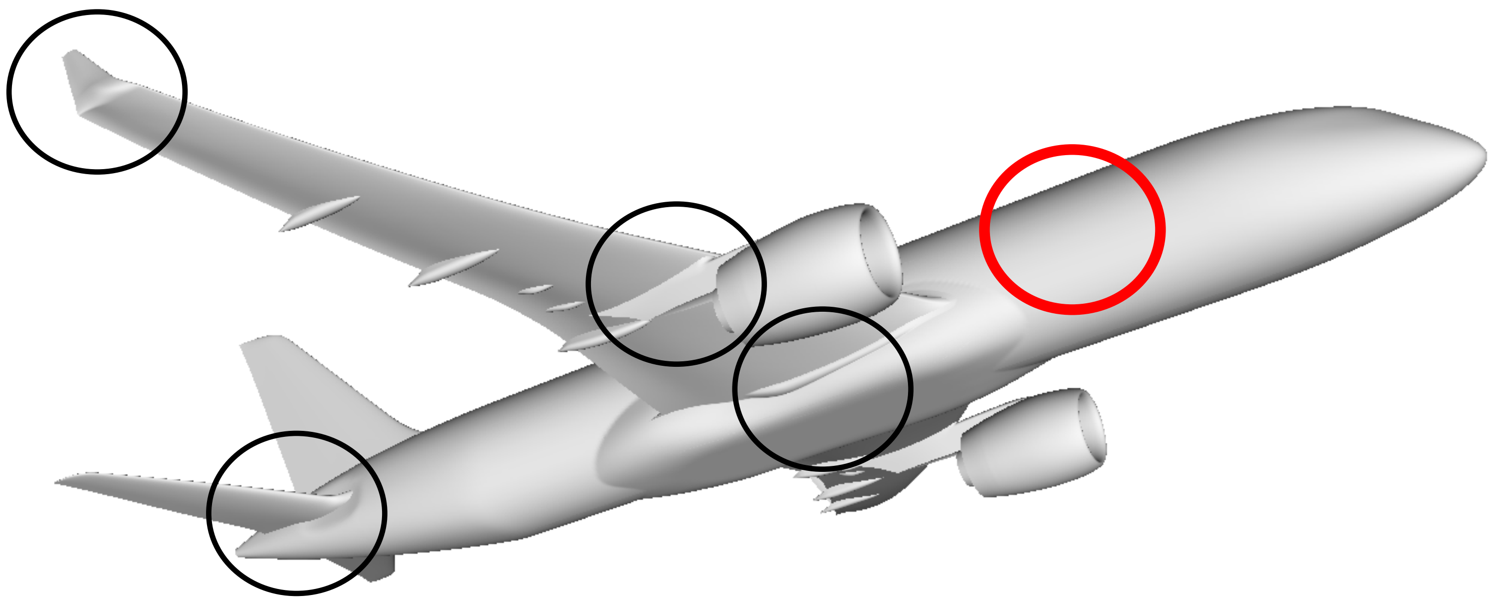
Examples
Strut/Nacelle Model Variations



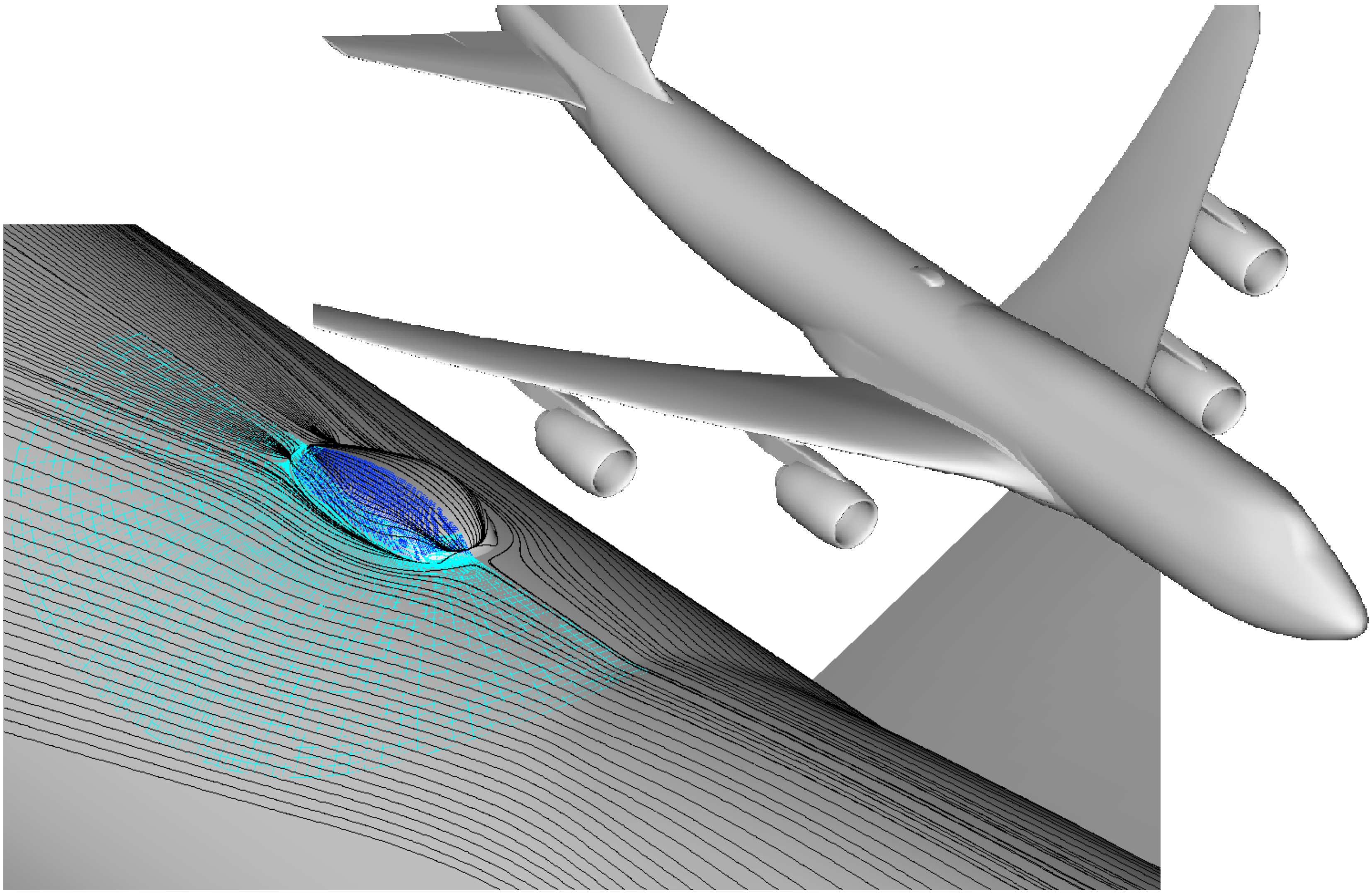
Increasing Level of SN Model Detail



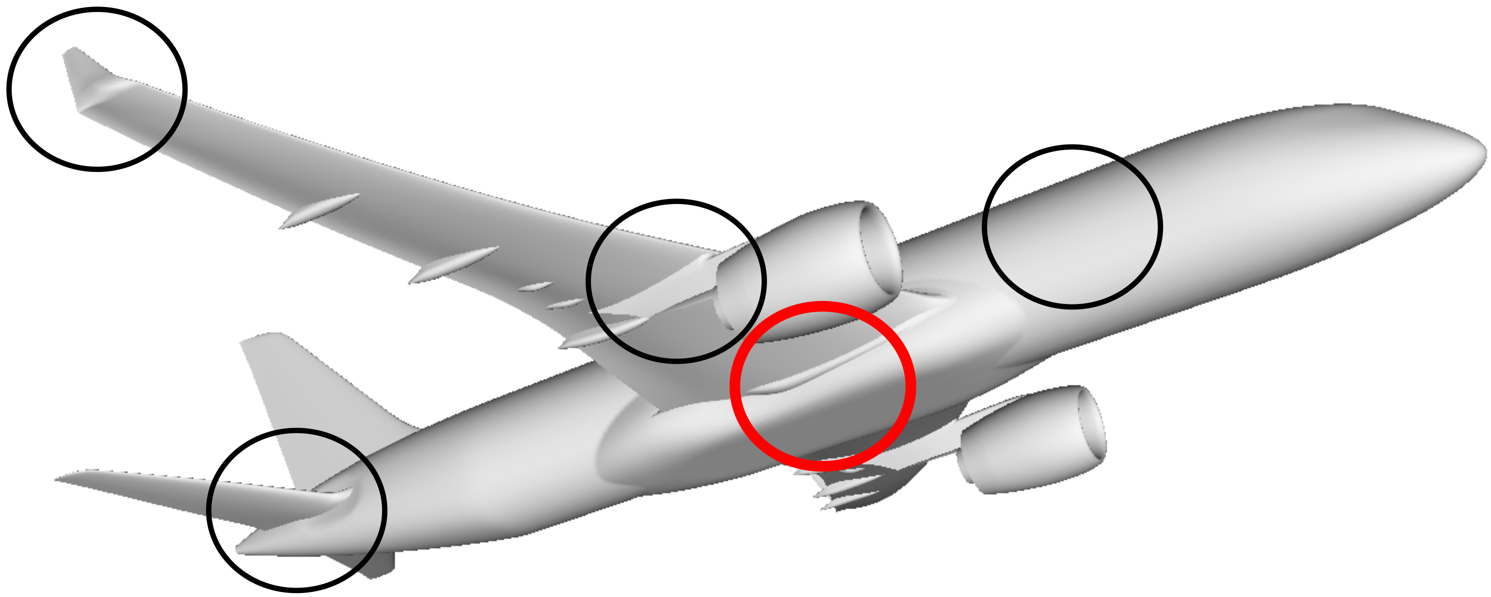
Examples
Blister Fairing Additions



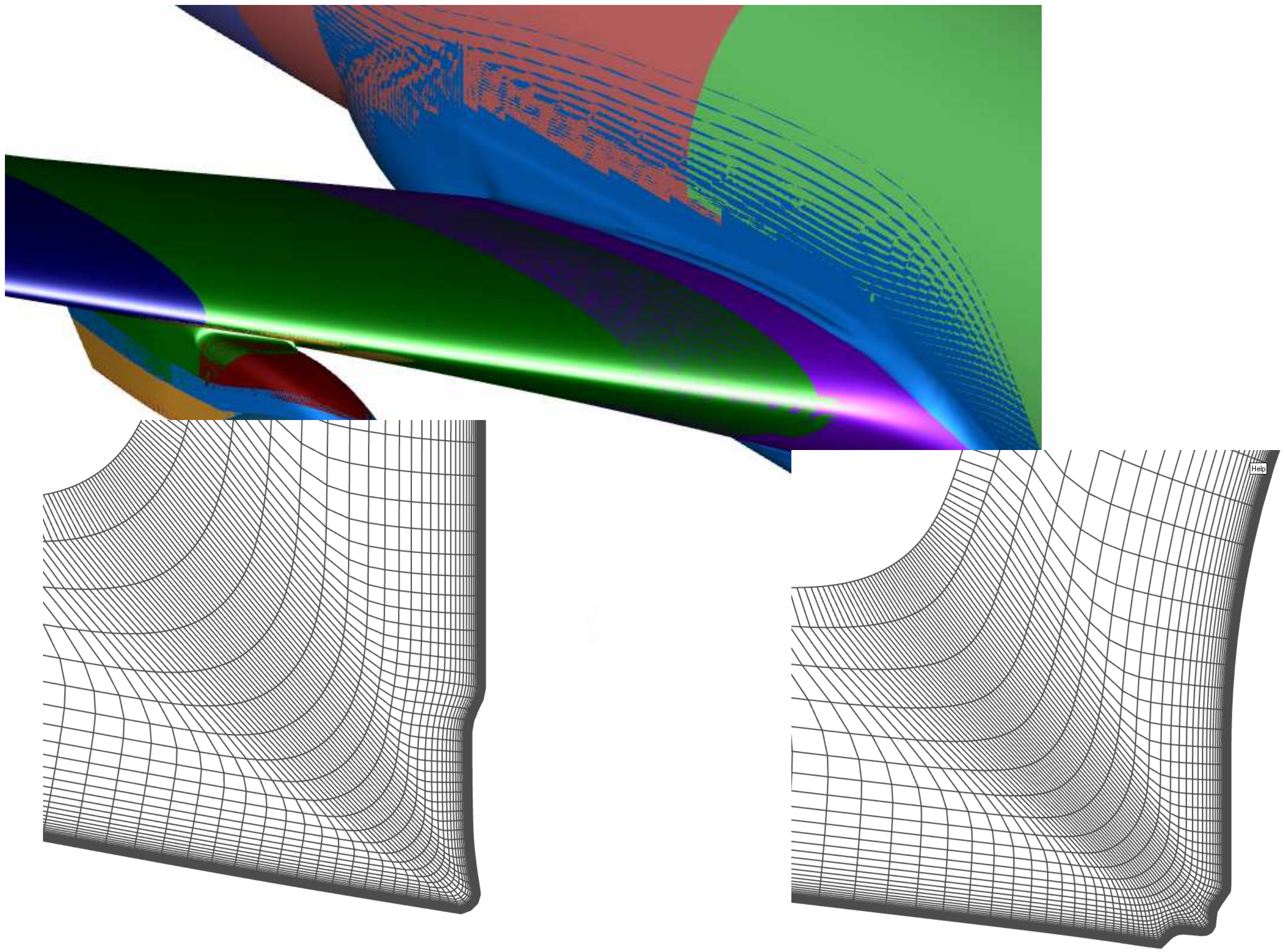
Antenna Fairing
Added to existing model



Examples
Wing/Body Juncture Modeling

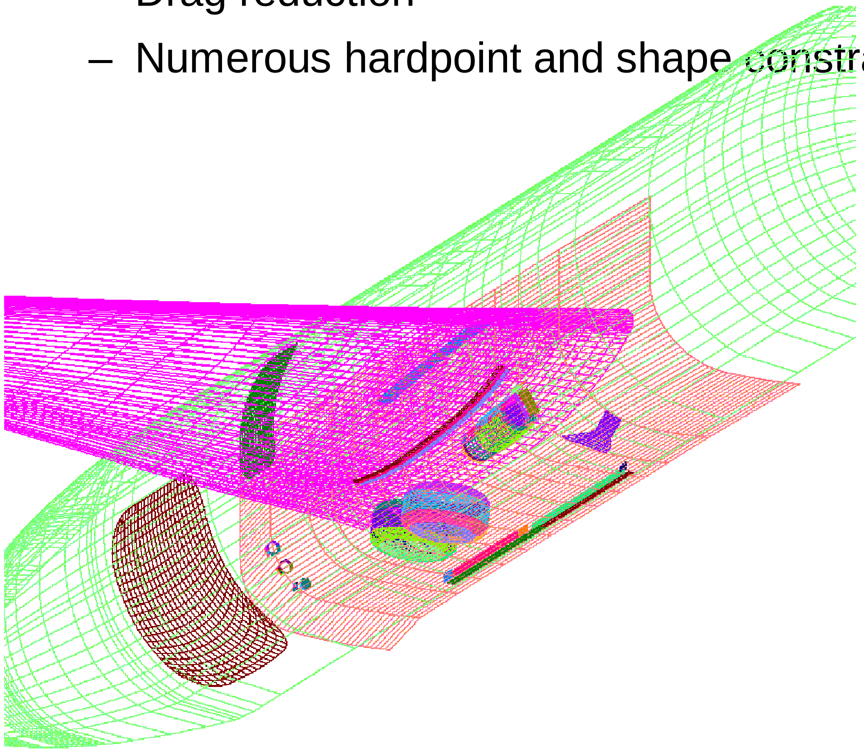


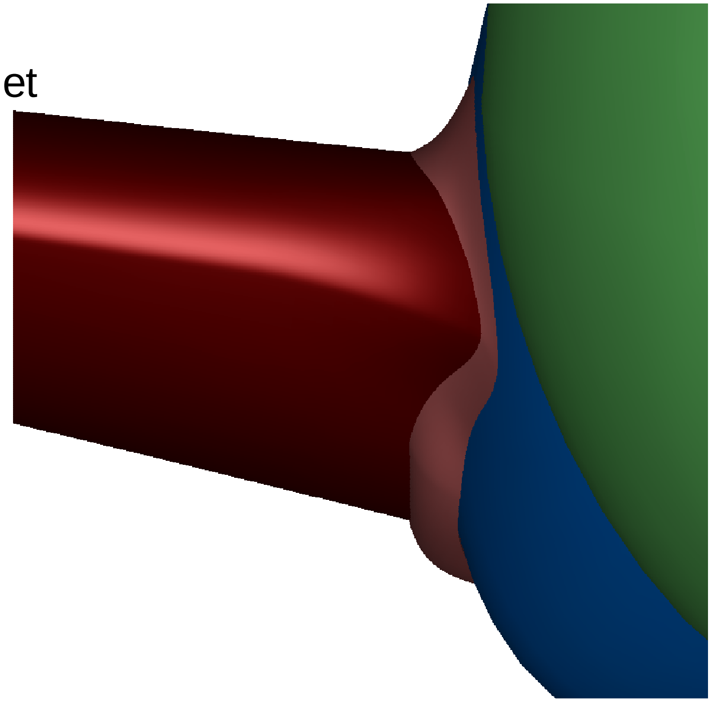
Typical Fillet/Bolt-Cover and Collar Volume Grid



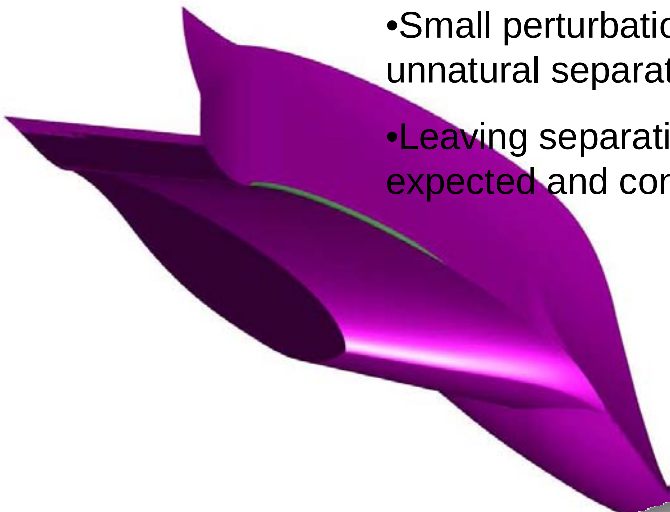
N-S Based Shape Optimization

- N-S process/accuracy level ready for analysis and design
- Numerical optimization of side-of-body geometry (MDOPT: response surface)
- Several optimizations and wind tunnel tests
  - Drag reduction
  - Numerous hardpoint and shape constraints met



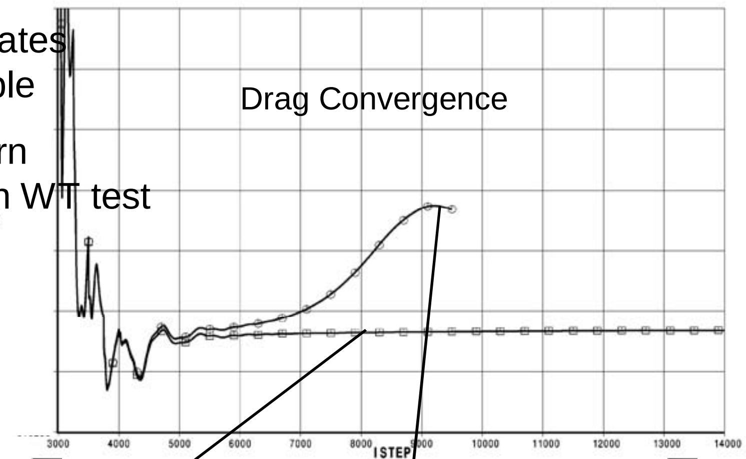


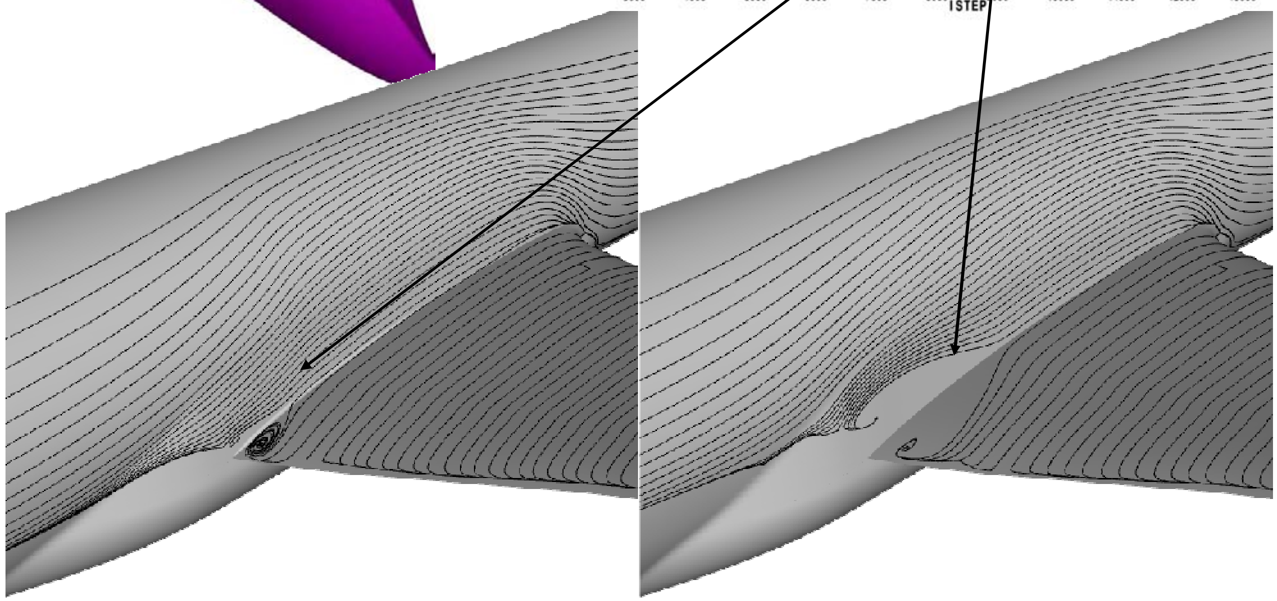
Wing/Body Juncture Divergent Solution



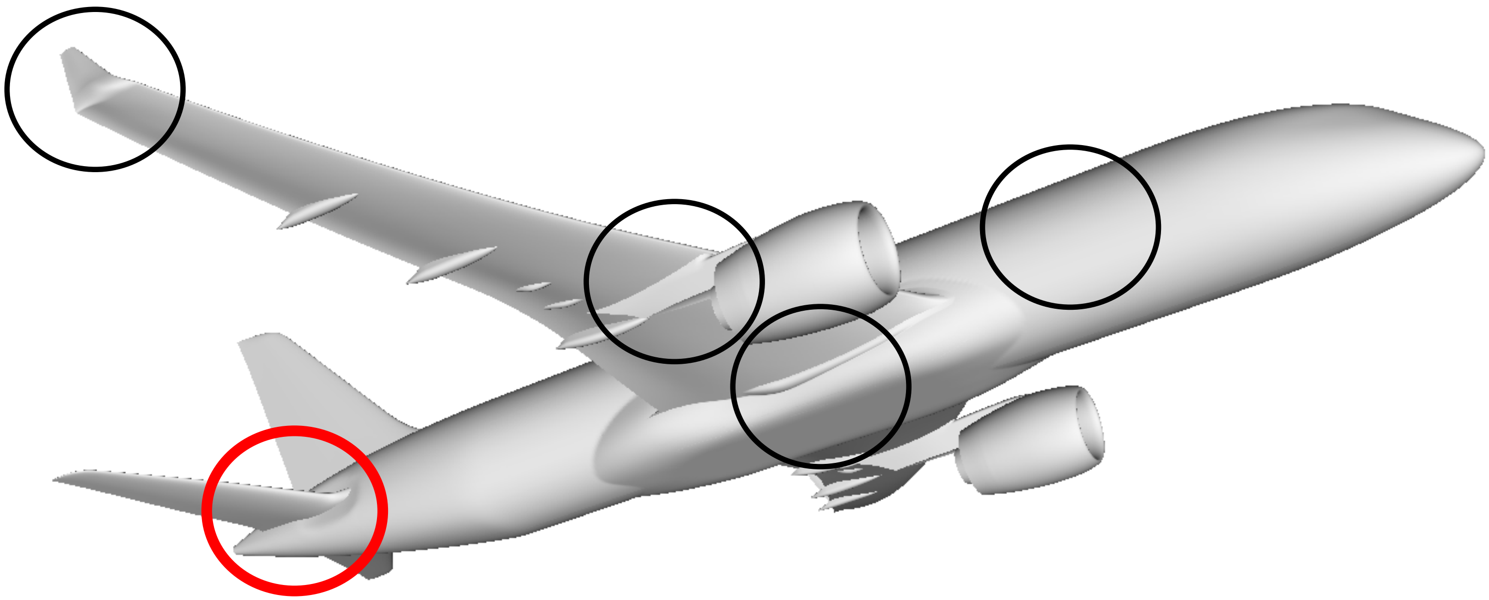
•Small perturbation eliminates unnatural separation bubble

•Leaving separation pattern expected and confirmed in WT test

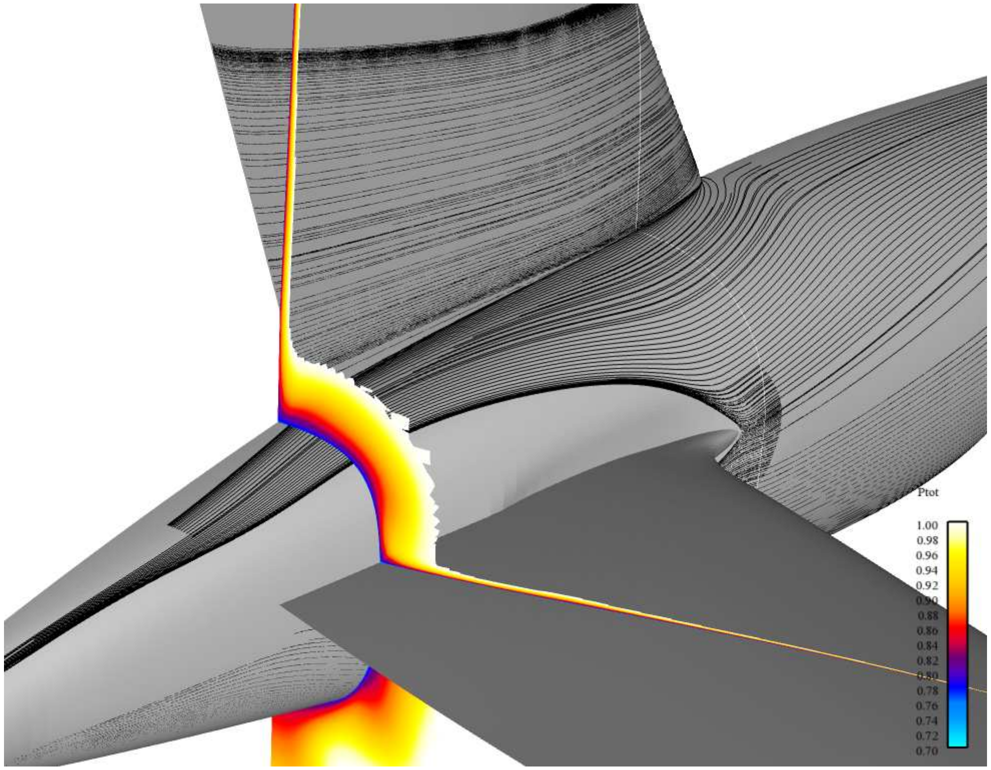


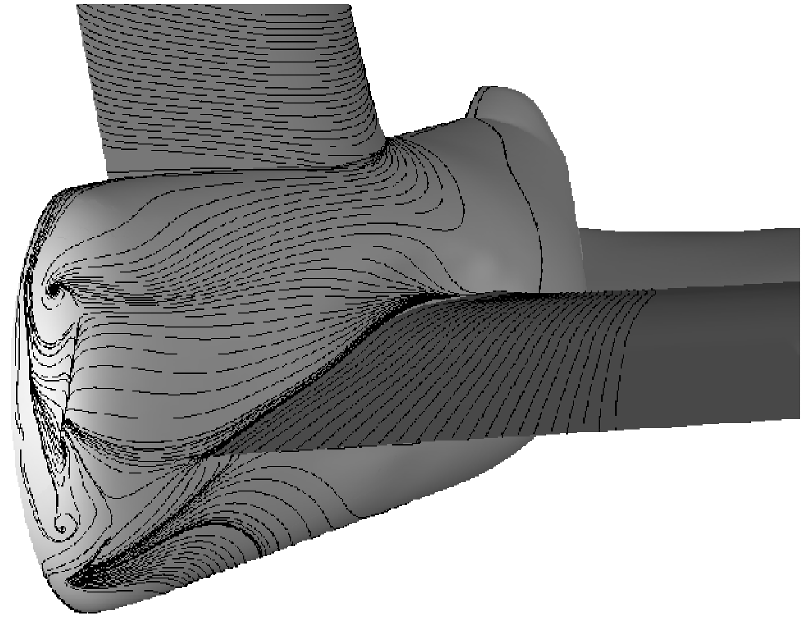


Examples
Empennage; Tail Movement for Trim



Viscous Flow Dominated Flowfields

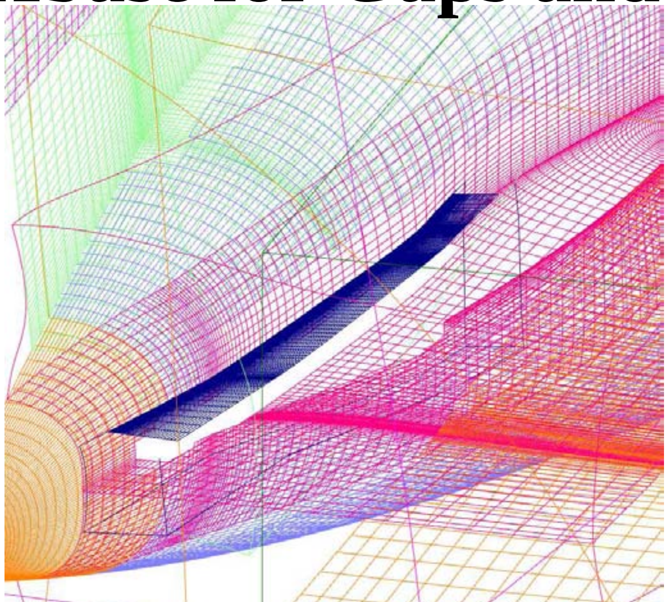


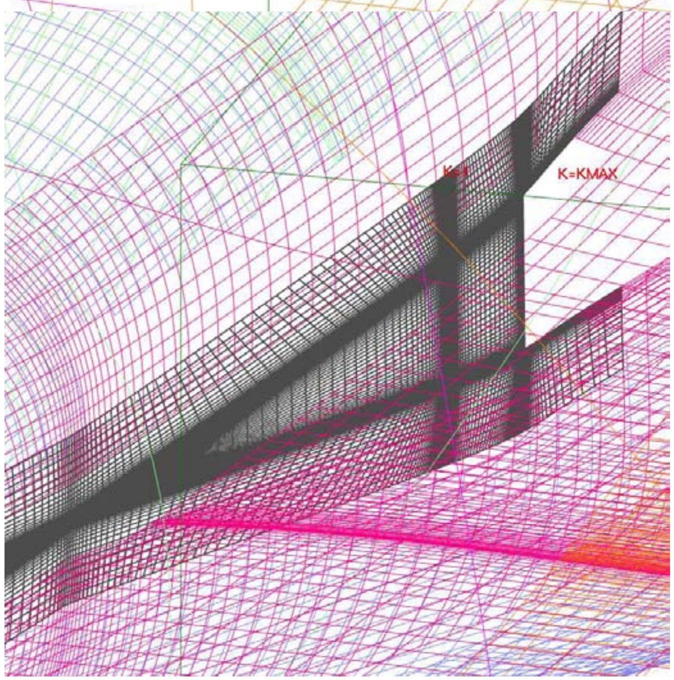


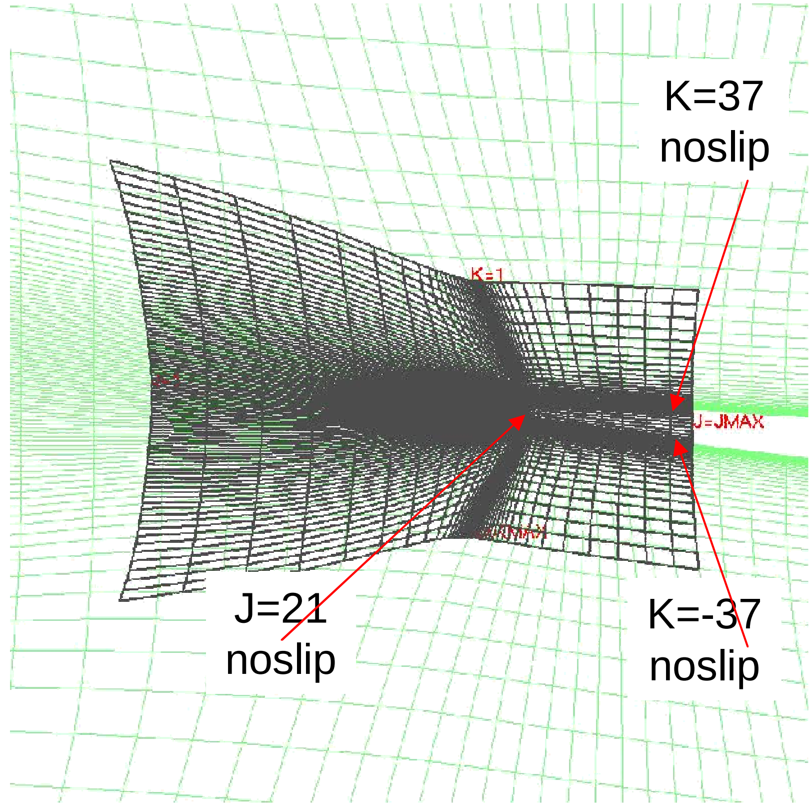
Separation on bluff base

Confluence of relatively large body BL and new BL on tail surfaces

Hbase for Gaps and Blunt trailing edges

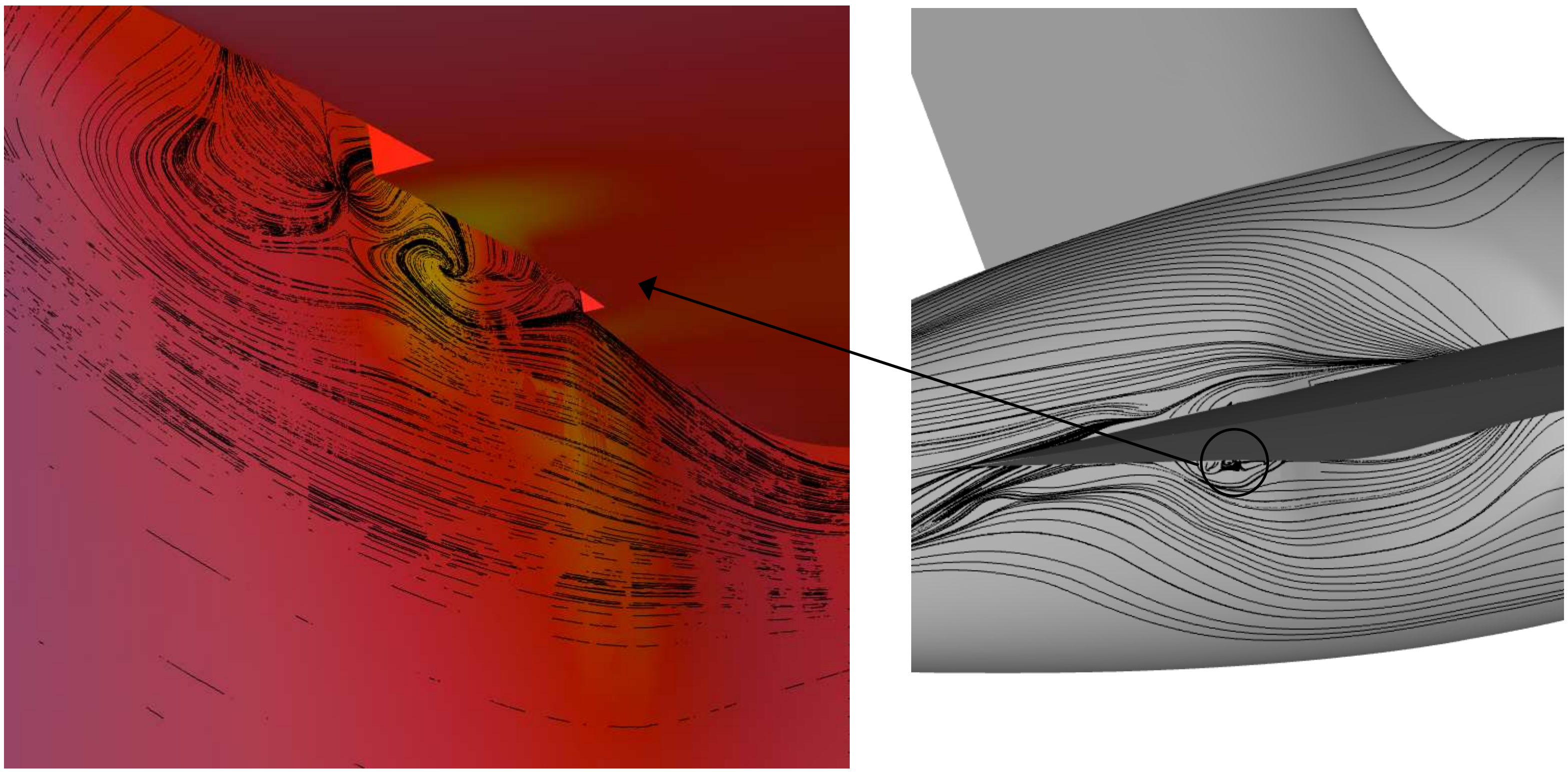




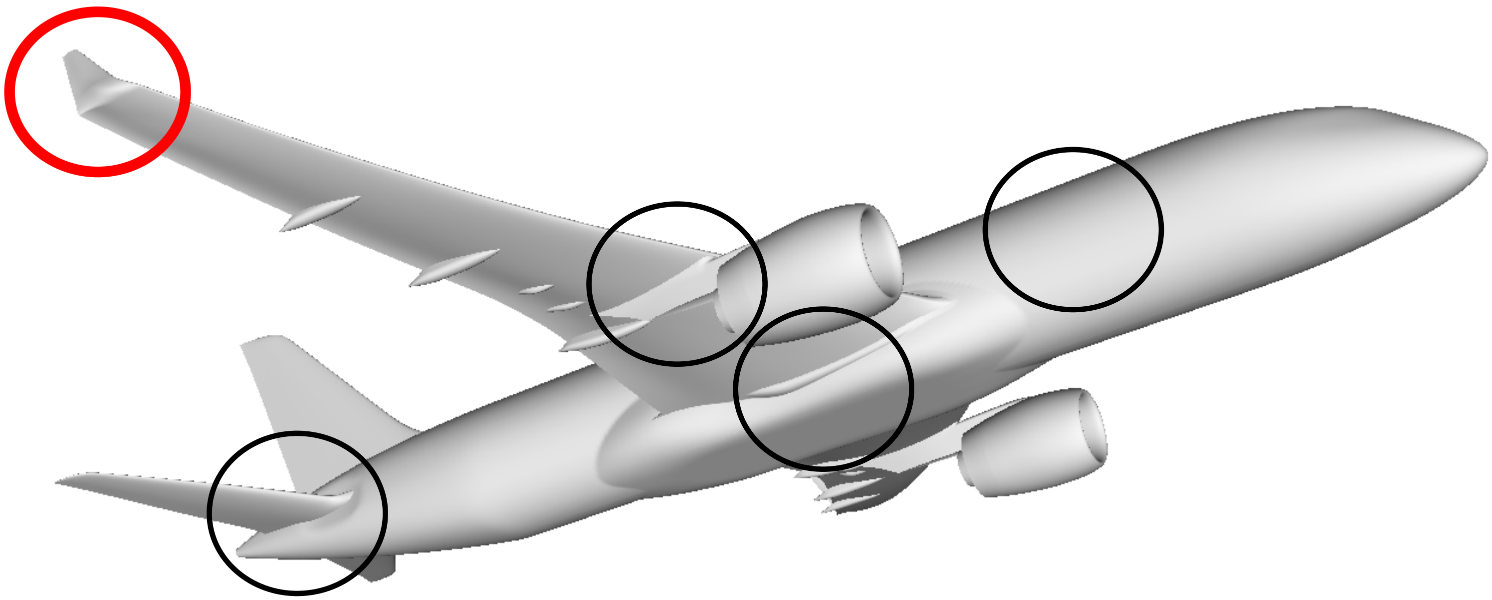


Internal no-slip surface BC's

Side-of-Body Gap Flow with Hbase Grid



Examples
Winglet Juncture Flow



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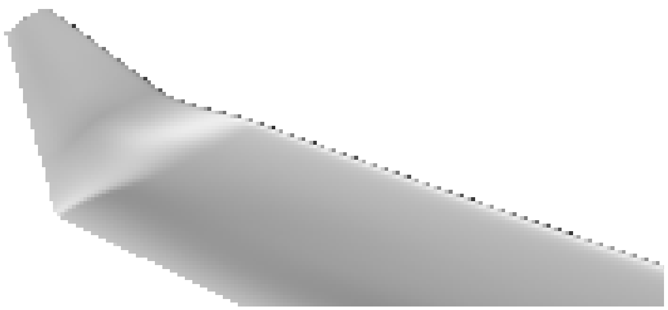
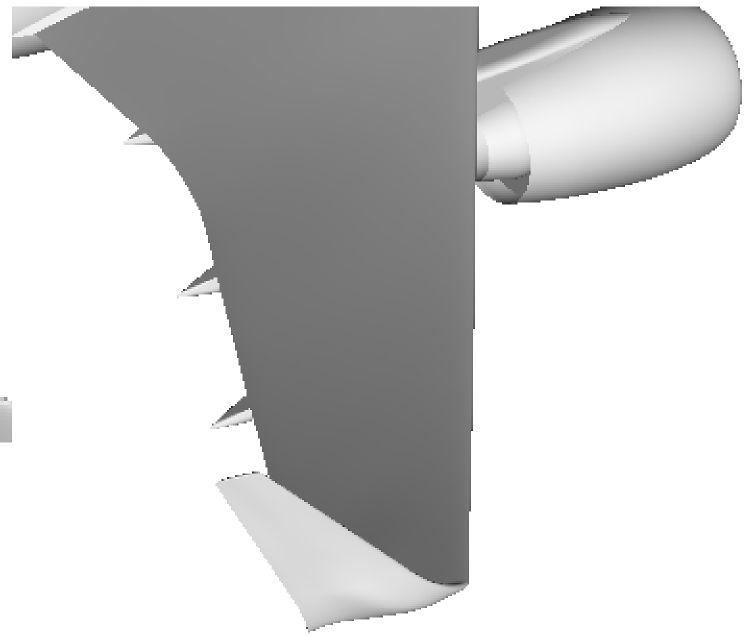
N-S Based Optimization of Winglet

- Overflow-MDOPT design space with a wide range of junction geometries (56 Design variables)
- N-S based design able to approach theoretical aero optimum tight juncture





Conclusion

- Overflow very productive tool for product development high-speed aero analysis and design
  - Structured grid currently best for consistent drag results
    - Drag Reduction; Risk Reduction (Flight Re# Simulation)

- Accelerate transition to Overflow2 in 2011
  - New O21 capability testing successful

- Issues and potential enhancements
  - Fan face BC controls mass flow without imposing Pconstant
  - Tail movement for trim during solution
  - Pegasus Level2 algorithm