

DEMONSTRATION OF AUTOMATICALLY GENERATED STRUCTURED OVERSET MESH CAPABILITY IN PRODUCING QUALITY COMPUTATIONAL SOLUTIONS

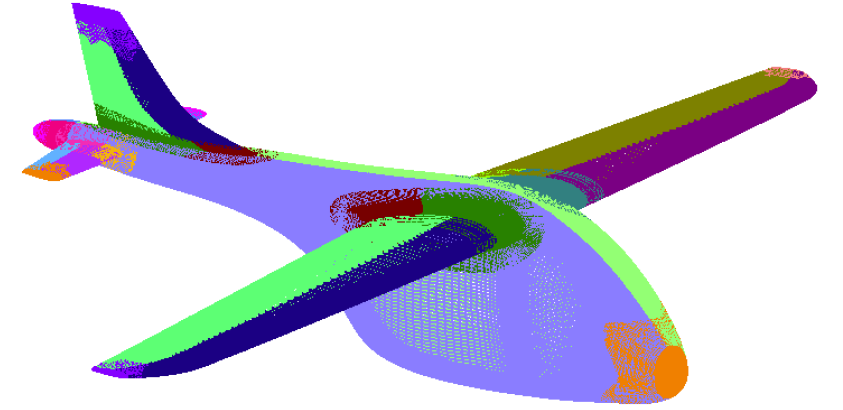
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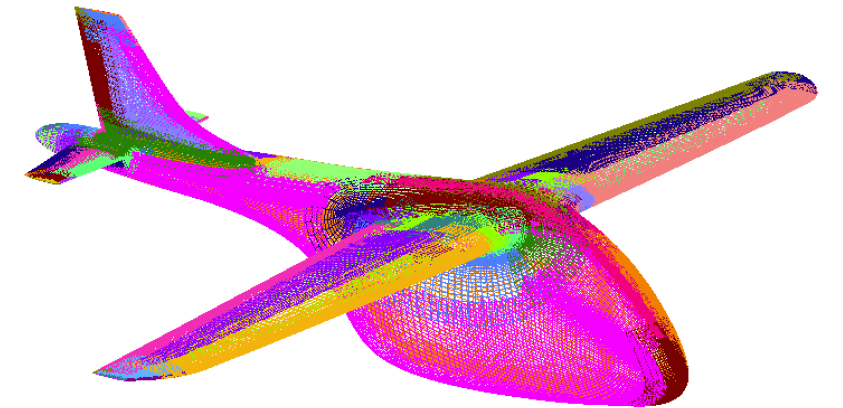
15th Overset Symposium, November 1-3, 2022 in Suffolk, VA

OUTLINE

- Motivation and objectives
- Auto-mesh vs. manual-mesh generation procedure
 - Lift+Cruise (L+C) no-pylons, no-gears configuration
- Overflow solution comparisons
- Summary and next steps



Manual



Automatic

MOTIVATION

- Urban Air Mobility research has matured significantly
- Many design problems
 - What is a right type of aircraft
 - What are the requirements they need to be optimized for
 - Often high-fidelity tools are needed to analyze a large variety of concept vehicles to get critical answers



MOTIVATION AND OBJECTIVES

- Structured overset viscous flow solvers are highly accurate and efficient compared to other methods
- Overset mesh generation requires significant user expertise, effort, time (weeks/months)
- NASA's RVLT project is motivated to streamline the design process and reduce the analysis cycle time



Recent Publications

Chan, W. M., Pandya, S. A., Chuen, A. M., Automation of Overset Structured Mesh Generation on Boundary Representation Geometries, AIAA Paper 2022-3607, Aviation Forum, 2022.

Chuen, A. M., Chan, W. M., Overlap Preservation Using Loosely-Coupled Boundary Conditions for Body-Fitted Structured Overset Grids, AIAA Paper 2022-0216, Sci-Tech Forum, 2022.

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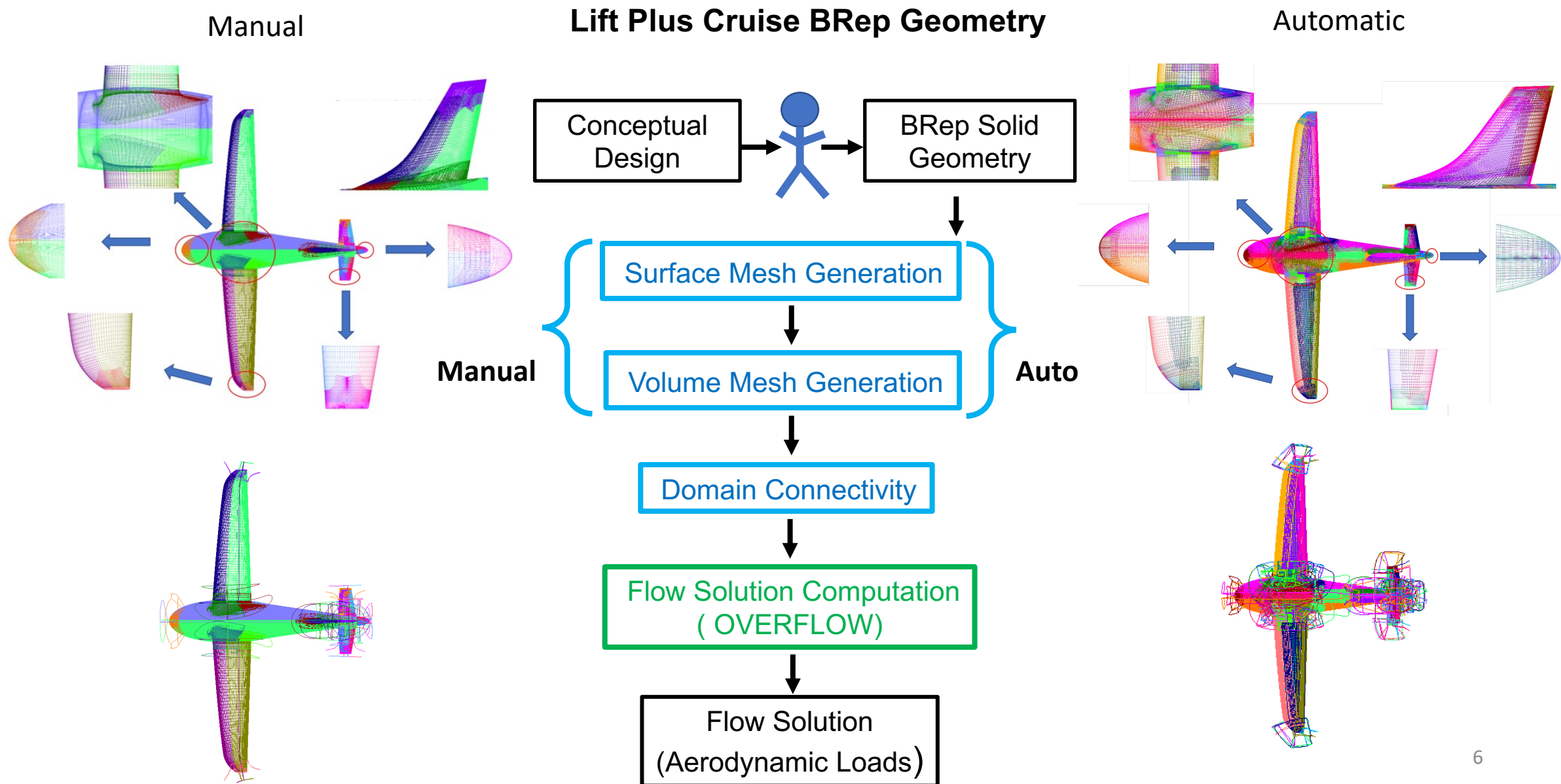
As part of this effort: we are working on developing and demonstrating automation tools to reduce human effort needed for overset mesh generation

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STRUCTURED OVERSET MESH GENERATION PROCEDURE (1)

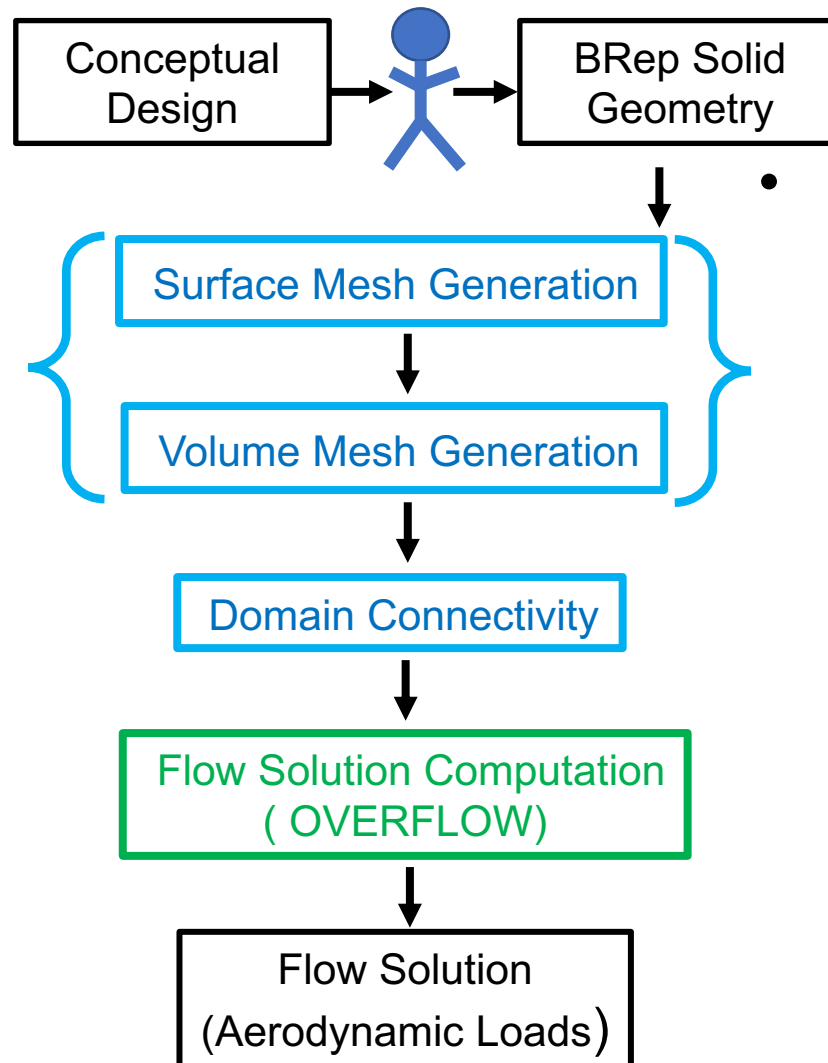


STRUCTURED OVERSET MESH GENERATION PROCEDURE (2)

Manual Mesh

- 31 Surface grids
 - 3-4 weeks
- 31 Near-body volume grids
 - < ~ a day

Manual effort ~ weeks



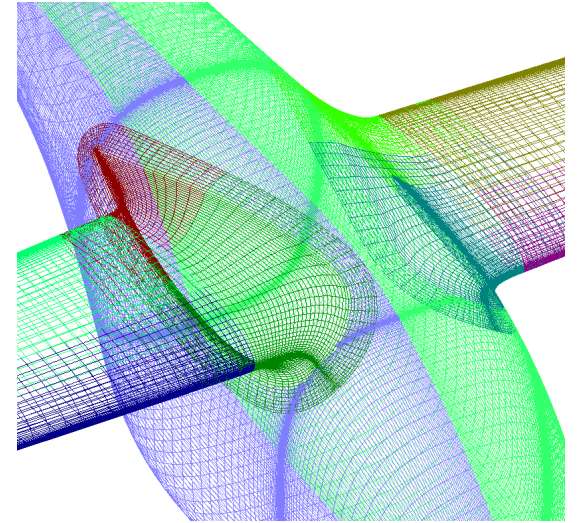
Hybrid Auto-mesh

- 102 Surface grids and 102 near-body volume grids
 - 100% auto generated
 - 92% auto generated
 - ~ 5 minutes
 - 8% manually repaired
 - ~ 60 minutes
 - ~ 4 hours (LCBC)

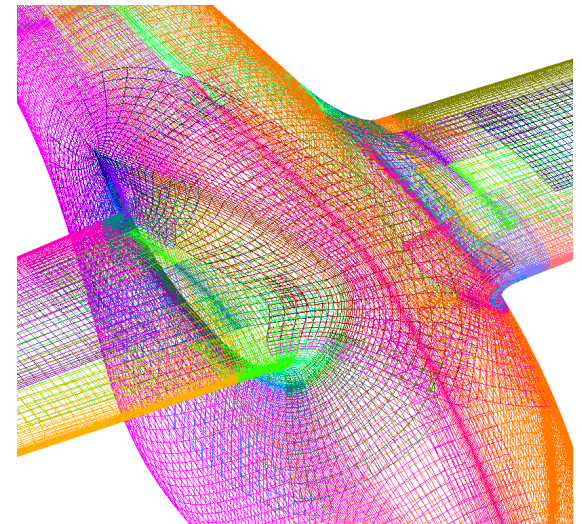
Manual effort ~ a day

GRID CONNECTIVITY

- The current automation software does not include auto-grid connectivity yet
- Manual X-ray maps and hole-cut instructions for both auto and manual meshes
- Same X-ray maps were created for both auto and manual meshes
- Hole cutting instructions were customized for each grid set
- This effort was similar for both cases and took a few days

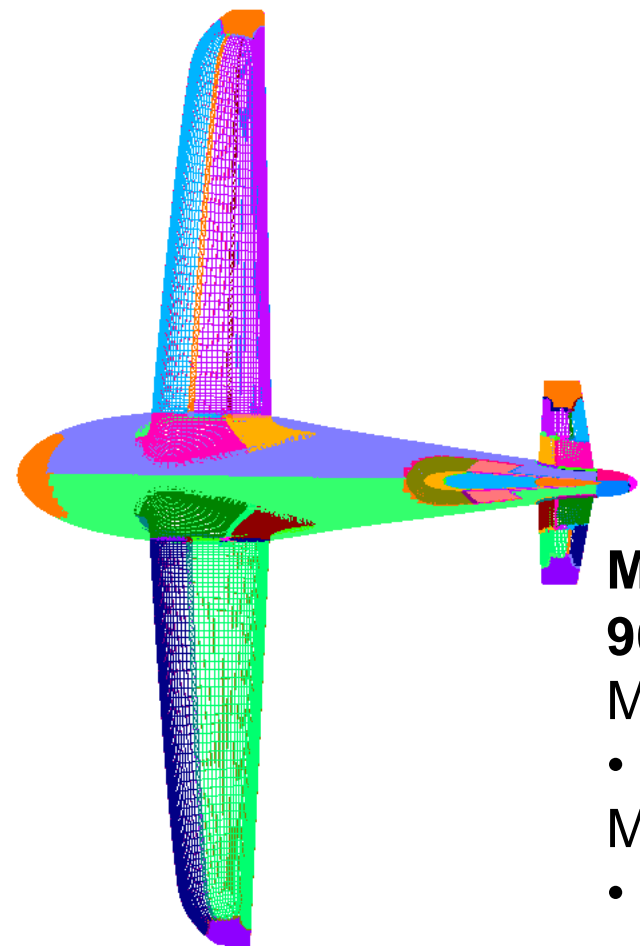


Manual Mesh



Auto Mesh

HYBRID MESH (FOMOCO) INTEGRATION SURFACE

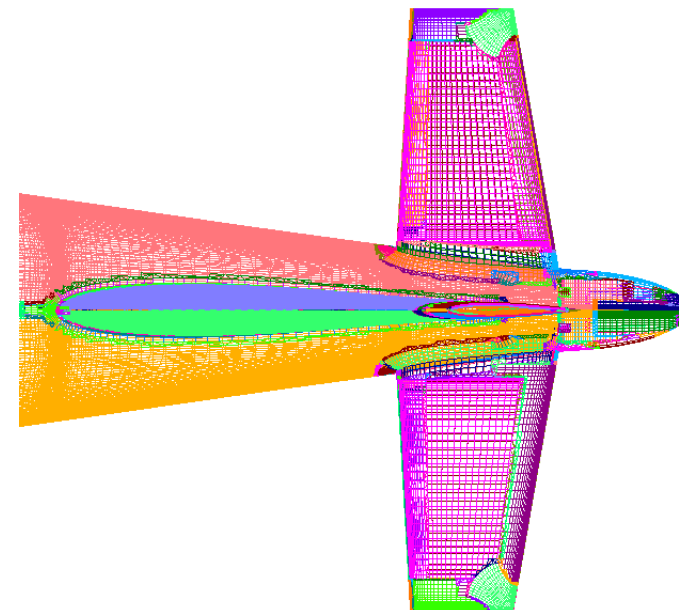
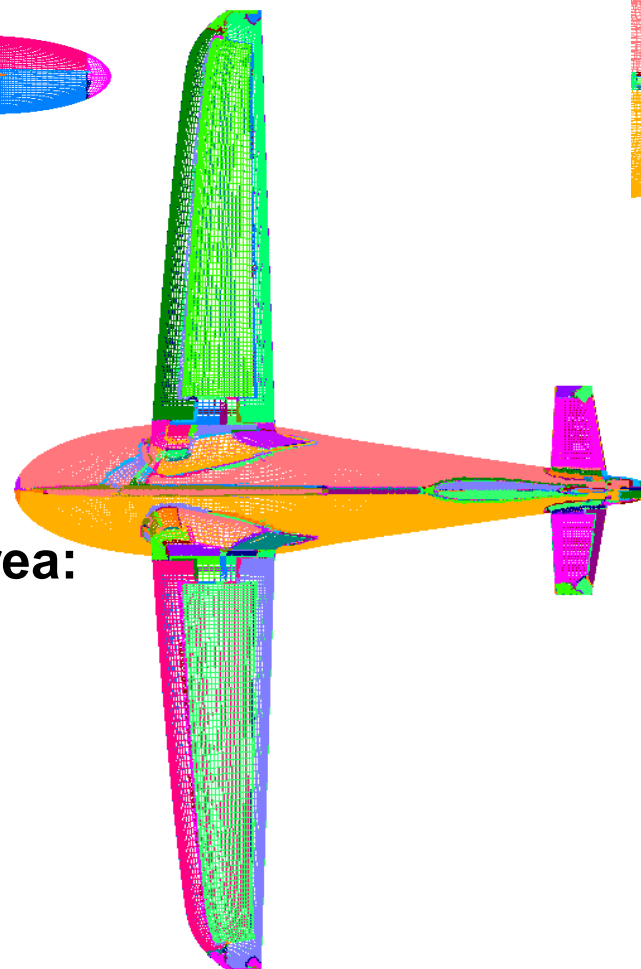
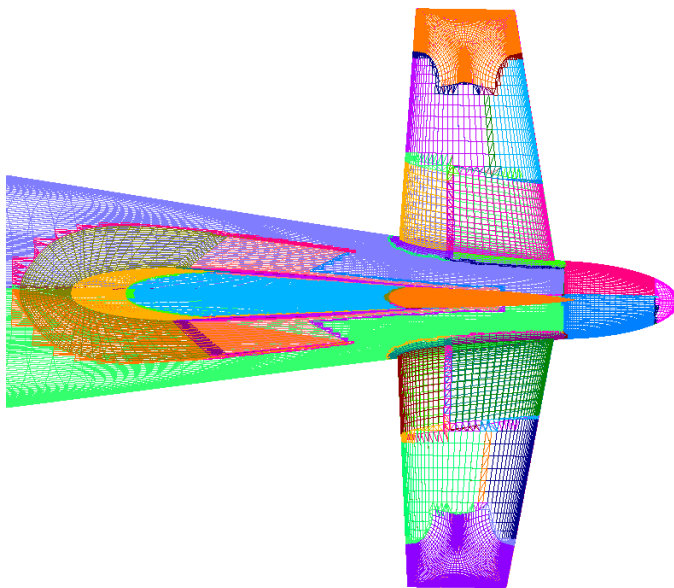


Manual-mesh surface area:
963.98 [ft^2]
Manually generated

- ~30 minutes

Manual iterations

- ~30 minutes



Auto-mesh surface area:
961.32 [ft^2]
Mostly auto generated

- < 5 minutes

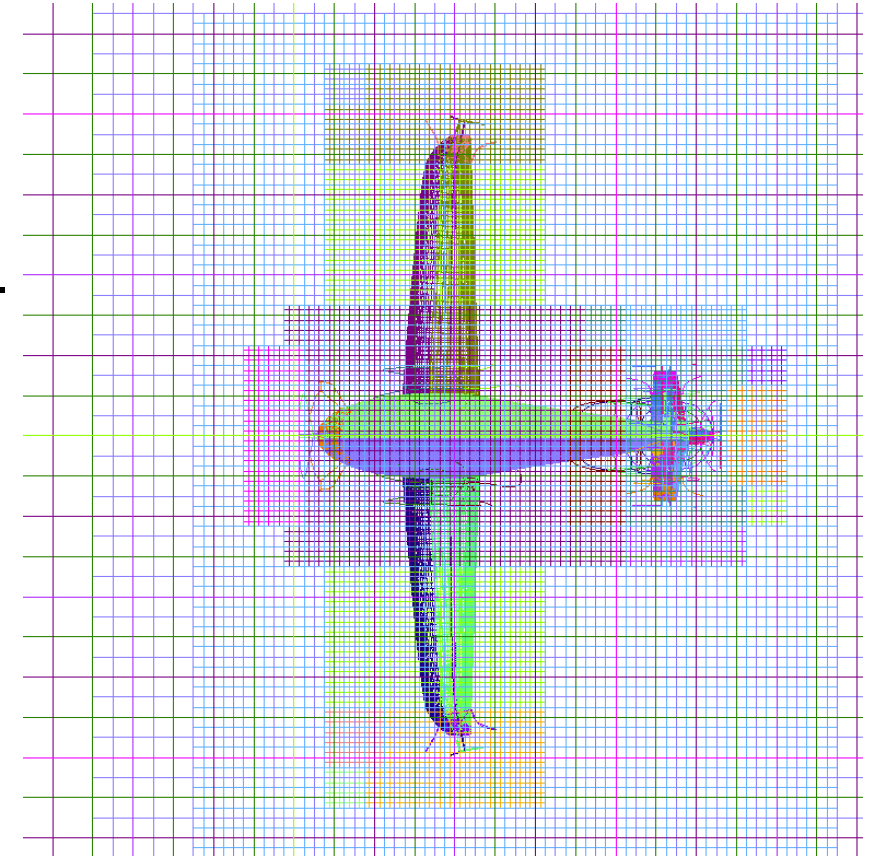
Manual iterations

- ~3hrs (fix gaps in hybrid mesh due to excessive overlap in some areas)

OVERFLOW SETUP

RANS OVERFLOW-D MODE

- Off-body grids grow 10 fuselage lengths out
 - Roe upwind scheme and Improved SSOR (with sub-iterations)
 - SA-neg with both RC and QCR2000 corrections
 - 72 Haswell CPUs
 - 20,000 steps
 - Flow Conditions
 - $U_{inf} = 80 \text{ knots}$
 - Altitude = 5,000 ft
 - AOA = 0 deg.
- Mach = 0.123
REY = 760,461



EFFECTS OF MPI SPLITTING IN OVERFLOW

Mesh	Prior to MPI splitting				After MPI splitting			
	# Near-body Grids	# Off-body Grids	Total # Grids	Total # Grids Points	# Near-body Grids	# Off-body Grids	Total # Grids	Total # Grids Points
Manual	31	102	133	12.3M	188	105	293	14.6M
Auto	102	90	192	12.3M	218	93	311	13.8M

Total number of grids is higher for auto-mesh:
 Prior to MPI splitting: ~44%
 Post-splitting: ~ 6%

MESH STATISTICS

RANS OVERFLOW-D MODE: 2.3c version

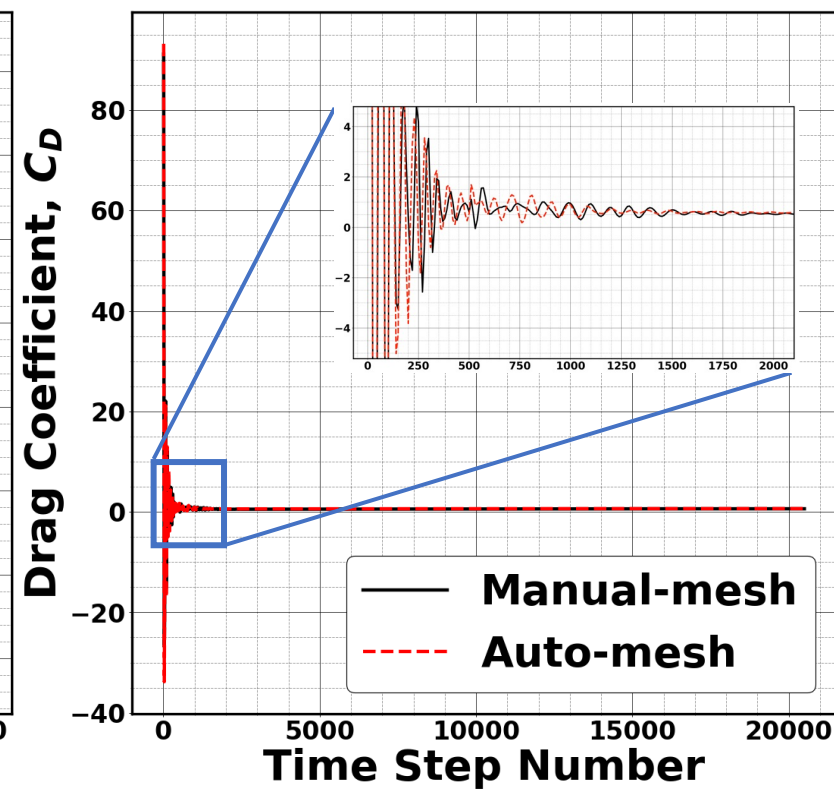
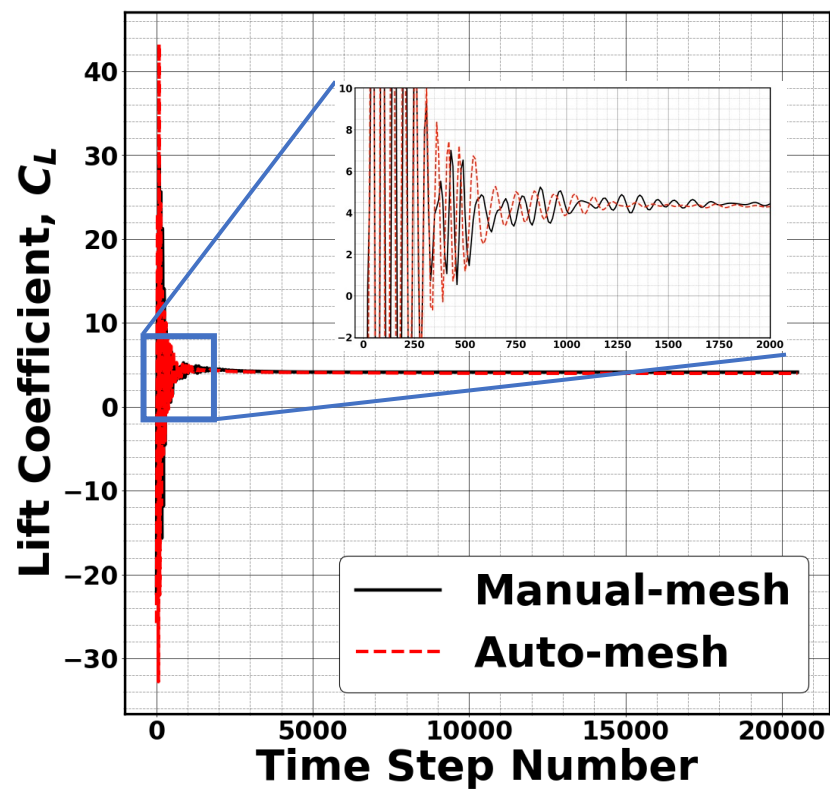
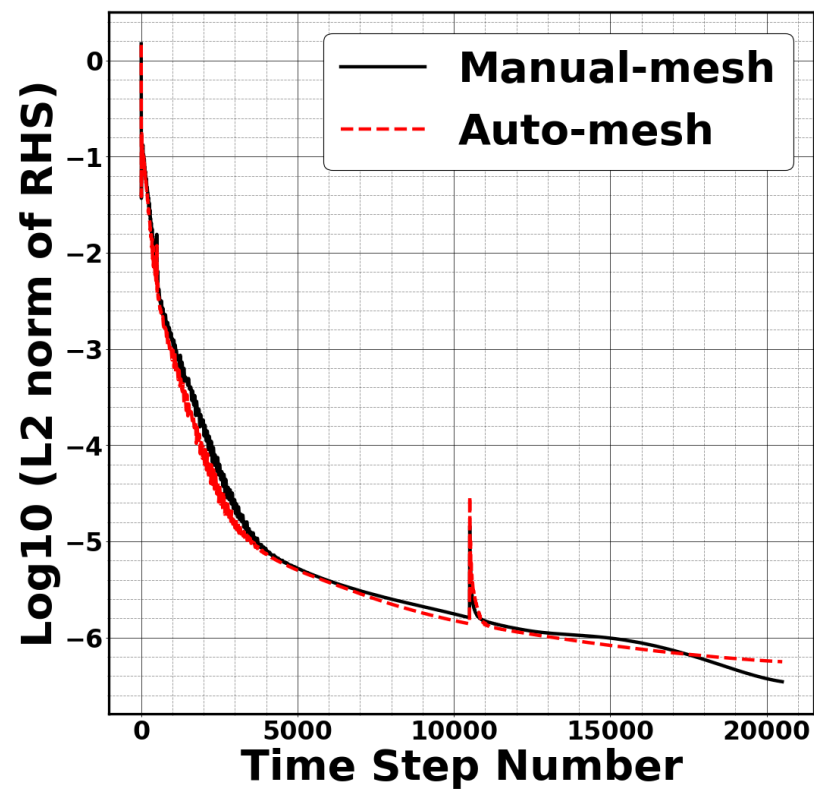
Mesh	Blanked points	Fringe points	Wall-clock time, 20,000 steps	Parallel-efficiency	Inter-grid communication time	Inter-grid communication time Time/Step
Manual 12.3M pts.	5.4%	15.9%				
Auto 12.3M pts.	6.4%	21.8%				
Difference	1%	5.9%				

MESH STATISTICS

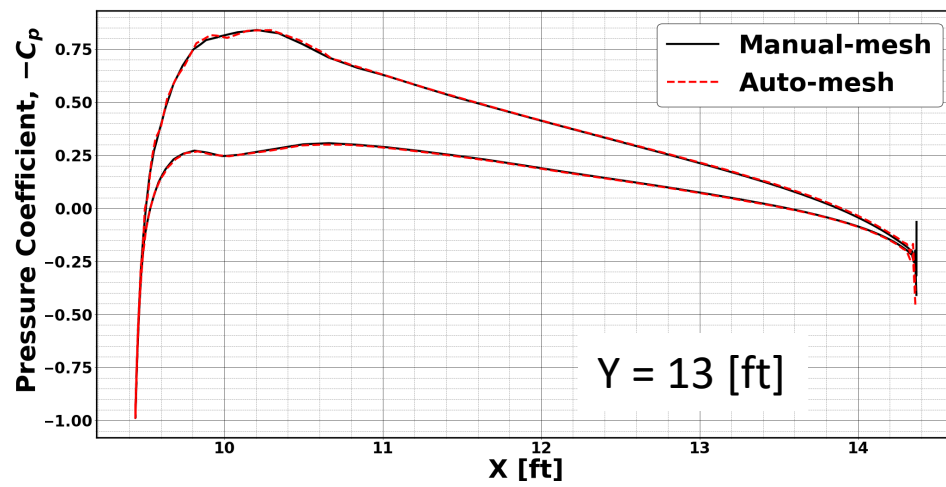
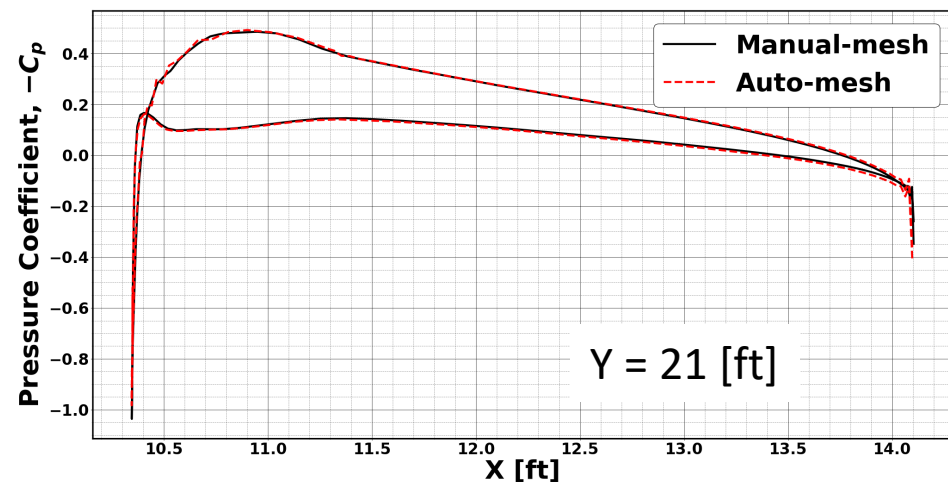
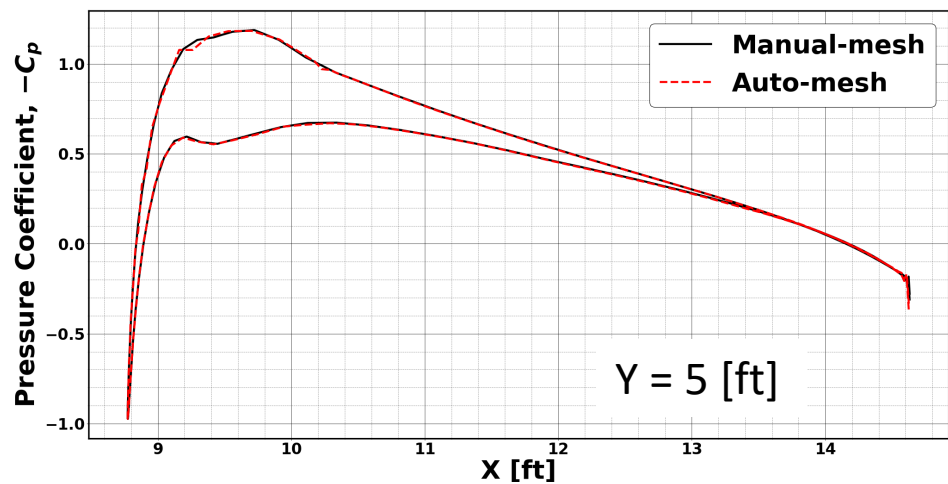
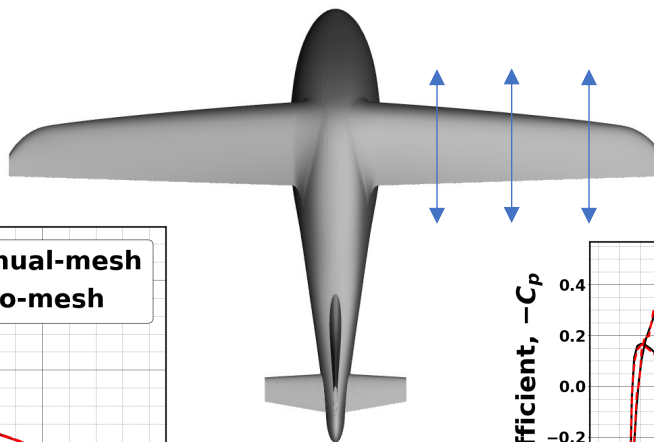
RANS OVERFLOW-D MODE: 2.3c version

Mesh	Blanked points	Fringe points	Wall-clock time, 20,000 steps	Parallel-efficiency	Inter-grid communication time	Inter-grid communication time Time/Step
Manual 12.3M pts.	5.4%	15.9%	6h15m	94.4%	1.77%	2.0019E-02
Auto 12.3M pts.	6.4%	21.8%	5h49m	94.9%	2.14%	2.2694E-02
Difference	1.0%	5.9%	26m	-	0.4%	13.4%

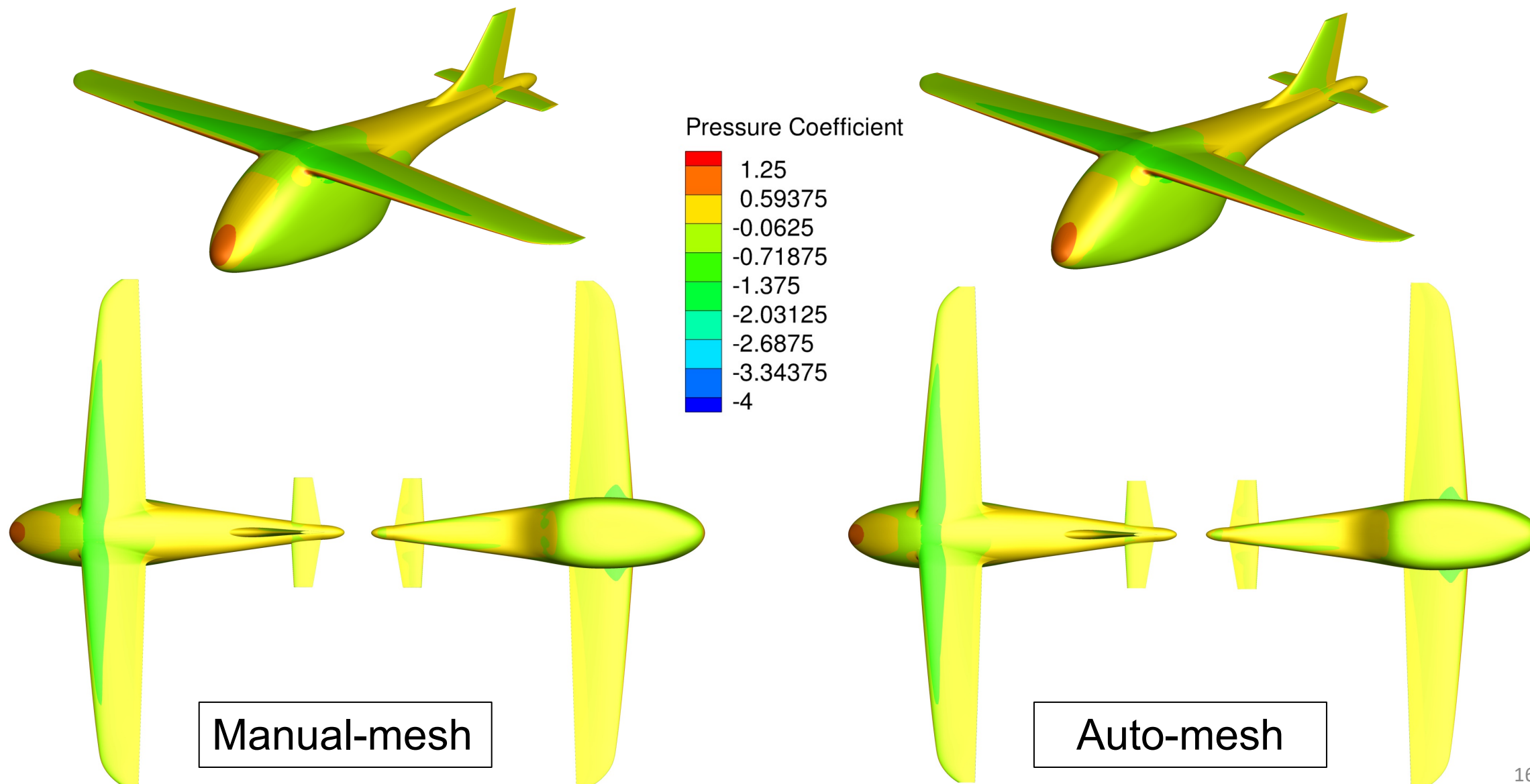
CONVERGENCE HISTORY



PRESSURE PROFILE COMPARISONS



CONVERGED SOLUTION SURFACE CP



MESH STATISTICS, CONVERGED LOADS AND RUN TIMES

RANS OVERFLOW-D MODE: 2.3c version

Mesh	C_L^*	C_D^*
Manual, 12.3M pts.	3.949	0.6207
Auto, 12.3M pts.	4.037	0.6453
Difference	2%	4%

*Reference length = 1.0 [m] = 3.3 [ft]
Reference area = 1.0 [m²] = 10.8 [ft²]

COMPONENT CONVERGED LOADS

C_L	Main body	Right Wing	Left Wing	Right Htail	Left Htail	Vertical Tail	Total
Manual Mesh	-1.247	2.533	2.535	0.062	0.069	-0.003	3.949
Auto Mesh	-1.292	2.588	2.595	0.067	0.082	-0.003	4.037
Δ	- 0.045	0.055	0.060	0.005	0.013	0.0	0.088

COMPONENT CONVERGED LOADS

C_D	Main body	Right Wing	Left Wing	Right Htail	Left Htail	Vertical Tail	Total
Manual Mesh	0.4838	0.0498	0.0496	0.0087	0.0082	0.0206	0.6207
Auto Mesh	0.4920	0.0586	0.0592	0.0072	0.0063	0.0220	0.6453
Δ	0.0082	0.0088	0.0096	-0.0015	-0.0019	0.0014	0.0246

MESH STATISTICS, CONVERGED LOADS AND RUN TIMES

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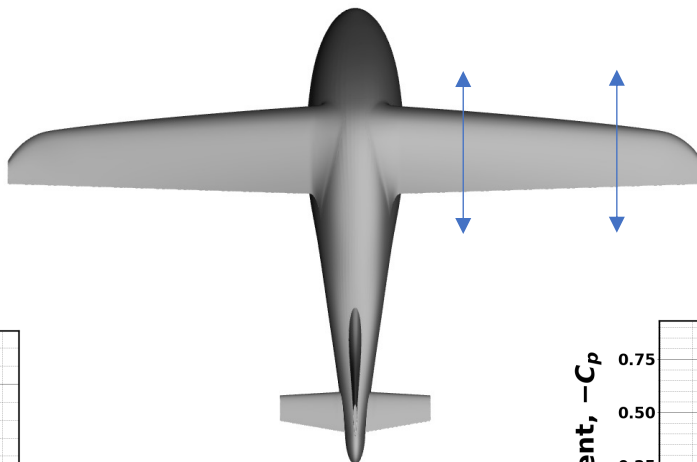
COMPARISON BETWEEN DIFFERENT SOLVER CHOICES

Variations due spatial discretization and implicit time-advancement.

- IRHS=4. Roe upwind
- IRHS = 0 Central differencing
- ILHS = 2 ARC3D diag. Beam-Warming scalar pent. scheme
- ILHS = 6 SSOR
- ILHS = 26 Improved SSOR
- Turbulence models:
 - SA SA-neg with both RC and QCR2000 corrections
 - SST with RC corrections

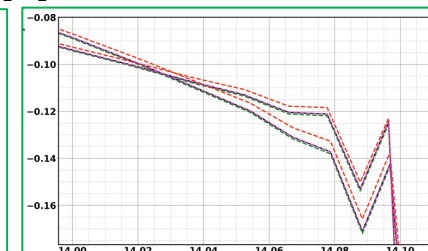
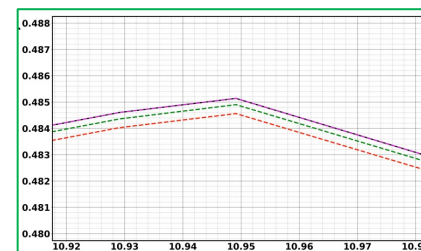
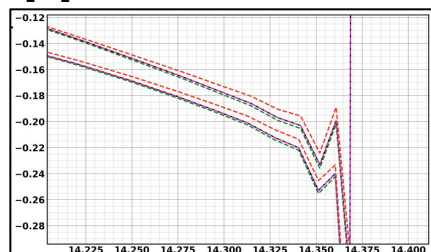
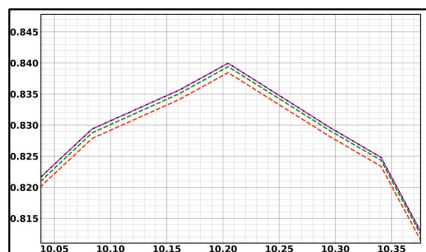
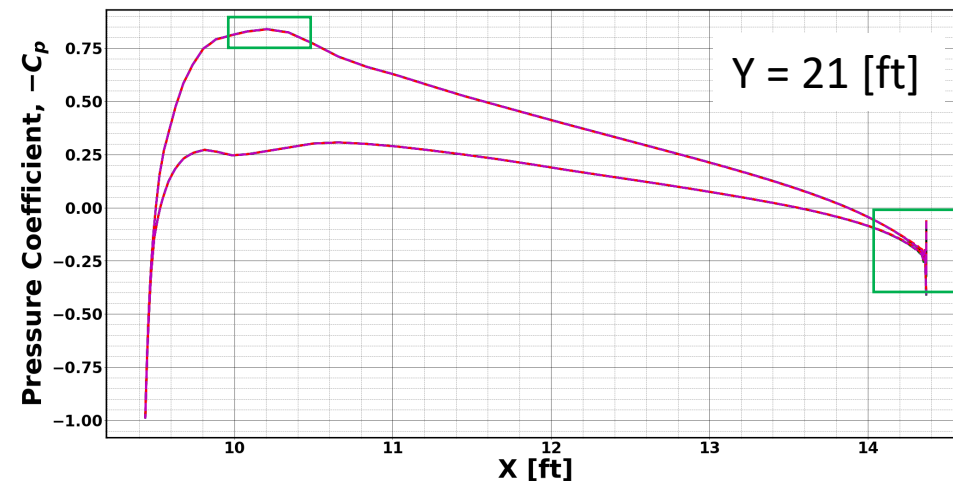
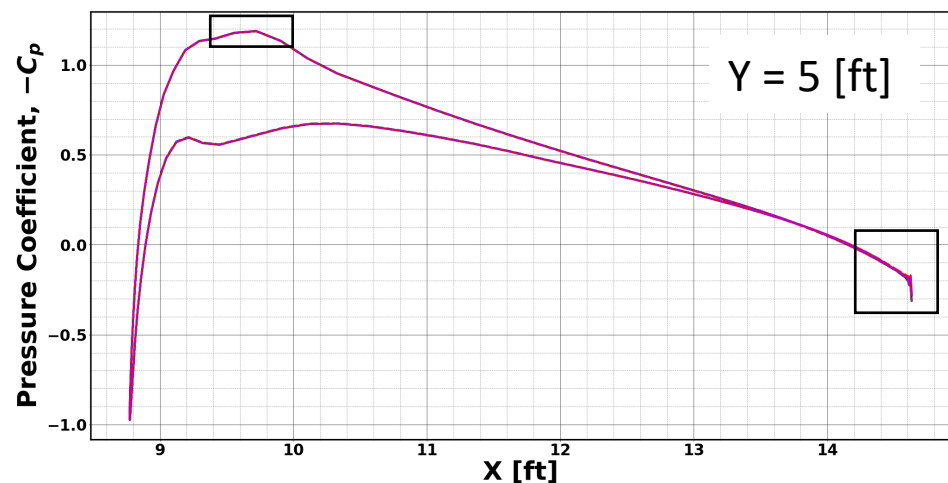
Manual Mesh	C_L	C_D
IRHS = 4, ILHS = 26, SA	3.949	0.6207
IRHS = 0, ILHS = 2, SA	4.220	0.6519
IRHS = 4, ILHS = 6, SA	3.949	0.5826
IRHS = 4, ILHS = 26, SST	3.905	0.6293
Difference	Up to 7%	Up to 6%
Auto Mesh		
IRHS = 4, ILHS = 26, SA	4.037	0.6453
Difference	2%	4%

PRESSURE PROFILE SOLVER COMPARISONS



— Manual-mesh, 2.3c, IRHS = 4, ILHS = 26, SA
 - - - Manual-mesh, 2.3c, IRHS = 4, ILHS = 6, SA
 - - - Manual-mesh, 2.3c, IRHS = 0, ILHS = 2, SA
 - - - Manual-mesh, 2.3c, IRHS = 4, ILHS = 26, SST
 - - - Manual-mesh, 2.4a, IRHS = 4, ILHS = 26, SA

— Manual-mesh, 2.3c, IRHS = 4, ILHS = 26, SA
 - - - Manual-mesh, 2.3c, IRHS = 4, ILHS = 6, SA
 - - - Manual-mesh, 2.3c, IRHS = 0, ILHS = 2, SA
 - - - Manual-mesh, 2.3c, IRHS = 4, ILHS = 26, SST
 - - - Manual-mesh, 2.4a, IRHS = 4, ILHS = 26, SA



CONCLUSIONS

- Demonstrated that automatically generated structured overset meshes were able to produce high-quality computational solutions.
- Auto-mesh produced similar converged OVERFLOW solutions to manual-meshes on the same geometry.
- The solution differences due to grid variations were similar to differences due to solver choices and turbulence models.
- No major computational overhead between manual and auto-mesh approach.
- Hybrid auto-mesh approach was significantly faster than manual meshing.
 - For this case, manual effort was reduced from weeks to days.
- Auto-mesh has potential to reduce concept vehicle analysis cycle time substantially.

NEXT STEPS

- Continue improving automatic mesh generation schemes/tools
 - Surface mesh
 - Implement projection to the analytical BRep geometry
 - Reduce regions of three or more mesh overlap
 - Volume mesh
 - Eliminate negative Jacobians
 - Grid connectivity
- Utilize current tools to analyze complete RVLT vehicles



ACKNOWLEDGMENTS

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Computational Resources

NASA Advanced Supercomputing (NAS) facility