NASA Ames Research Center Contribution to GMGW-1

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PID 02

1st AIAA Geometry and Mesh Generation Workshop
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Summary of Grids Generated

Case	Code(s)	Starting Geometry Model	Grid Type	Number Grid Levels
HL-CRM full gap	Chimera Grid Tools	STEP	Overset Structured	4
HL-CRM partially sealed	Chimera Grid Tools	STEP	Overset Structured	1

Chimera Grid Tools (CGT)

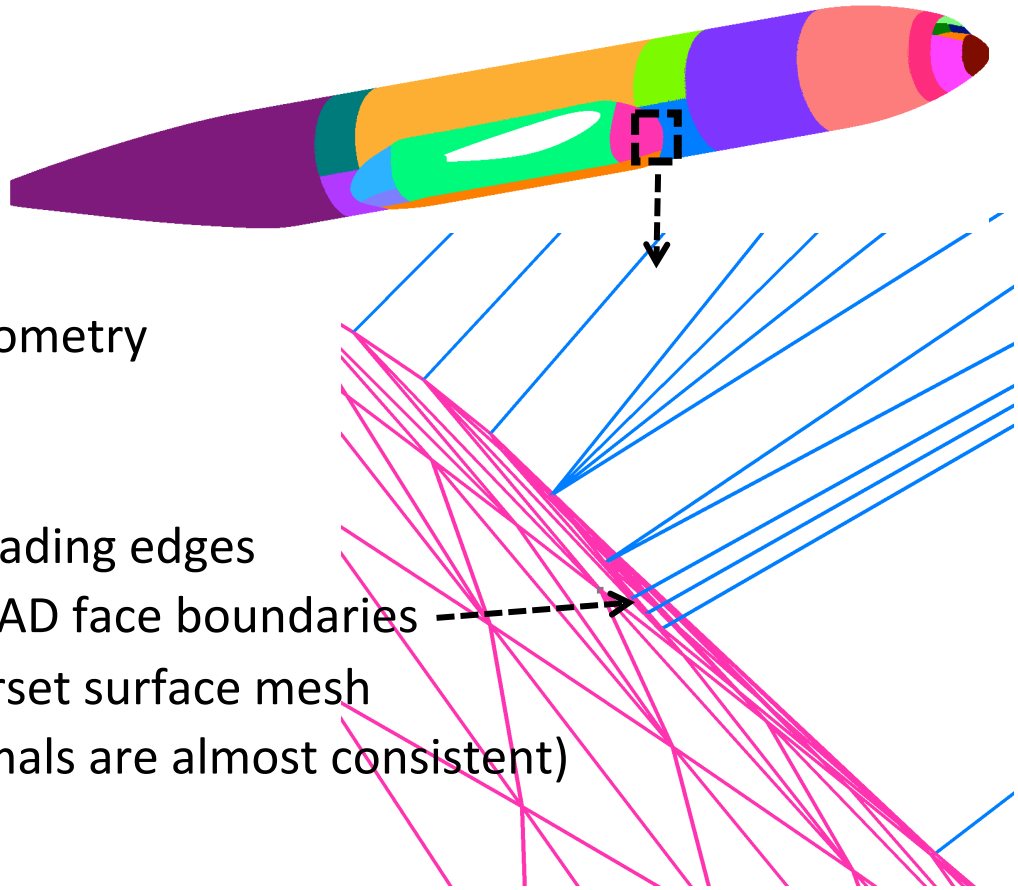
- A collection of software tools for pre- and post-processing of CFD simulation using structured overset grids
- Geometry/Grid Tools: geometry/grid processing, algebraic and hyperbolic surface and volume grid generation
- Analysis Tools: grid quality, aerodynamic loads, flow solution
- High Level Tools: OVERGRID graphical interface, Script Library (200+ macros)

Chan, W. M., Developments in Strategies and Software Tools for Overset Structured Grid Generation and Connectivity, AIAA 2011-3051.

Chan, W. M., Gomez, R. J., Rogers, S. E., Buning, P. G., Best Practices in Overset Grid Generation, AIAA 2002-3191

Geometry Import and Preparation

- Import STEP file into ANSA
  - Generate triangulation that accurately resolves geometry
  - Grid resolution in high curvature regions (leading edges) needs to be equal or higher than the structured surface grids to be generated



- No import difficulties
- No modifications performed on geometry
- Lessons learned
  - Introduce CAD edge along all leading edges
  - Be careful on tolerances near CAD face boundaries (does not affect structured overset surface mesh generation if local surface normals are almost consistent)

Mesh Generation Process Summary

- Surface mesh generation
  - Identify domains for algebraic meshing (2, 3, or 4 initial curves)
    hyperbolic meshing (1 initial curve)
  - Prescribe grid point distribution on initial curves
  - Create surface mesh using TFI or hyperbolic marching
- Volume mesh generation (near-body: hyperbolic, off-body: Cartesian)
- Domain connectivity: Distance-based hole cuts (C3P), or
  X-ray hole-cut (OVERFLOW-DCF)
- Mesh export formats: Grid system - PLOT3D
  Overset mesh connectivity data – XINTOUT
- Entire process recorded in Tcl script system based on CGT Script Library

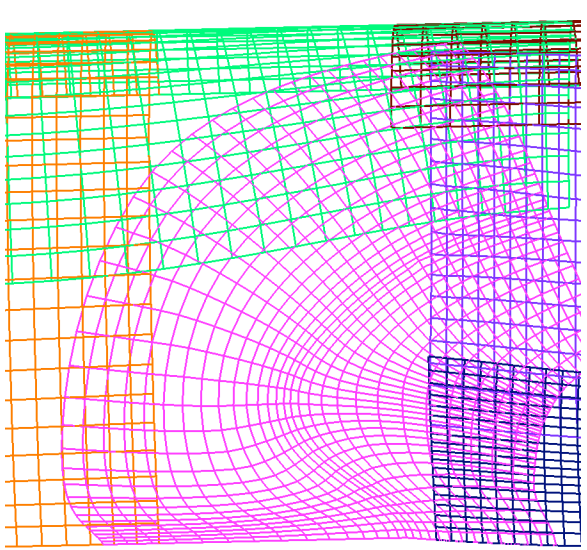
Mesh Generation Issues (I)

Parameter Adjustments at Different Mesh Resolution Levels (A)

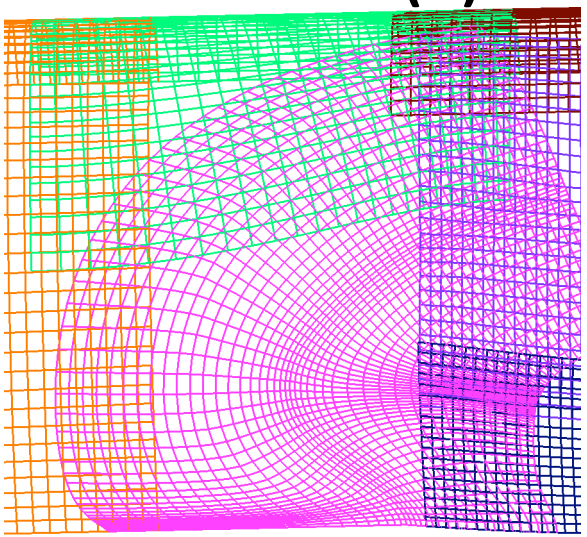
Hyperbolic grid marching distances chosen to provide proper overlap at medium level (e.g., 5-point overlap for 5-point flow solver stencil)

In some regions:

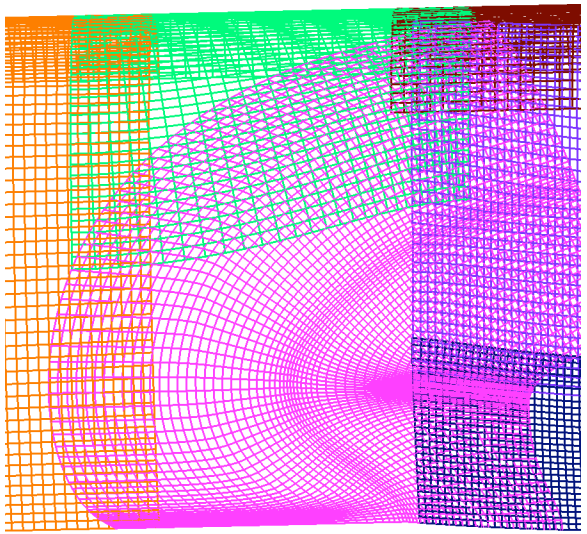
- Insufficient overlap at coarse level
- Too much overlap at fine and extra fine levels



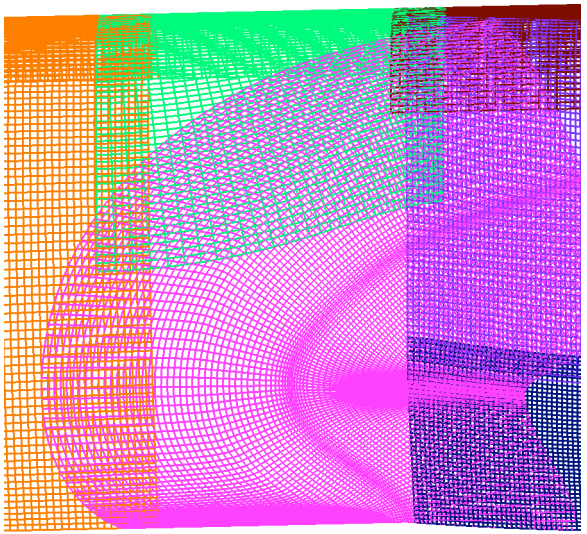
Coarse



Medium



Fine

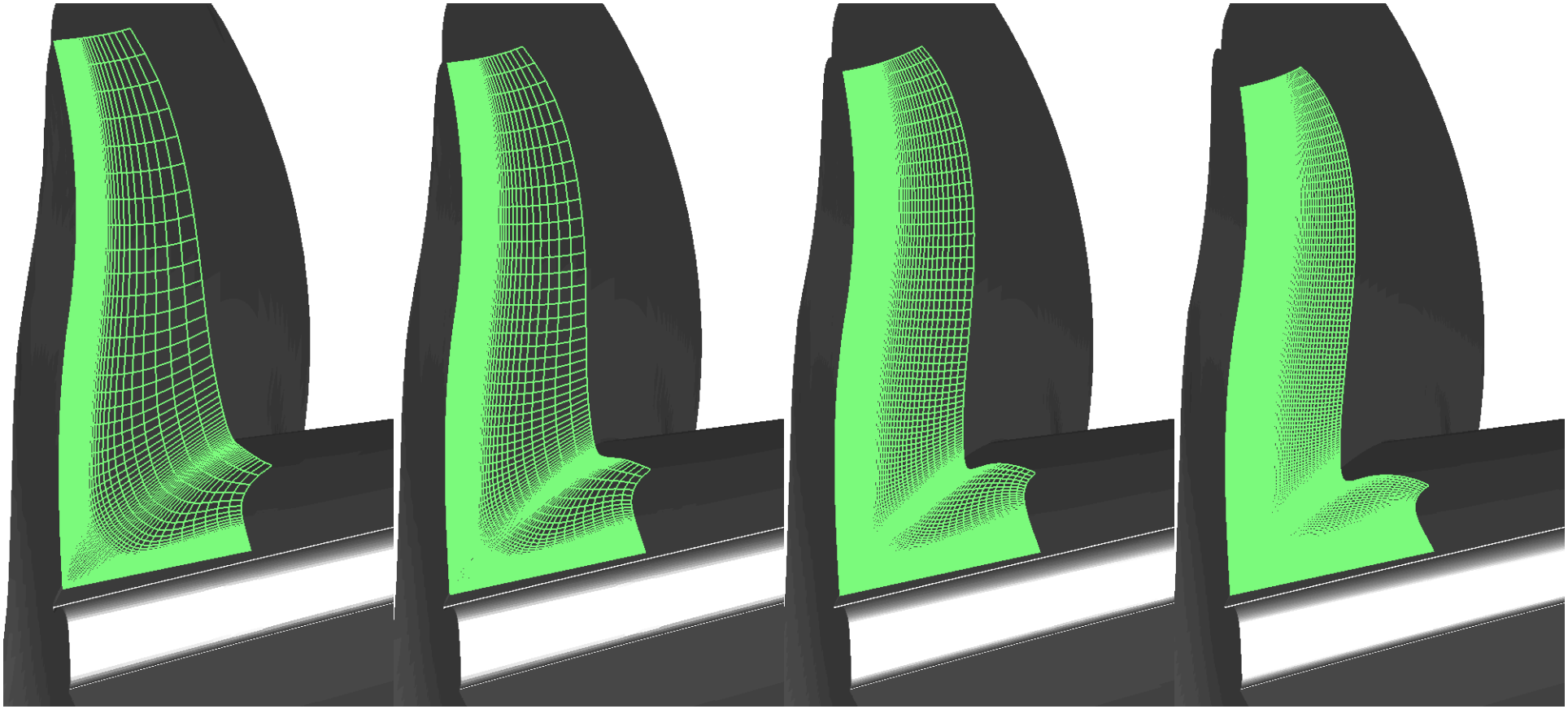


Extra Fine

Mesh Generation Issues (I)
Parameter Adjustments at Different Mesh Resolution Levels (B)

Finer grid spacing in concave corners in finer levels

- Need to adjust smoothing parameters for hyperbolic marching

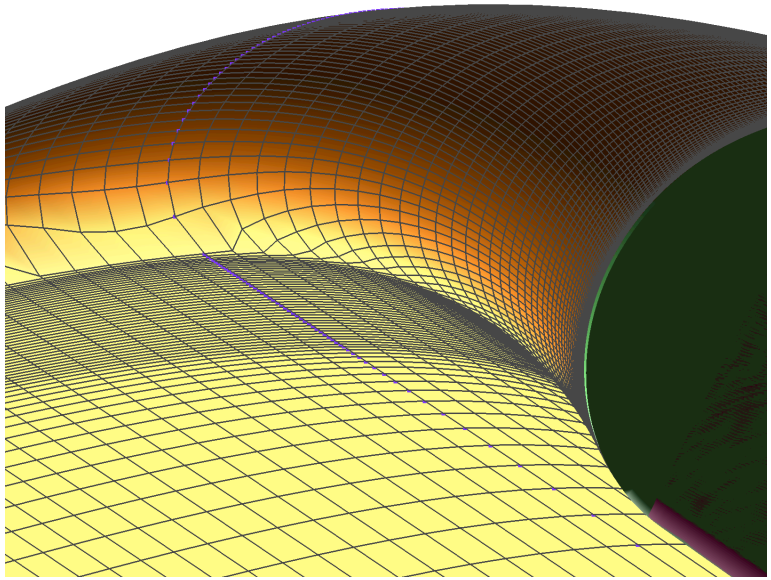


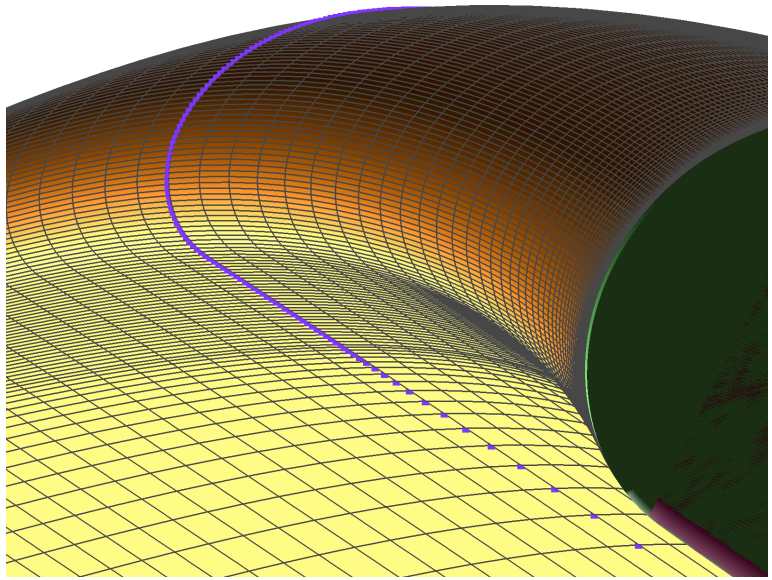
Coarse Medium Fine Extra-fine

Mesh Generation Issues (II)
Negative Cell Volumes and Bad Projection

Two problems were discovered after initial version of mesh system

1. A very small number of negative cell volumes found
   - Disregarded initially since flow solver is node centered
   Fix: lower smoothing values
2. TFI surface mesh around flap leading edge had large stretching ratio
   - Bad projection to geometry definition from lack of leading edge geometry curve
   - Surface grid points are on geometry, but surface cells are far from geometry
   Fix: introduce leading edge curve, redo TFI and projection to geometry definition

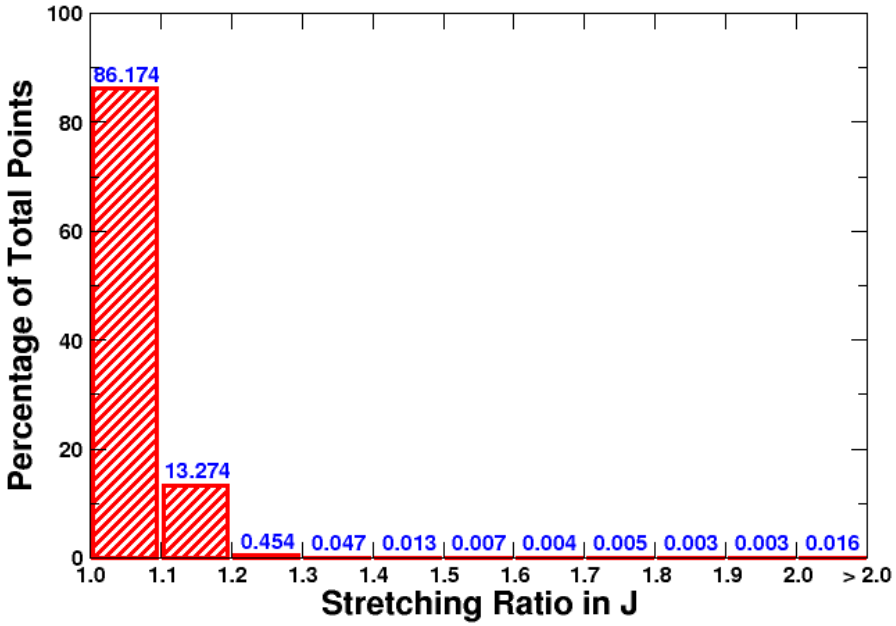


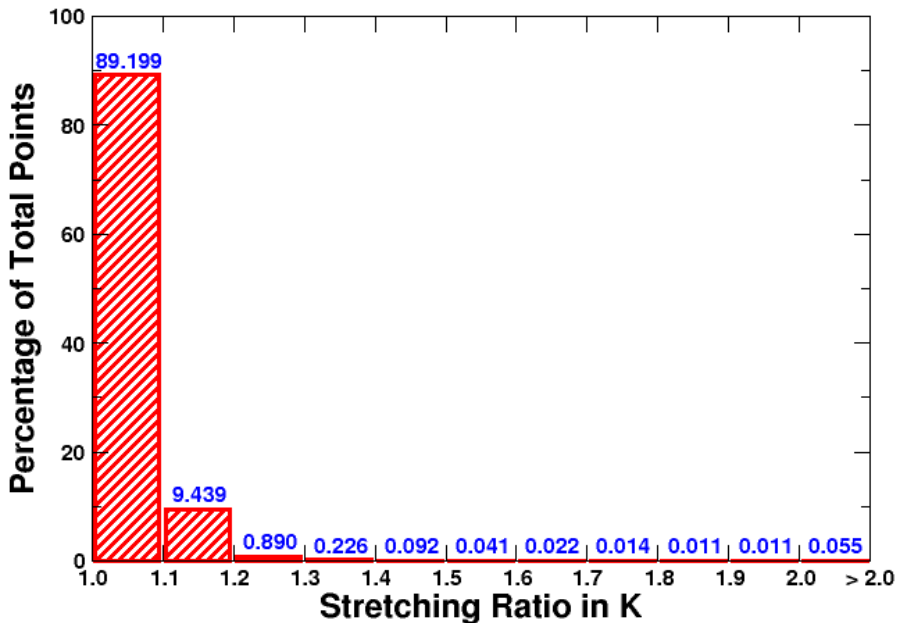


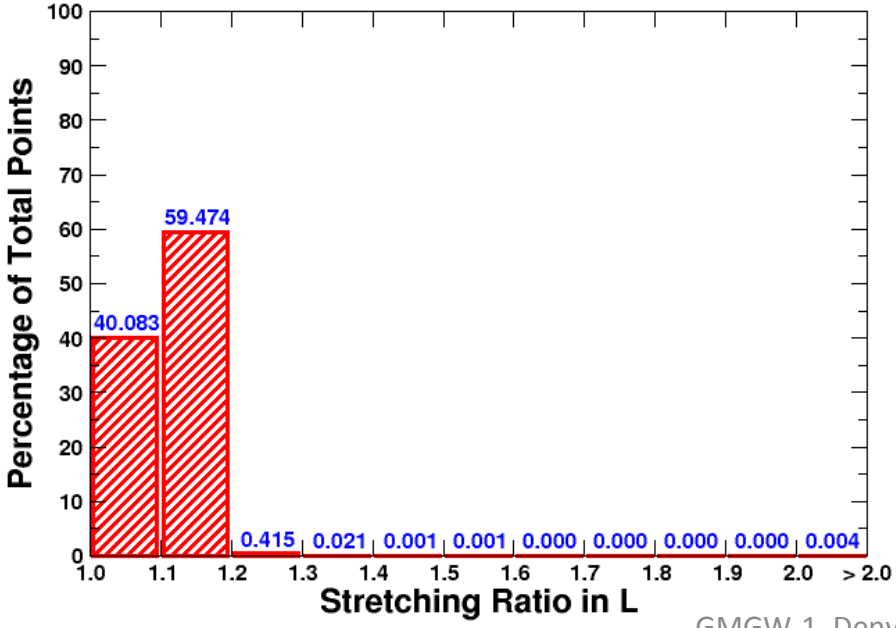
Mesh Statistics

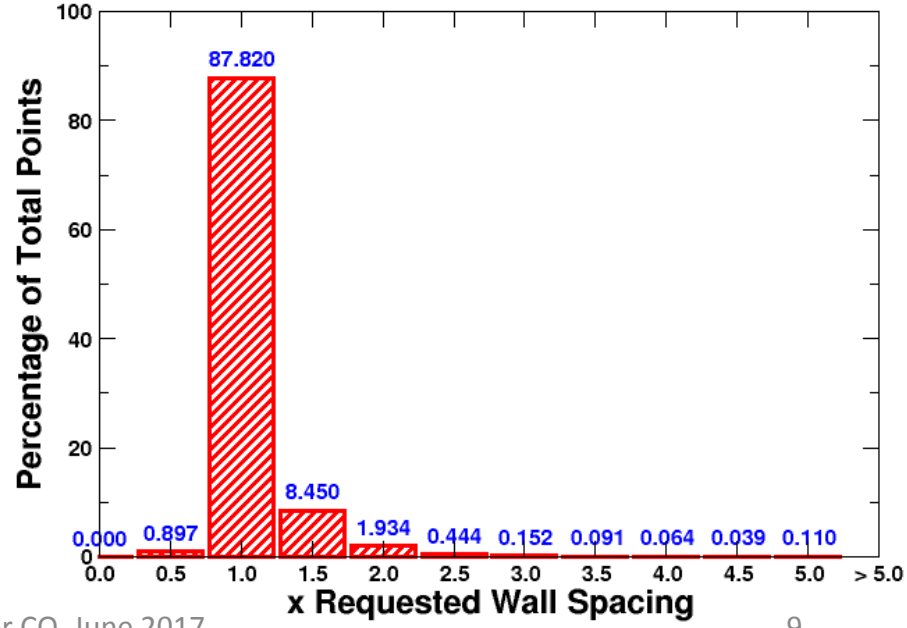
Geometry Model	Grid Type	Grid Level	Blocks	Surface Grid Points	Volume Grid Points	Orphan Points
HLCRM Full Gap	Overset Structured	Coarse	72	0.27M	24.1M	2
		Medium	72	0.51M	65.4M	6
		Fine	76	1.02M	189.3 M	16
		Extra-Fine	102	2.08M	564.9M	119
HLCRM Partial Seal	Overset Structured	Medium	73	0.53M	66.3M	22

Grid Attribute Histograms for Full Gap Medium Mesh

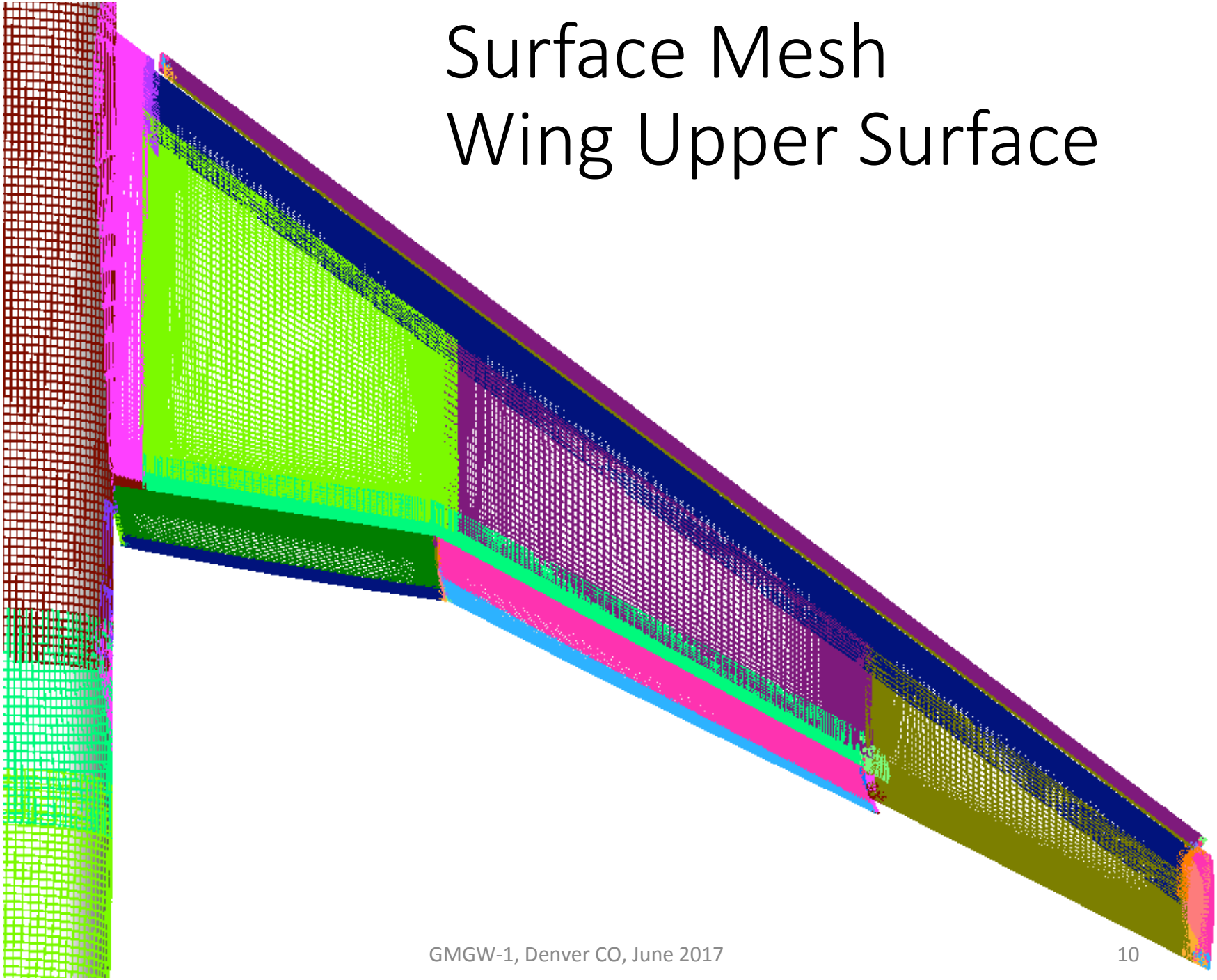




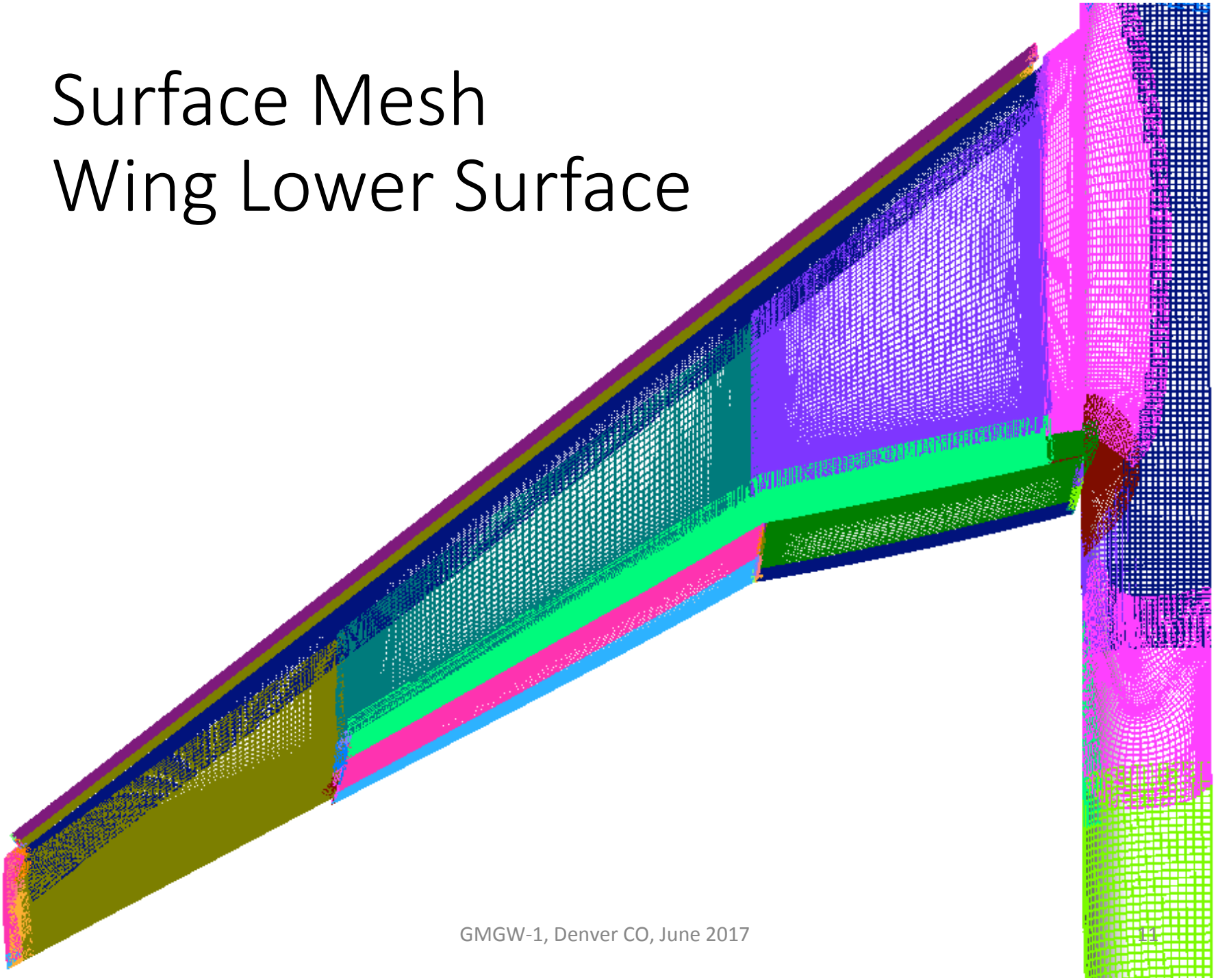




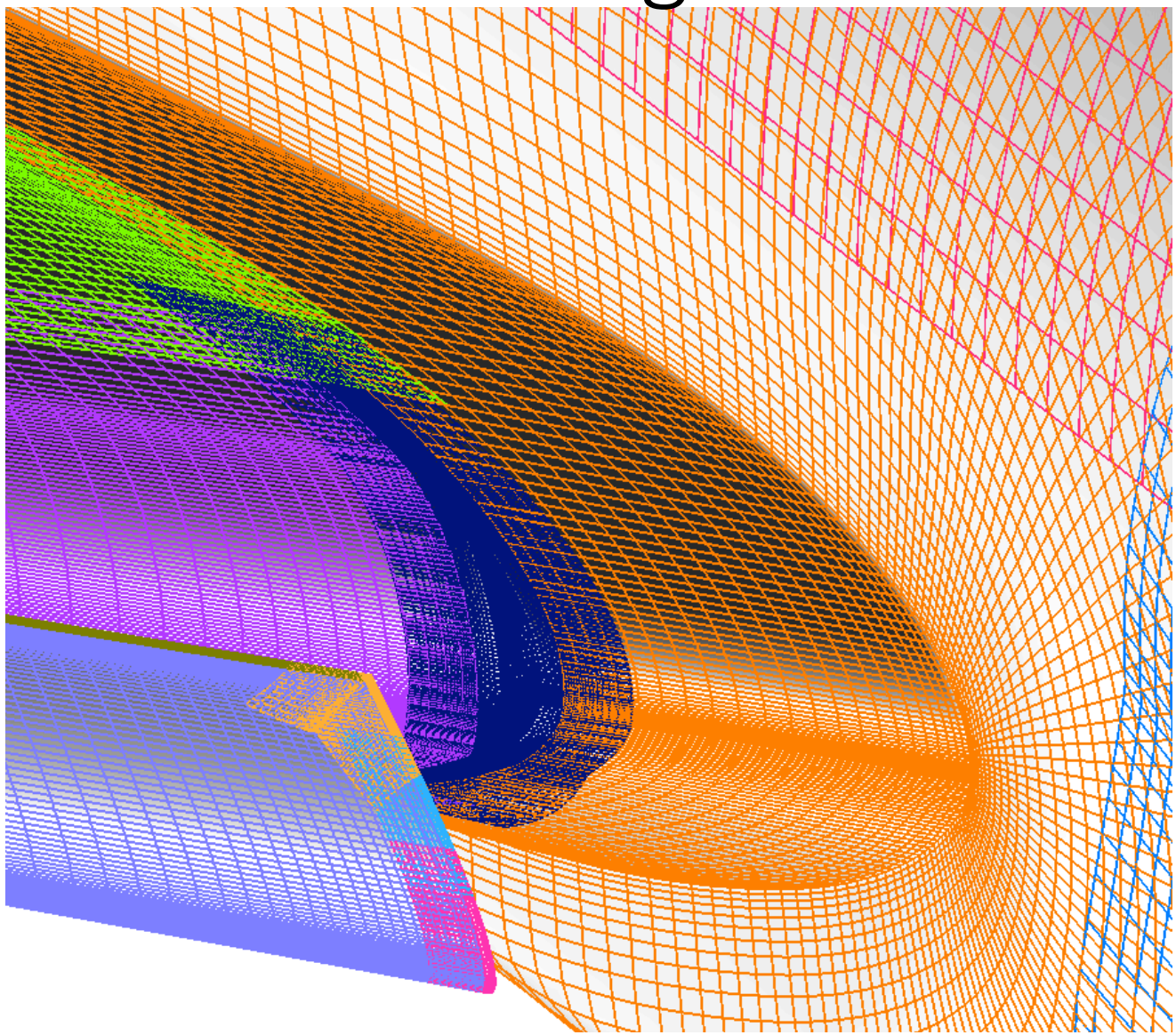
Surface Mesh
Wing Upper Surface



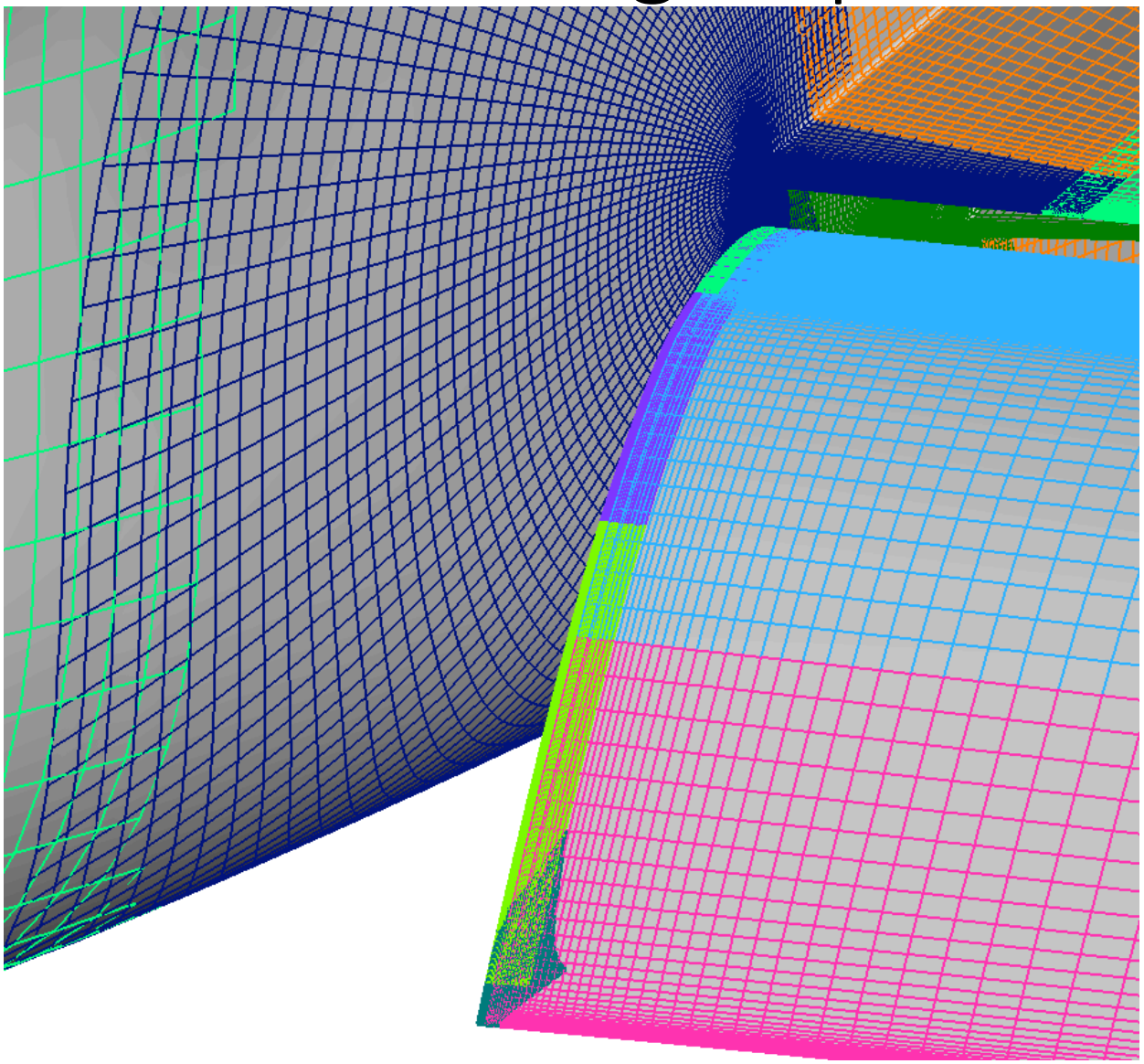
Surface Mesh
Wing Lower Surface



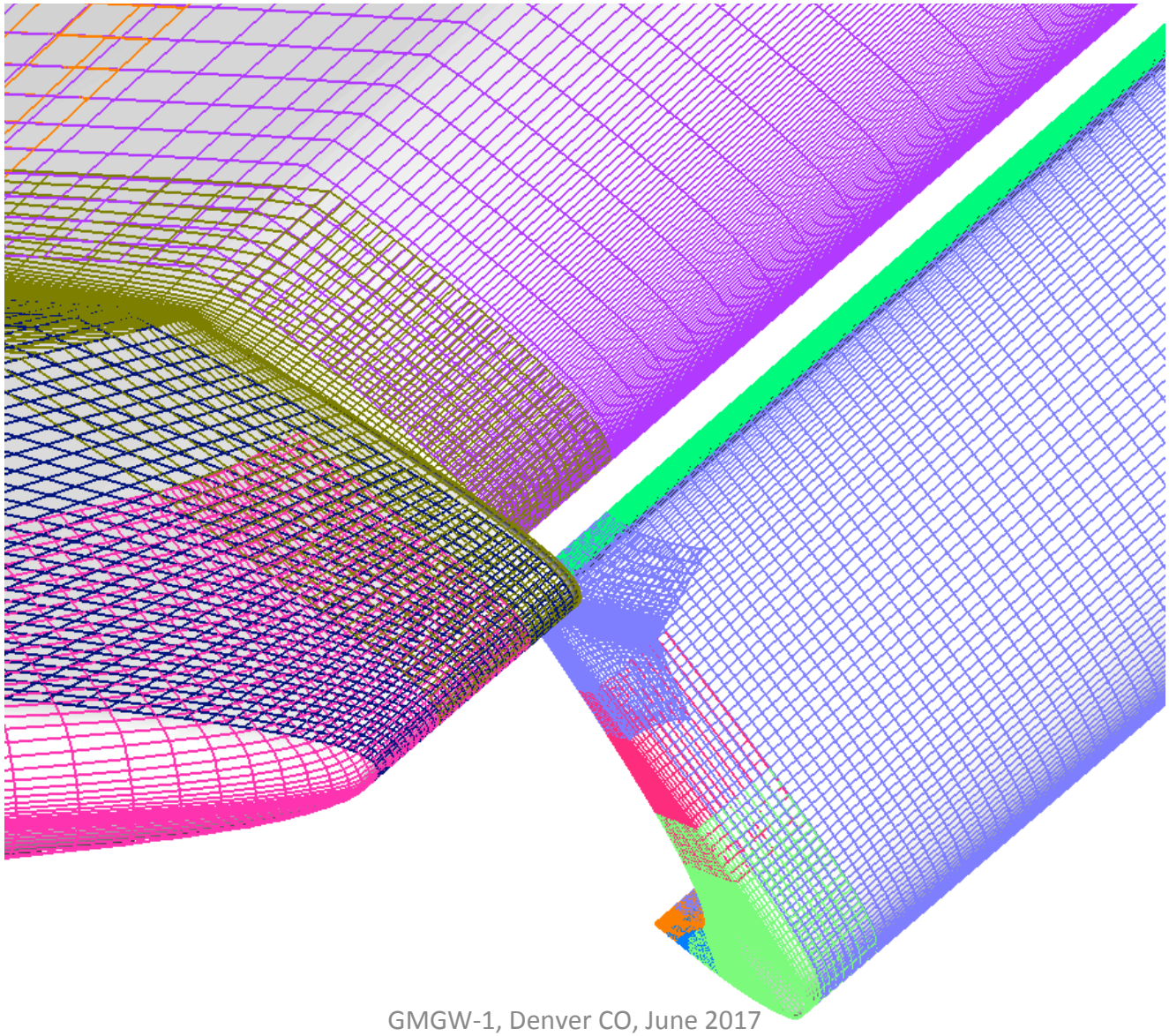
Surface Mesh - Wing Slat LE at Root



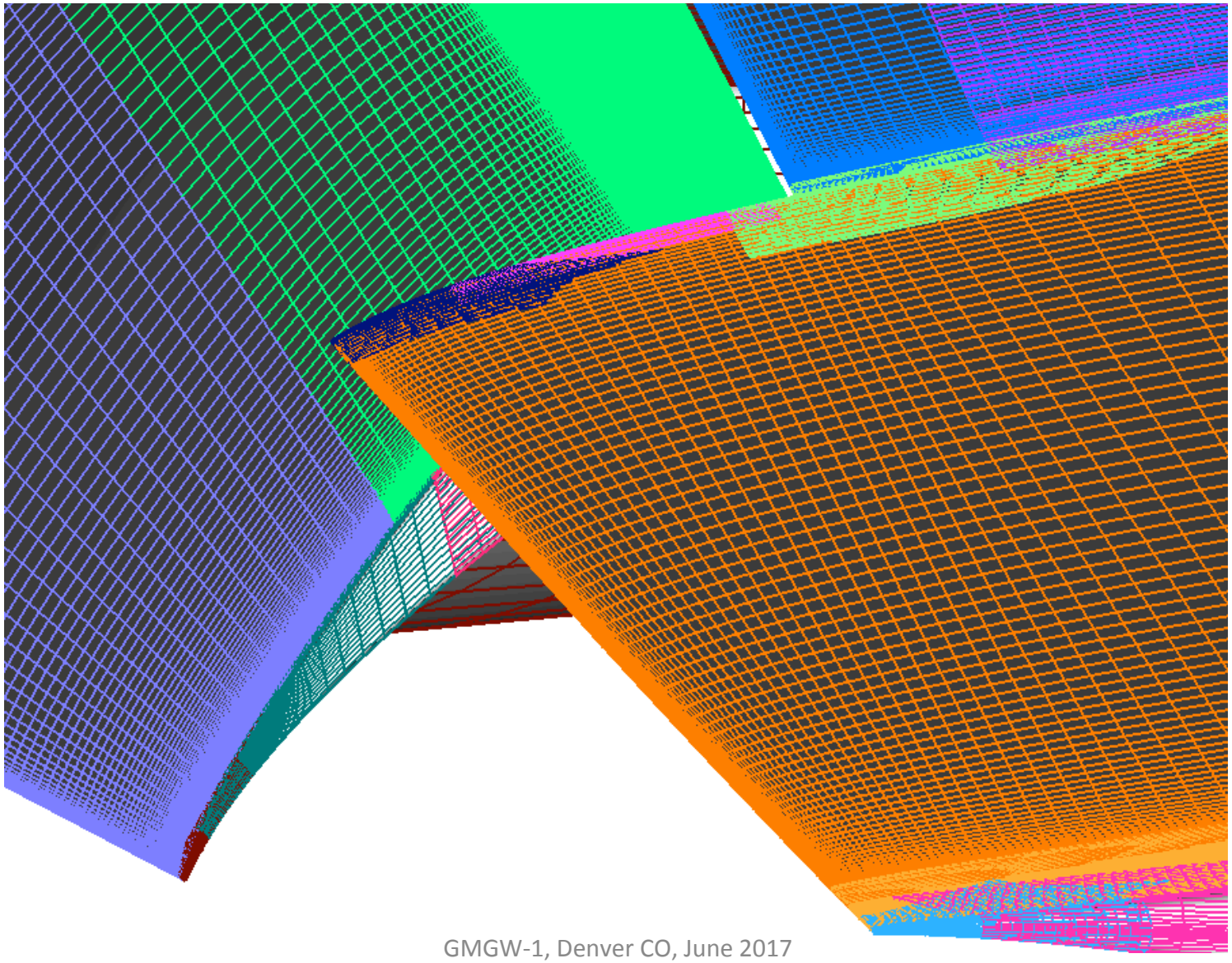
Surface Mesh - Wing Flap TE at Root



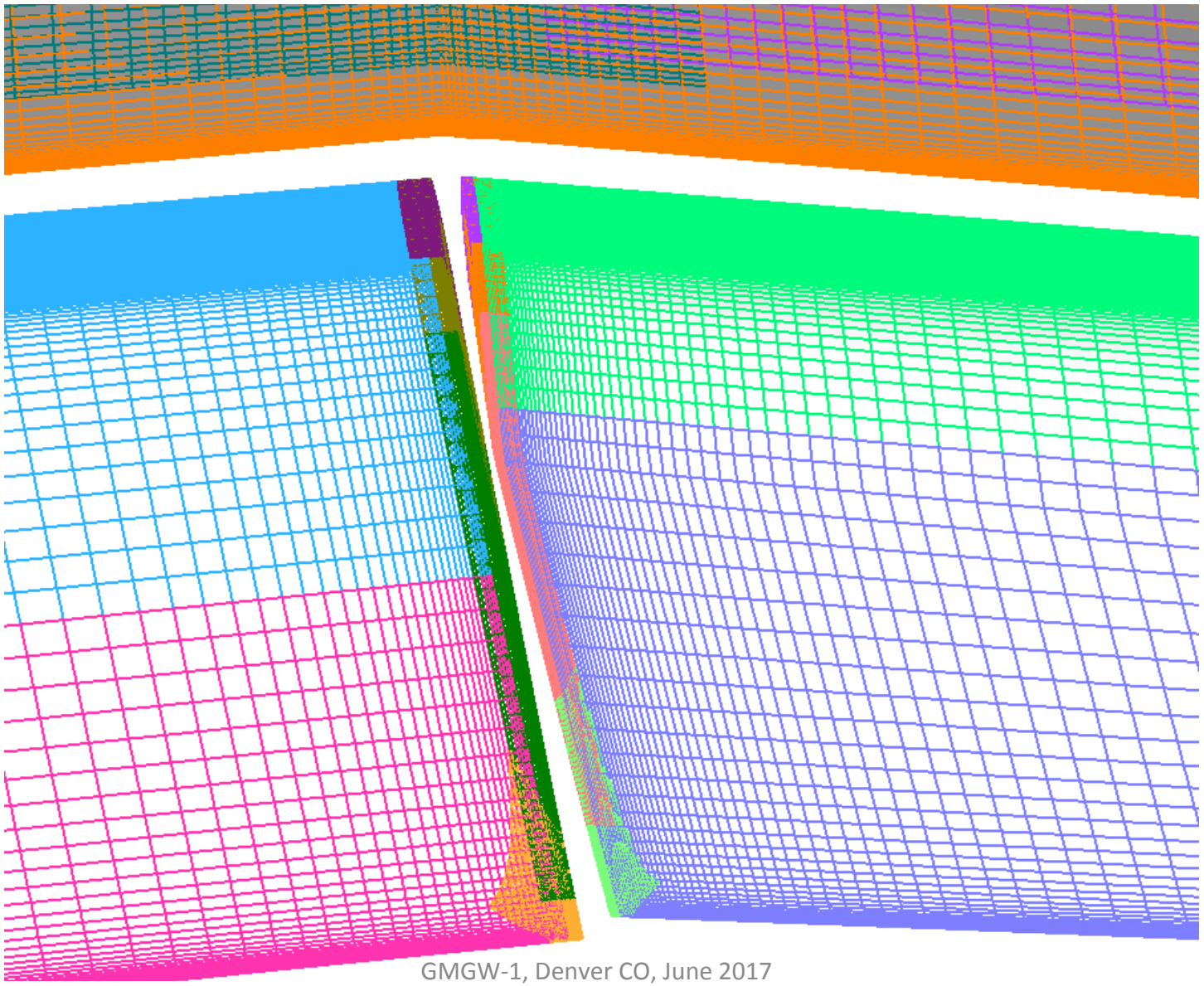
Surface Mesh - Wing Tip LE



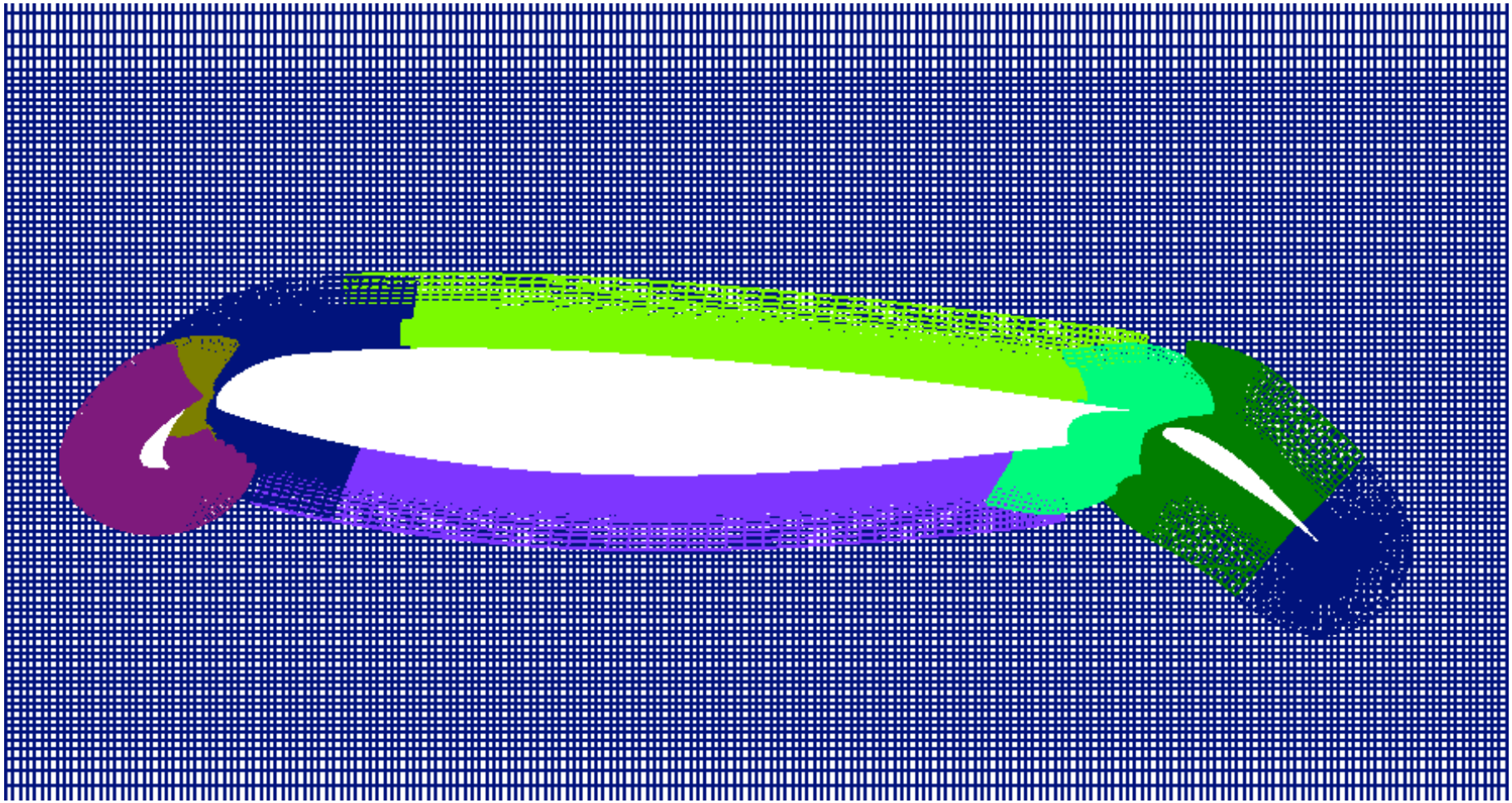
Surface Mesh - Wing Tip TE



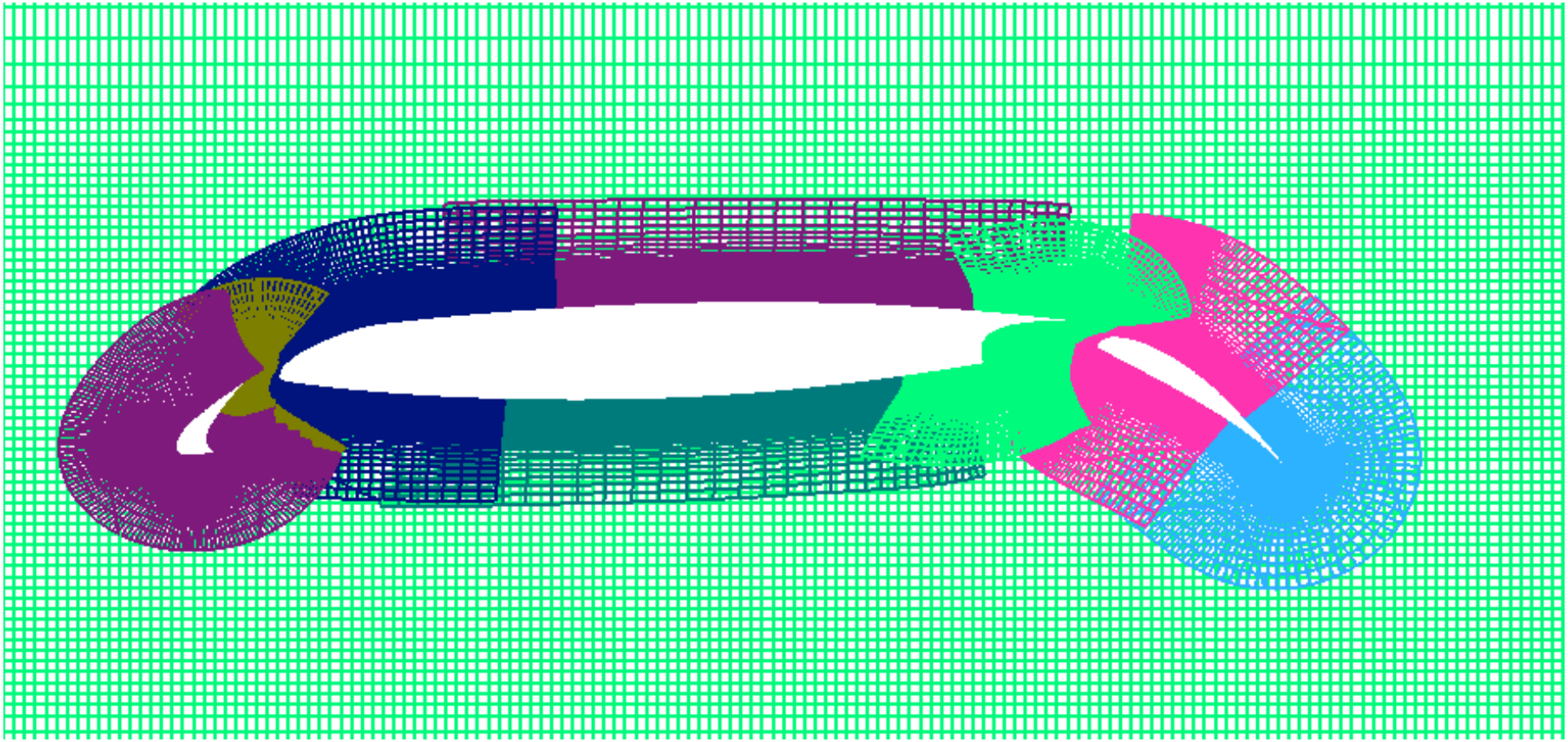
Flap Gap Upper Surface



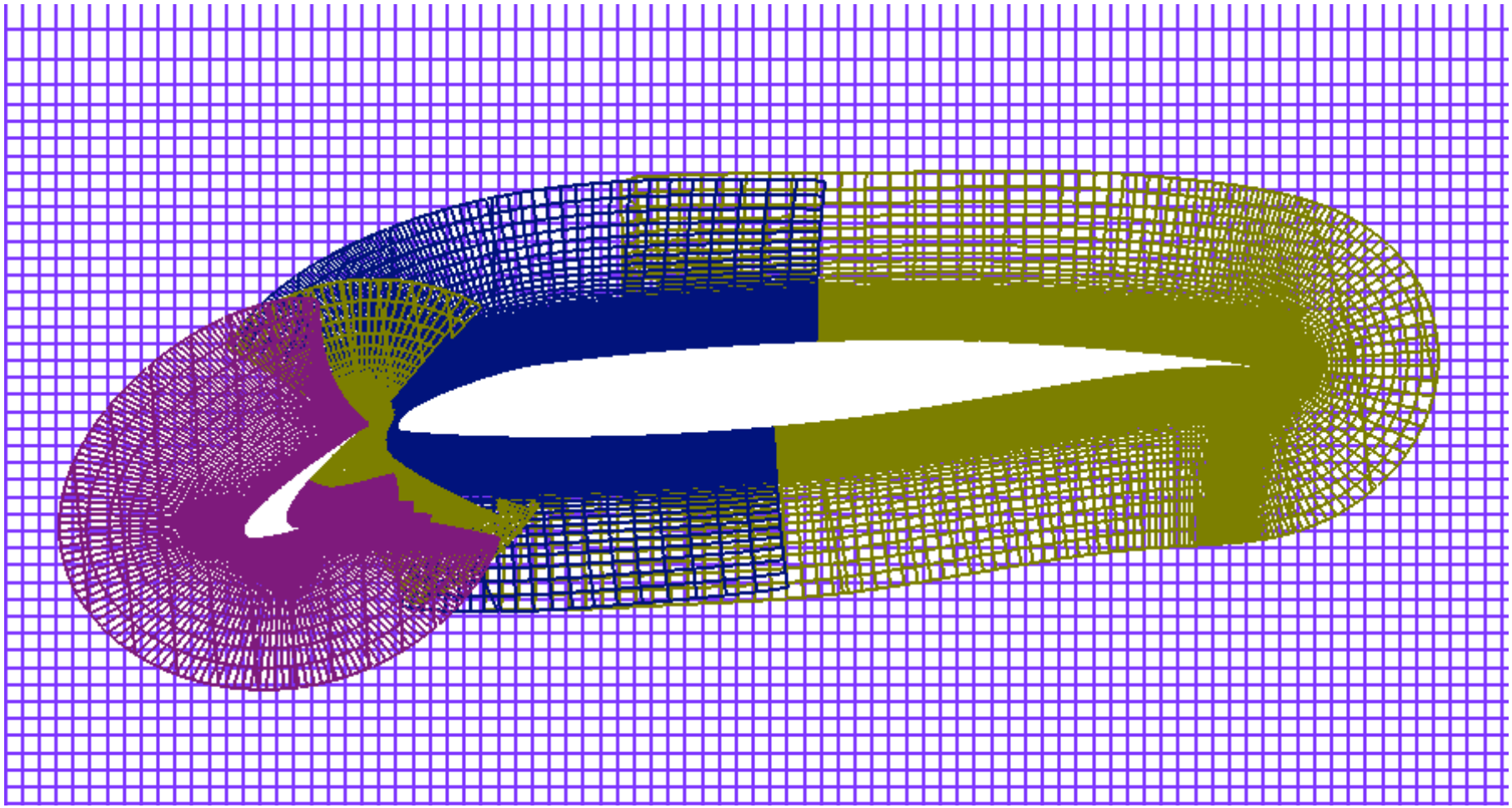
Volume Mesh Cut at y=277.5



Volume Mesh Cut at y=638



Volume Mesh Cut at y=1050

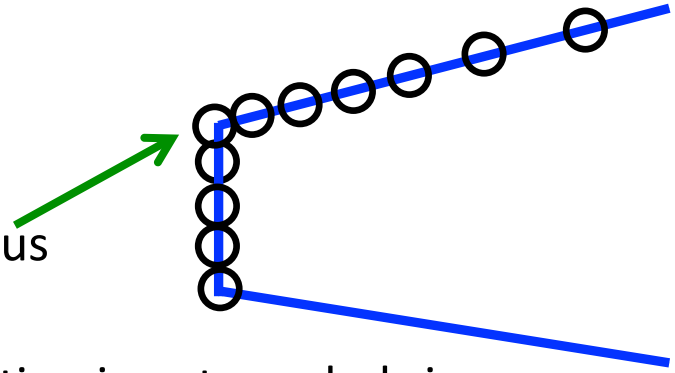


Mesh Evaluation: Surface and Volume Meshes

- Must-pass
  - Jacobian > 0 at volume mesh vertices as computed by OVERFLOW flow solver
  - Cell volume > 0 (decomposition into 6 tets)
  - No self-intersection of volume grid points against surface grid

- Mostly-pass
  - Stretching ratio mostly around 1.2

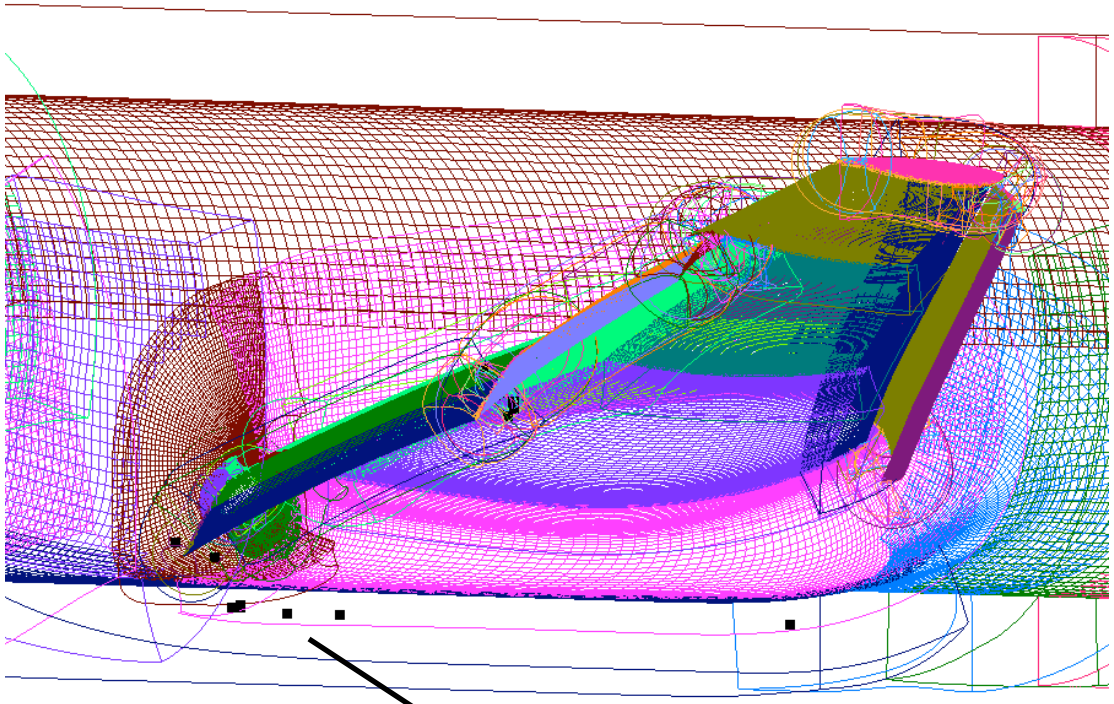
- Adherence to meshing guidelines
  - Trailing edge grid spacing made to be continuous around finite thickness trailing edge
  - Multi-griddable number of points in each direction is not needed since OVERFLOW flow solver has no such restrictions

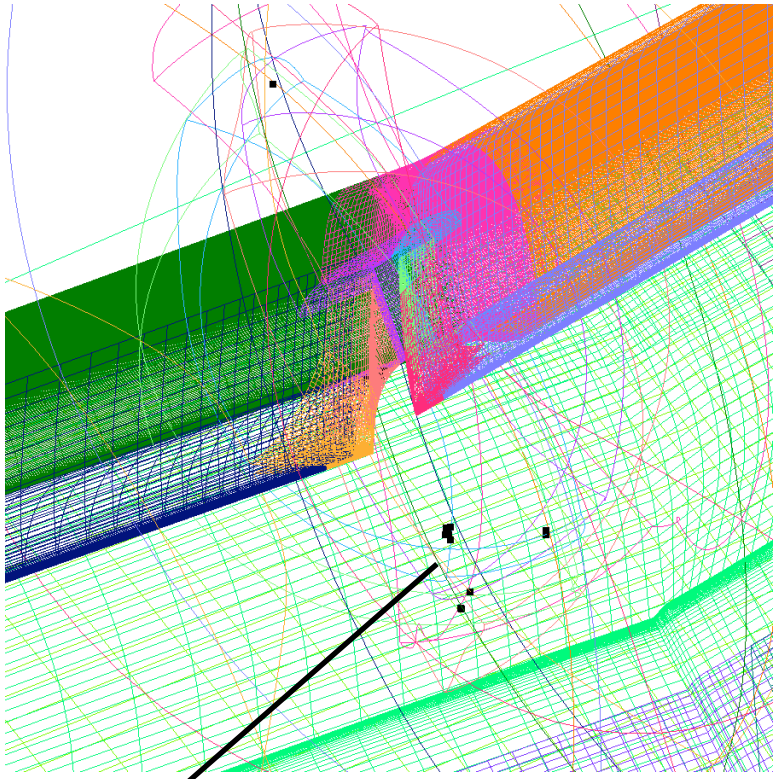


- Lessons learned
  - Need native CAD, STEP, IGES geometry interrogation grid tool (e.g., EGADS)
    1. project surface grid points onto geometry definition
    2. check distance of surface grid points from geometry definition

Mesh Evaluation: Overset Connectivity (I)
Orphan Points

Count, location, and spread (CGT: OVERGRID)





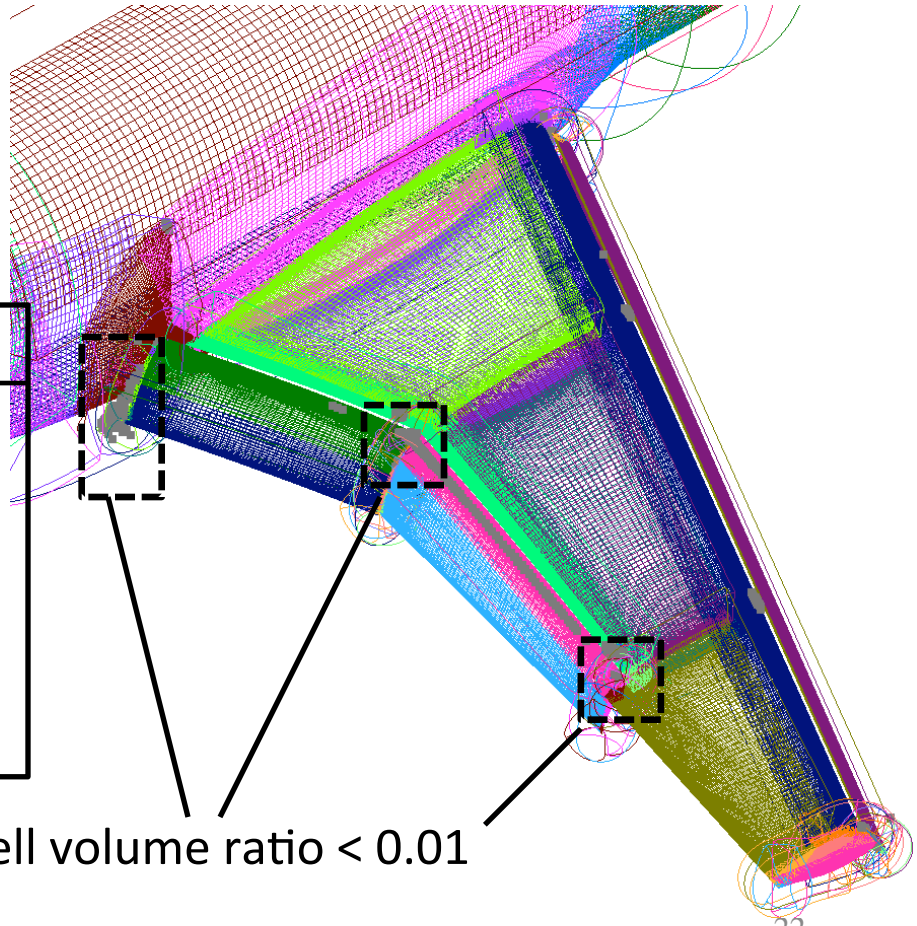
Total = 25, sparse points away from surface

Mesh Evaluation: Overset Connectivity (II)
Compatibility of Cell Attributes Between Fringe Point and Donor Stencil

- Cell volume ratio histogram table (CGT: intchk) and location map (CGT: OVERGRID)
- Bad ratio => gradients cannot be transferred accurately between grids

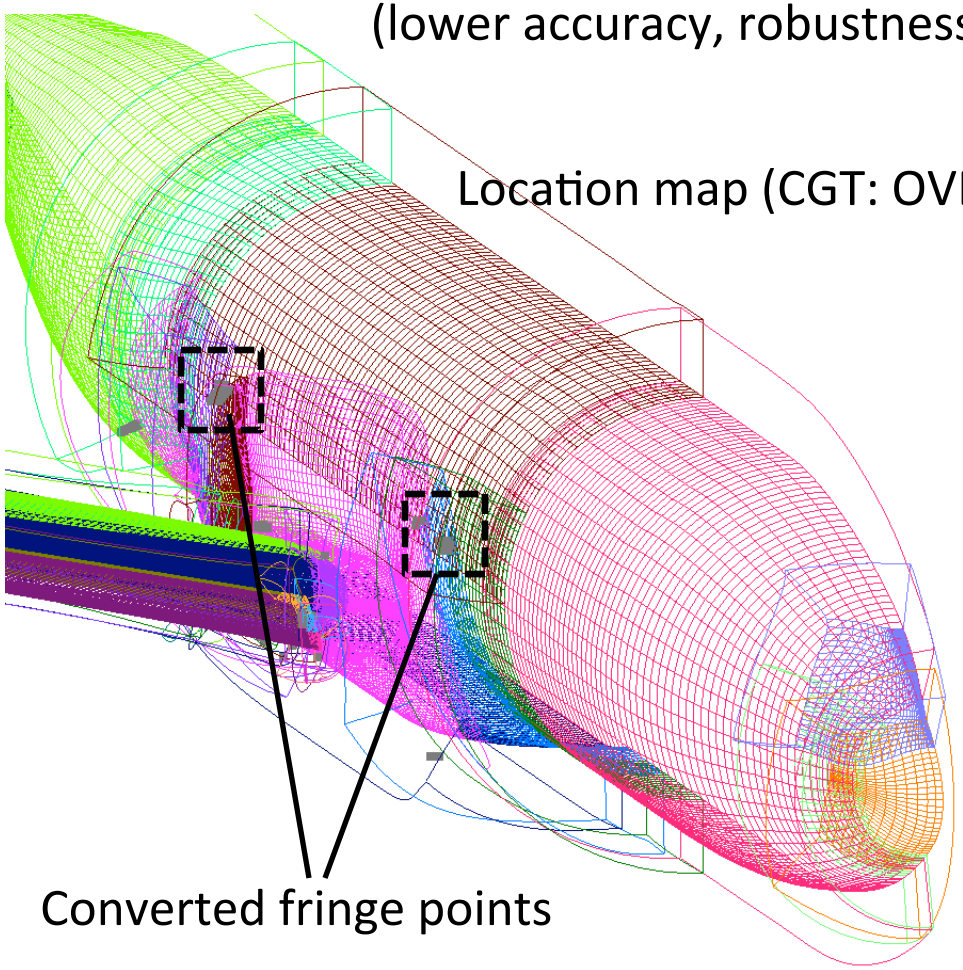
Other attributes that could be checked
- Cell aspect ratio, orientation

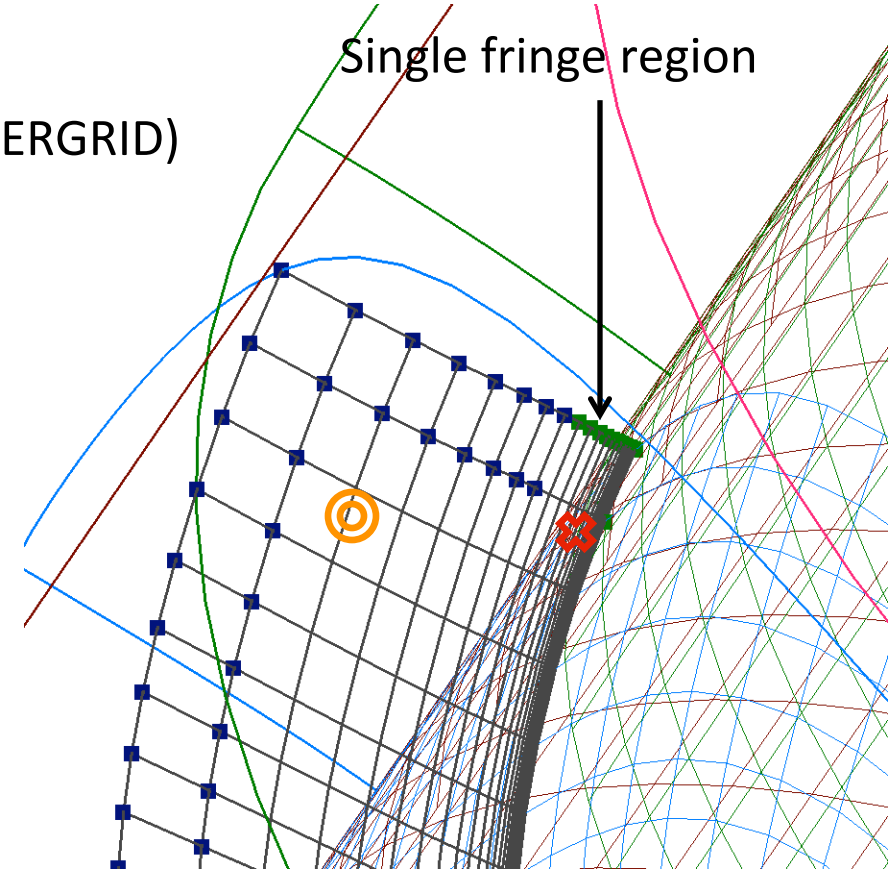
Cell Volume Ratio	# Pts.	% Total
0.5 <= R <= 1.0	2714268	48.26
0.2 <= R < 0.5	1705036	30.32
0.1 <= R < 0.2	670232	11.92
0.01 <= R < 0.1	525048	9.34
0.001 <= R < 0.01	9631	0.17
R < 0.001	21	0.37E-03



Mesh Evaluation: Overset Connectivity (III)
Conversion to Lower Number of Fringe Layers

- Insufficient grid overlap to support double fringe locally
- Option to convert from double fringe to single fringe
  => full 5-point differencing stencil not supported in flow solver
  (lower accuracy, robustness)

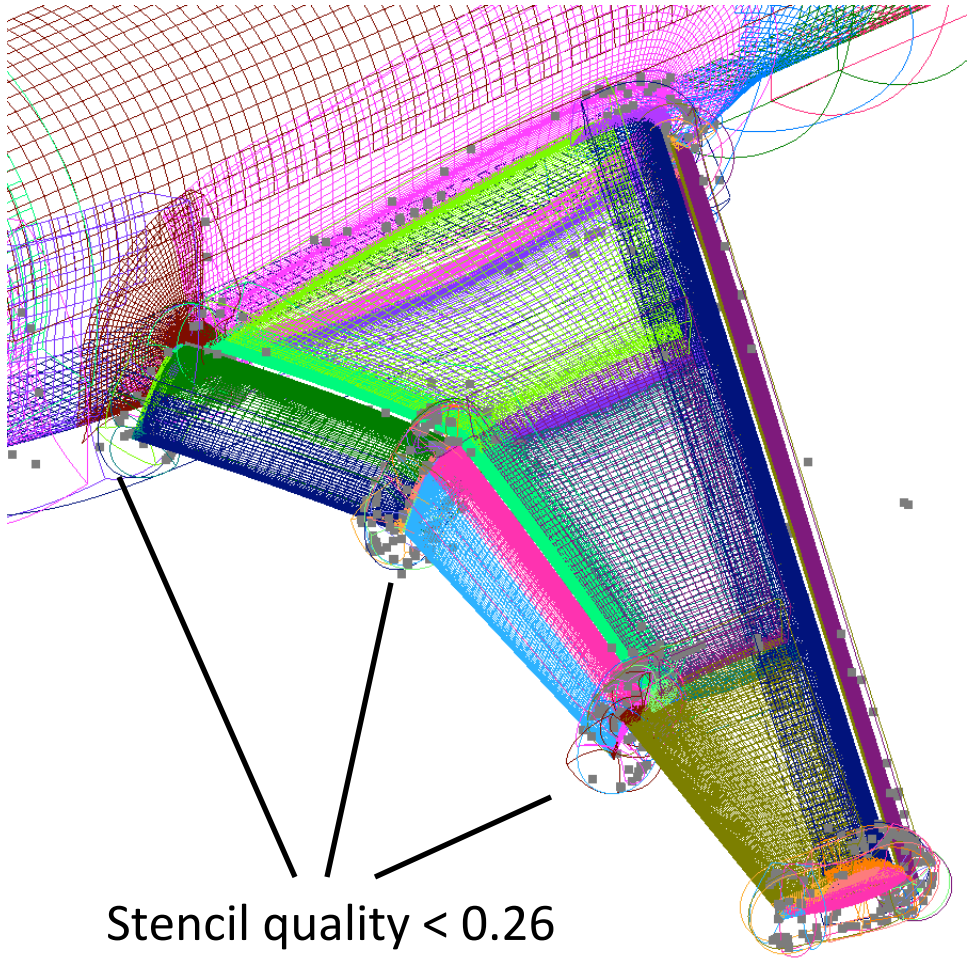




Mesh Evaluation: Overset Connectivity (IV)
Donor Stencil Quality

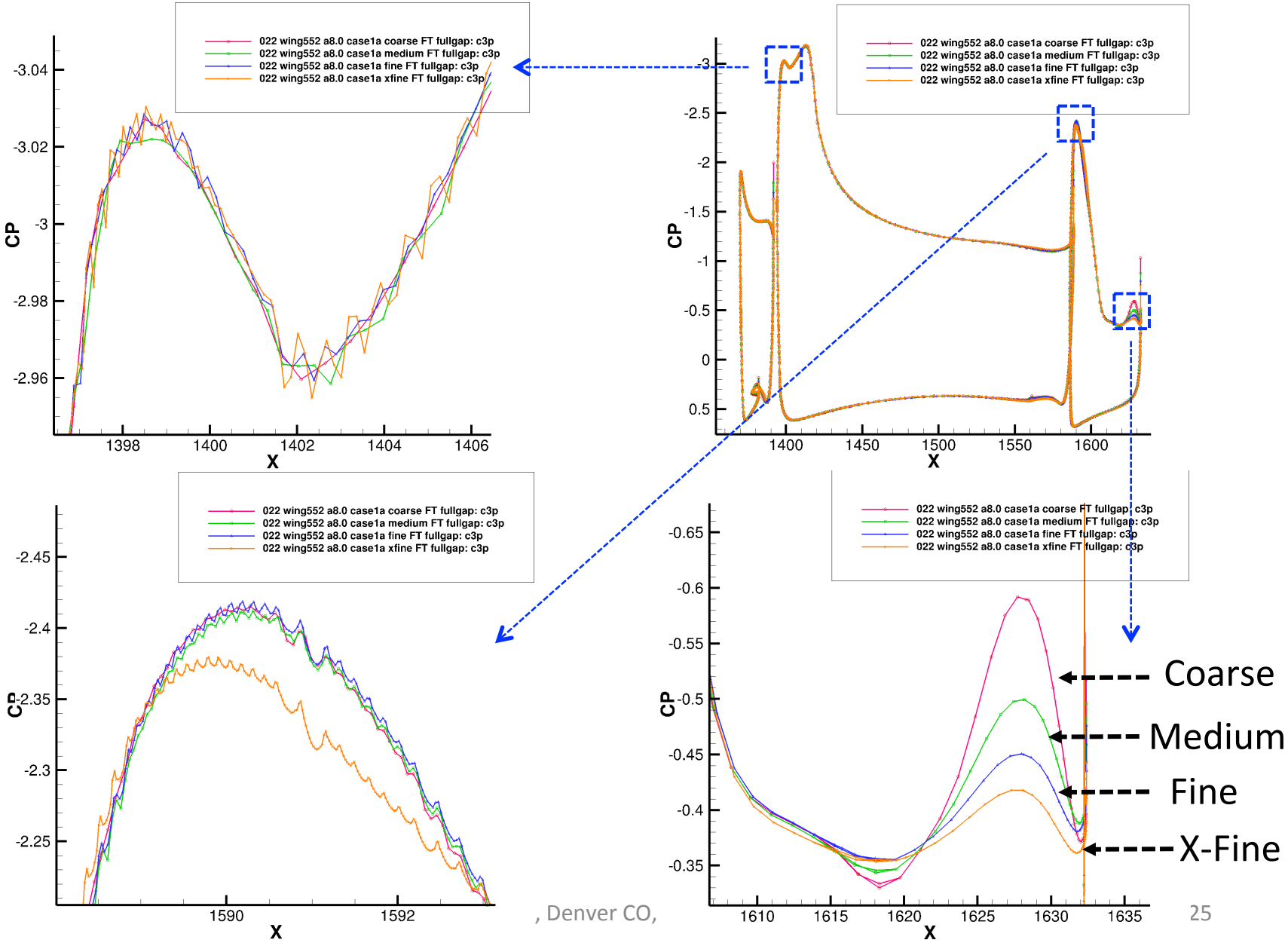
Histogram table (CGT: intchk) and location map (CGT: OVERGRID)

Stencil Quality	Count	% Total
Q = 0.0	0	0.00
0.0< Q < 0.1	0	0.00
0.1<= Q < 0.2	0	0.00
0.2<= Q < 0.3	4858	0.17
0.3<= Q < 0.4	12120	0.42
0.4<= Q < 0.5	14660	0.51
0.5<= Q < 0.6	14054	0.48
0.6<= Q < 0.7	19504	0.67
0.7<= Q < 0.8	24788	0.85
0.8<= Q < 0.9	23280	0.80
0.9<= Q < 1.0	45317	1.56
Q = 1.0	2573858	94.54



Mesh Evaluation: Flow Solver Test

See High-Lift Prediction Workshop 3 talks on OVERFLOW and LAVA results



Future Technology

- Develop connection between surface grid generation software and geometry interrogation tool (e.g., using EGADS) to bring surface grid points onto native CAD, STEP, or IGES

- Develop more automated overset surface mesh generation algorithm and software ("*Strategies Toward Automation of Overset Structured Surface Grid Generation*", to be presented at AIAA Aviation 2017)

- Develop more grid quality check software (minmax, histograms, contour plots of various grid attributes)

Summary

Task (Medium full gap mesh, 1st mesh generated)	Time (hr.)	% of Total
Geometry processing / Ref. triangulation generation	3.75	5.5
Surface grid generation	56.05	81.7
Volume grid generation	4.50	6.6
Domain connectivity (C3P)	1.20	1.7
Input prep. (flow solver b.c., post-processing)	3.1	4.5
Total	68.6	100

- Overset surface grid generation requires the most manual effort
- Creation of grid systems with different mesh resolution levels using the scripting approach is not as simple as first anticipated (marching distance and smoothing parameter adjustments)
- Need to be able to project surface grid points back to native CAD, STEP, or IGES geometry definition
- Need more grid quality check tools

Acknowlegement: NASA T^3 Project, Transformative Aeronautics Concepts Program (ARMD)