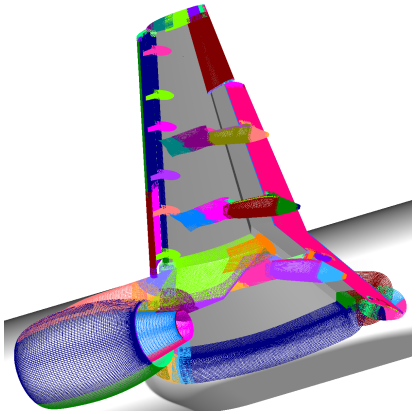
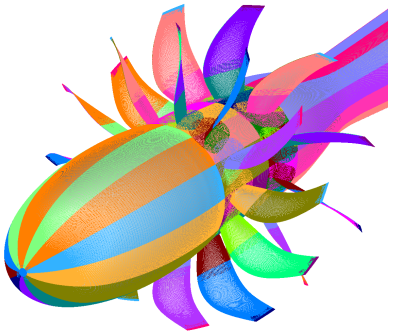
Ames Research Center

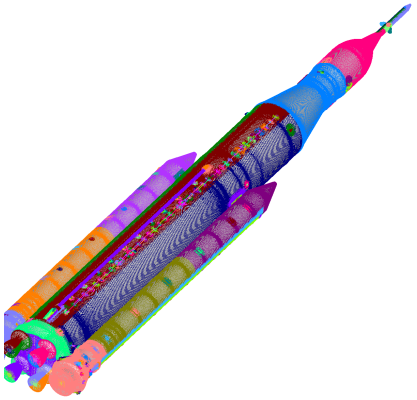


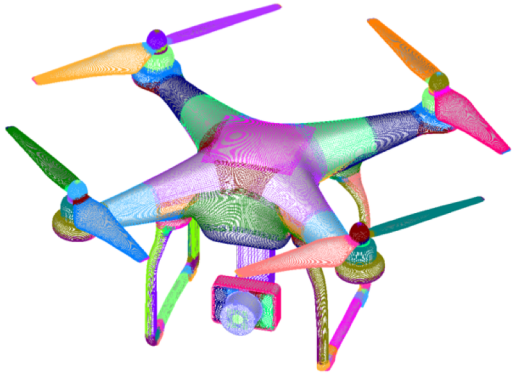
NEW FEATURES IN CHIMERA GRID TOOLS VERSION 2.2



William M. Chan

NASA Ames Research Center





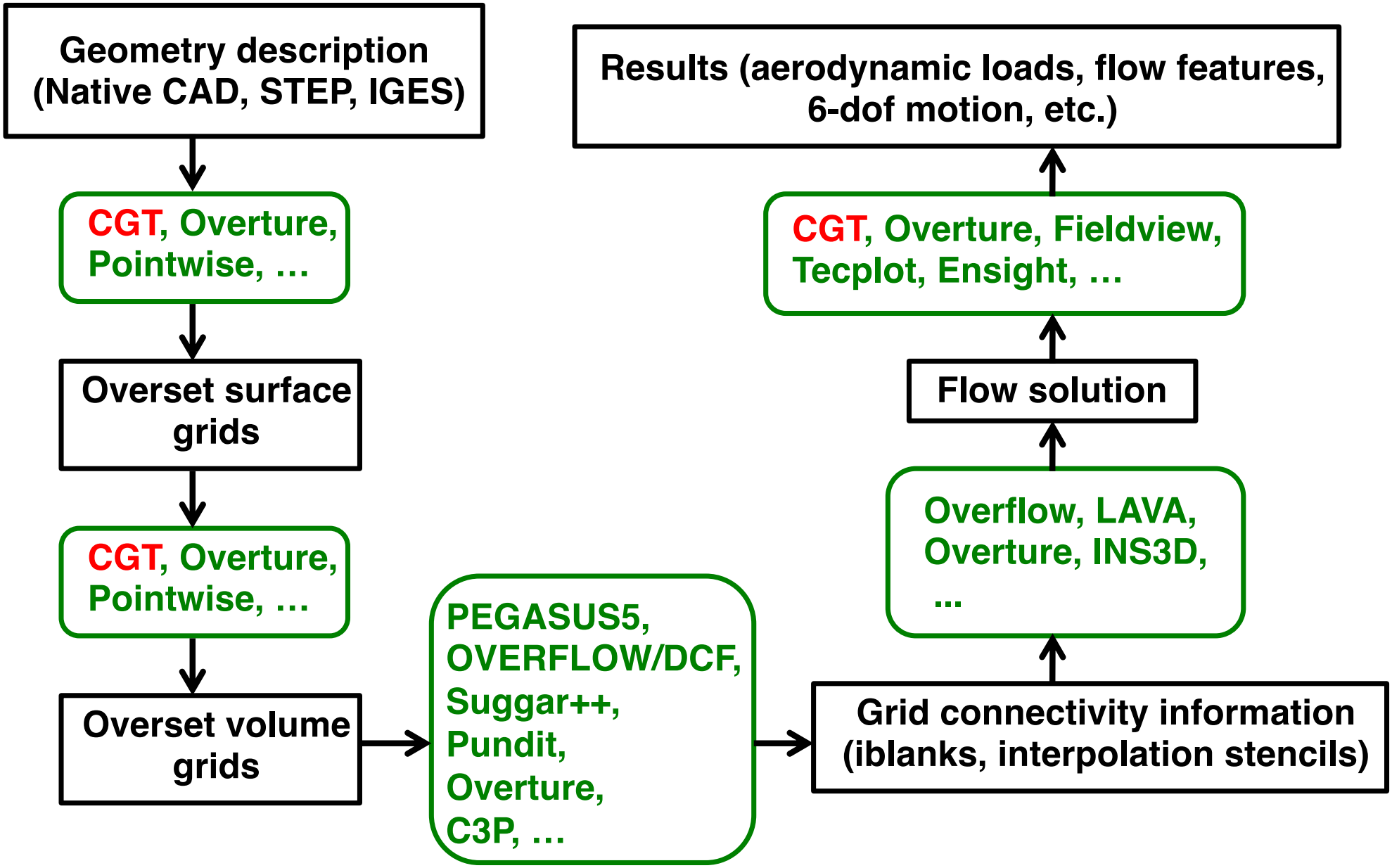
AMS Seminar Series, December 4, 2018

OVERVIEW

- Introduction

- New features in version 2.2

TYPICAL MODELING AND SIMULATION PROCESS USING OVERSET GRIDS

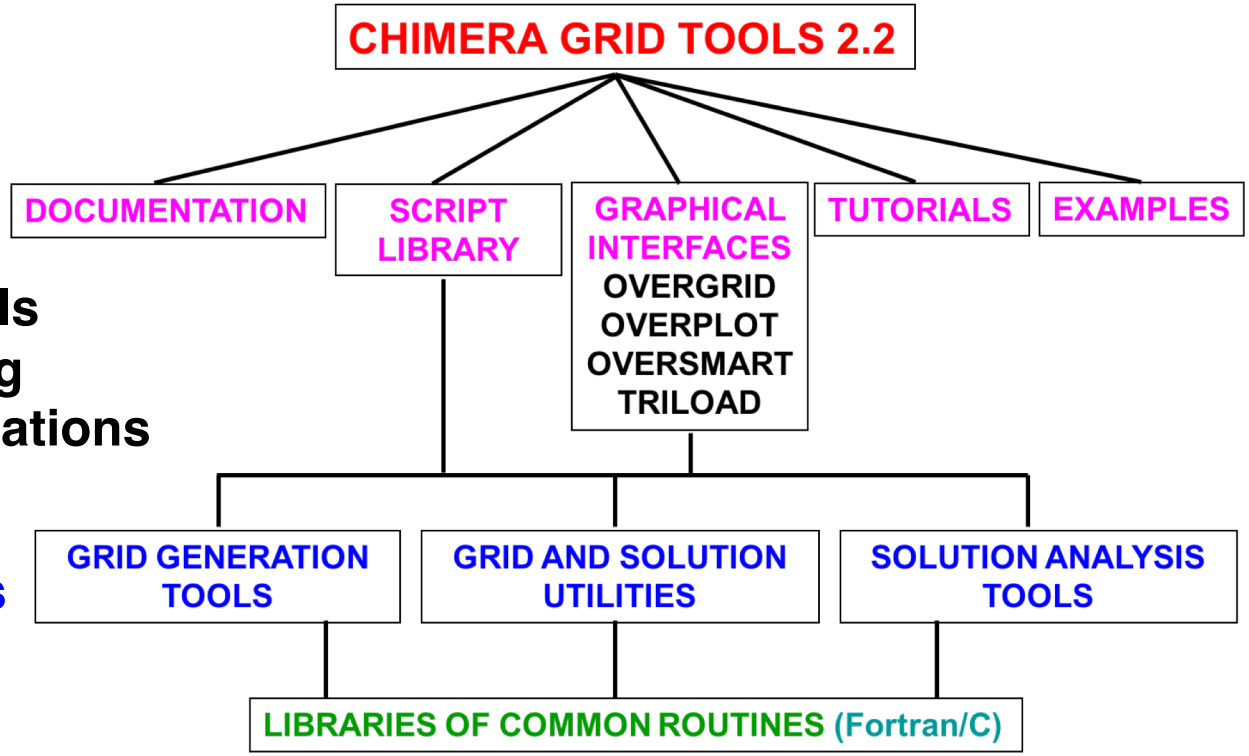


CHIMERA GRID TOOLS (CGT) Version 2.2

What is CGT

- A collection of software tools
  for pre- and post-processing
  of overset grid CFD computations

70+ tools



Authors

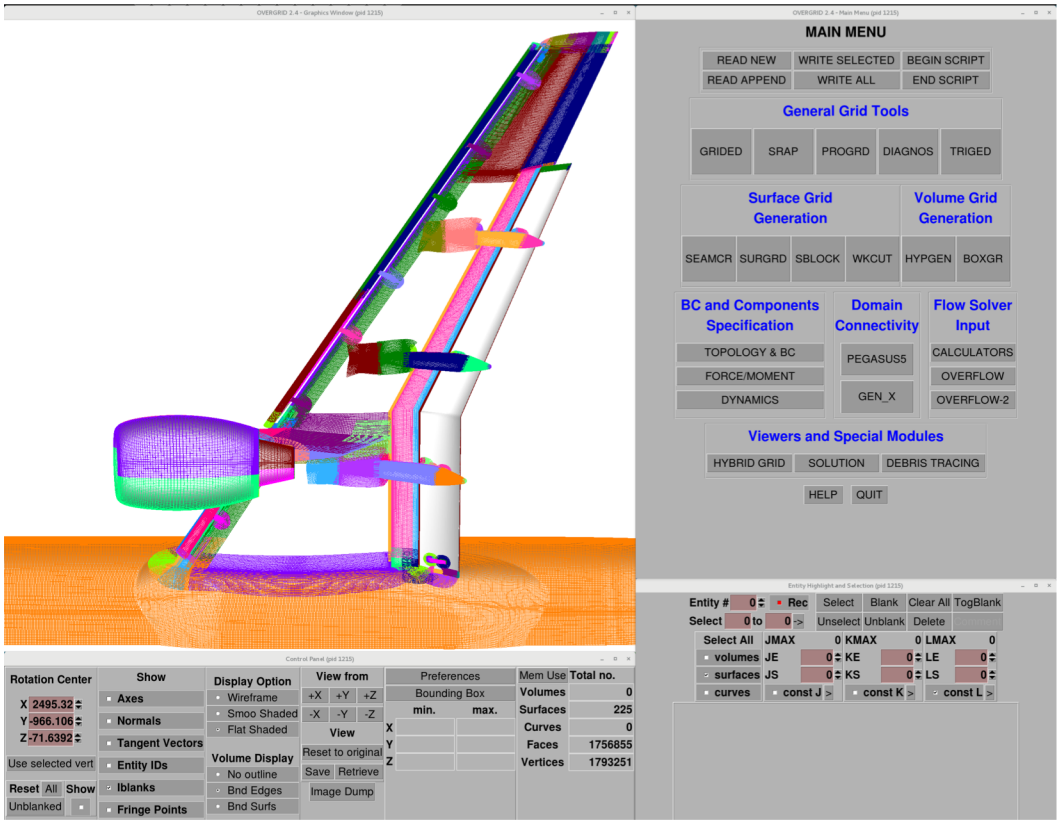
2.2: William Chan, Shishir Pandya, Stuart Rogers, James Jensen, Henry Lee
Earlier: David Kao, Pieter Buning, Robert Meakin, David Boger, Steve Nash

Availability

NASA Software Catalog (https://software.nasa.gov/software/ARC-16025-1B)
- U.S. citizens/permanent residents working under U.S. organization in the U.S.
- Fill out and return Software Usage Agreement form
- Source (Linux, Unix, Mac OS-X)
- Version 2.2+ available for use by authors' associated projects

MAIN FRONT END MODULES

OVERGRID



SCRIPT LIBRARY

Objective

- Enable fast replayable parametric grid generation, pre- & post-processing script development

Approaches

- Grid-based (Configuration/Build scripts)
- Component-based

Library

- About 250 Tcl procedures for performing various pre- and post-processing tasks

Geometry - interface via ESP
Grid - processing, redistribution, projection
Generators - surface grids, volume grids, hole-cutters
Diagnostics - grid & connectivity quality
Input preparation - flow solver b.c. & params, debris trajectory
Animation - multi-comp. dynamics
Calculators - Standard atmosphere, mass properties, 6-dof
Viewers - solution, force/moment components, strand mesh

INSTALLATION, DOCUMENTATION, TUTORIALS

Installation software requirements

- Fortran 90 compiler (ifort, gfortran 4.4+) : all
- C compiler (gcc 4.4+, icc) : all
- C++ compiler (g++ 4.4+, icc) : USURP
- OpenGL, X11, Tcl/Tk 8.6.8 or earlier : OVERGRID
- Python, swig, gnuplot : OVERSMART
- Tcl wish, xmgrace or gnuplot : OVERPLOT

Installation instructions

- chimera2.2/doc/{INSTALLATION.html, overgrid.html}

Supported platforms

- Linux, Mac OS-X, (Windows: workable, unsupported)

Documentation

- chimera2.2/doc/man.html -> *.html

Tutorials

- chimera2.2/tutorials/* contains tutorials for OVERGRID, Script Library, and various scripting exercises

MAIN NEW FEATURES IN CGT 2.2

- Geometry interface for STEP and IGES files via Engineering Sketch Pad (ESP) (EGADS2SRF, SRF2EGADS, OVERGRID)

- Diagnostics for grid quality, domain connectivity (GRIDINF, INTCHK, OVERGRID)

- Visualization of
  - cut planes for curvilinear grids/solutions (OVERGRID)
  - components defined for forces/moments computation (OVERGRID)

- Command-line options for image dump (OVERGRID)

- Auto-determination/conversion of file types/attributes (FFIO Lib., overConvert)

- Multi-threaded Tcl script execution for volume mesh generation (Script Library)

- Residual history plots for components (OVERPLOT)

- Line loads computation (TRILOAD)

- Tutorial for script development for complete overset CFD pre-processing tasks

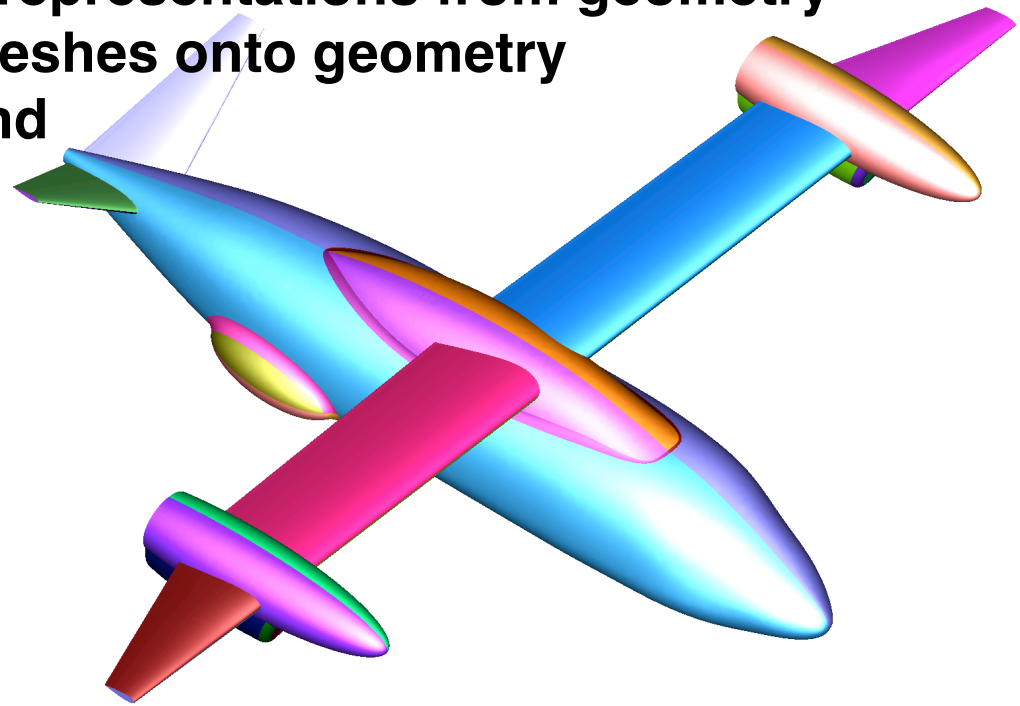
- See chimera2.2/doc/cgt2.2.txt for more details

GEOMETRY INTERFACE

- Engineering Sketch Pad (ESP) open source library from MIT
  - Parametric geometry creation and processing

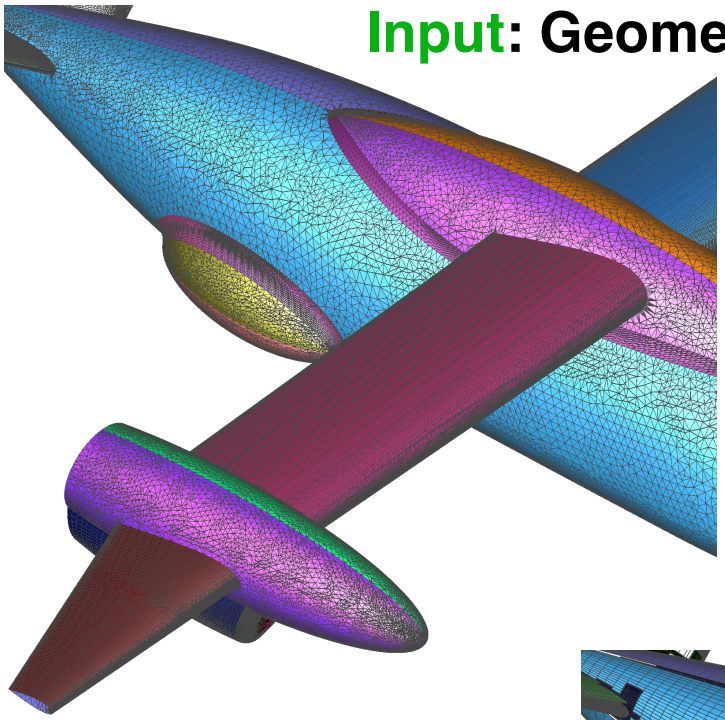
- Geometry formats allowed
  - Boundary Representation (BRep) solids in STEP or IGES files
  - Engineering Geometry Aircraft Design System (EGADS) geometry files

- CGT modules
  - EGADS2SRF generates discrete representations from geometry
  - SRF2EGADS projects discrete meshes onto geometry
  - OVERGRID provides GUI front end



EGADS2SRF

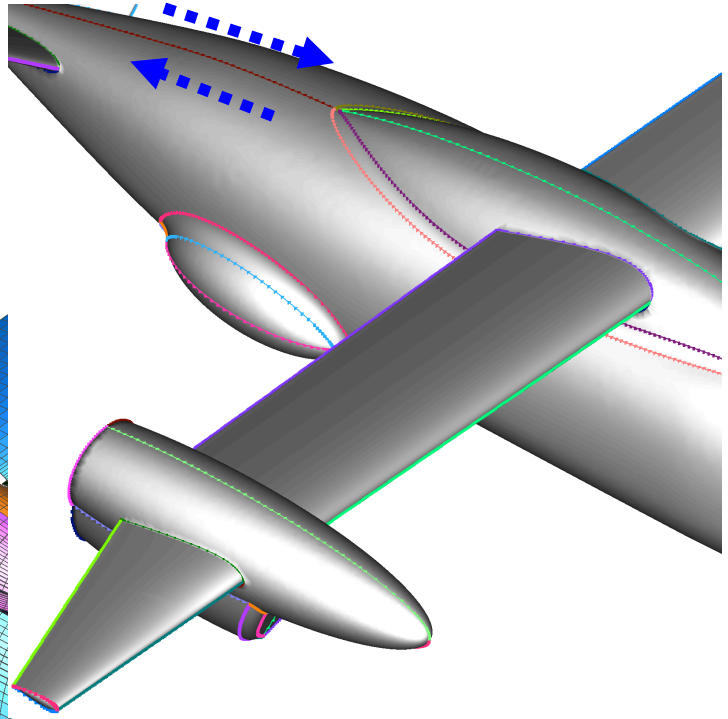
Input: Geometry from STEP, IGES, or EGADS files

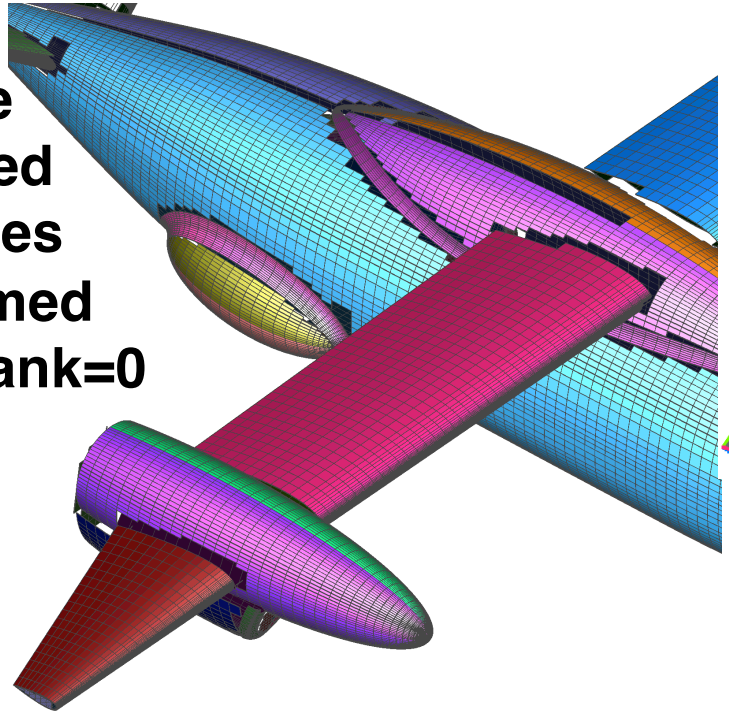


Output

1. Surface triangulation on tessellated trimmed BRep faces (CART3D)

3. Structured curves on tessellated BRep edges (PLOT3D)



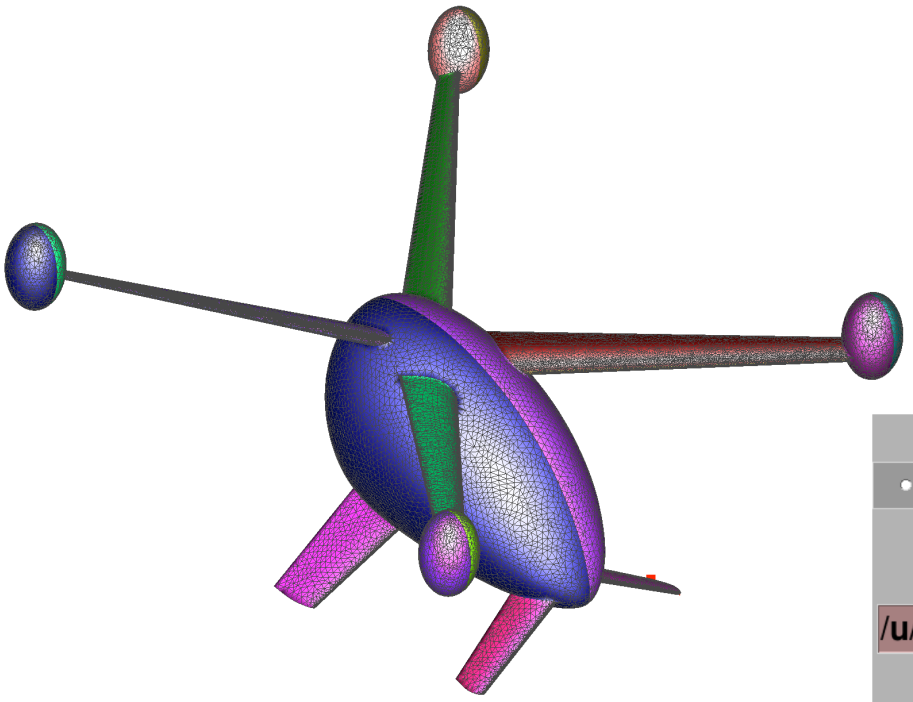


2. Structured surface patches on tessellated untrimmed BRep faces with vertices in trimmed region tagged by iblank=0 (PLOT3D)

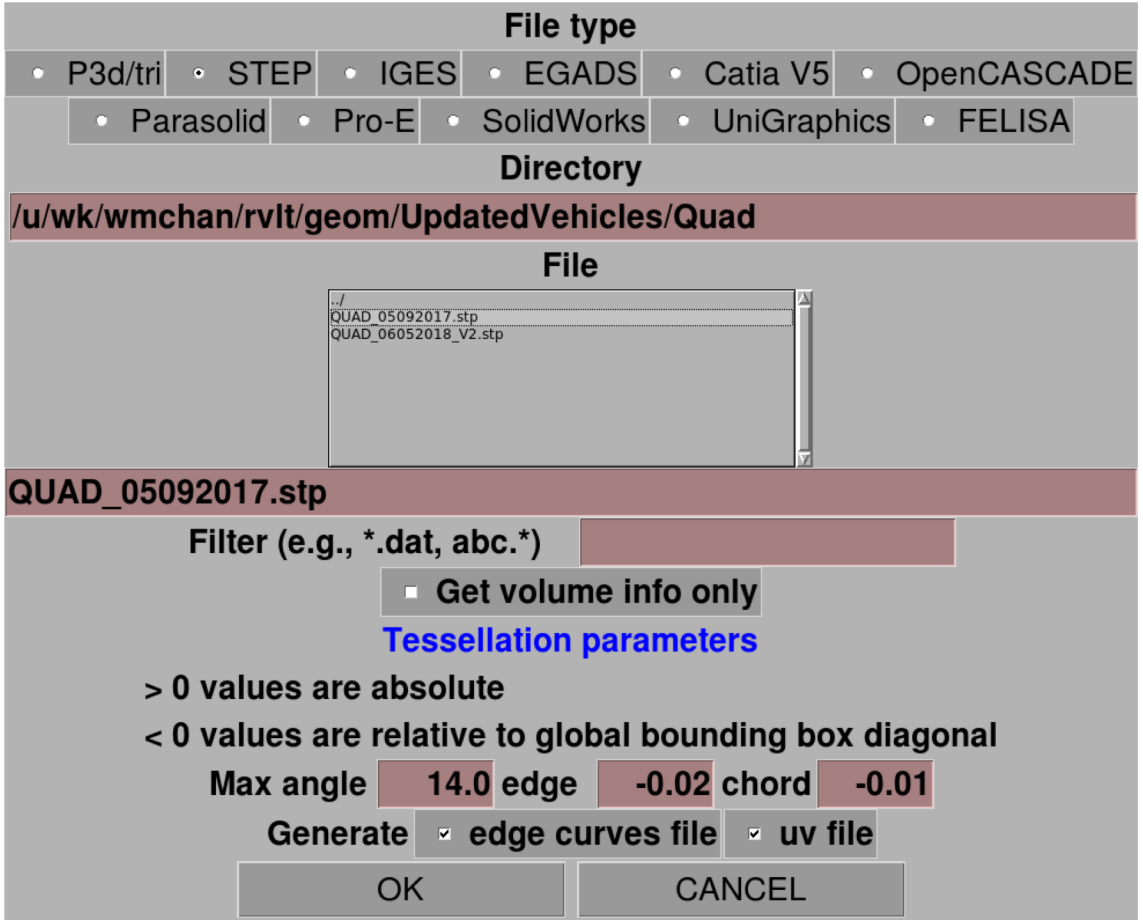
Control: maximum
- **dihedral angle**
- **cell size**
- **chordal deviation**

4. Topology data: BRep edge sense and adjacent faces (ASCII)

OVERGRID: VISUALIZATION OF STEP AND IGES FILES



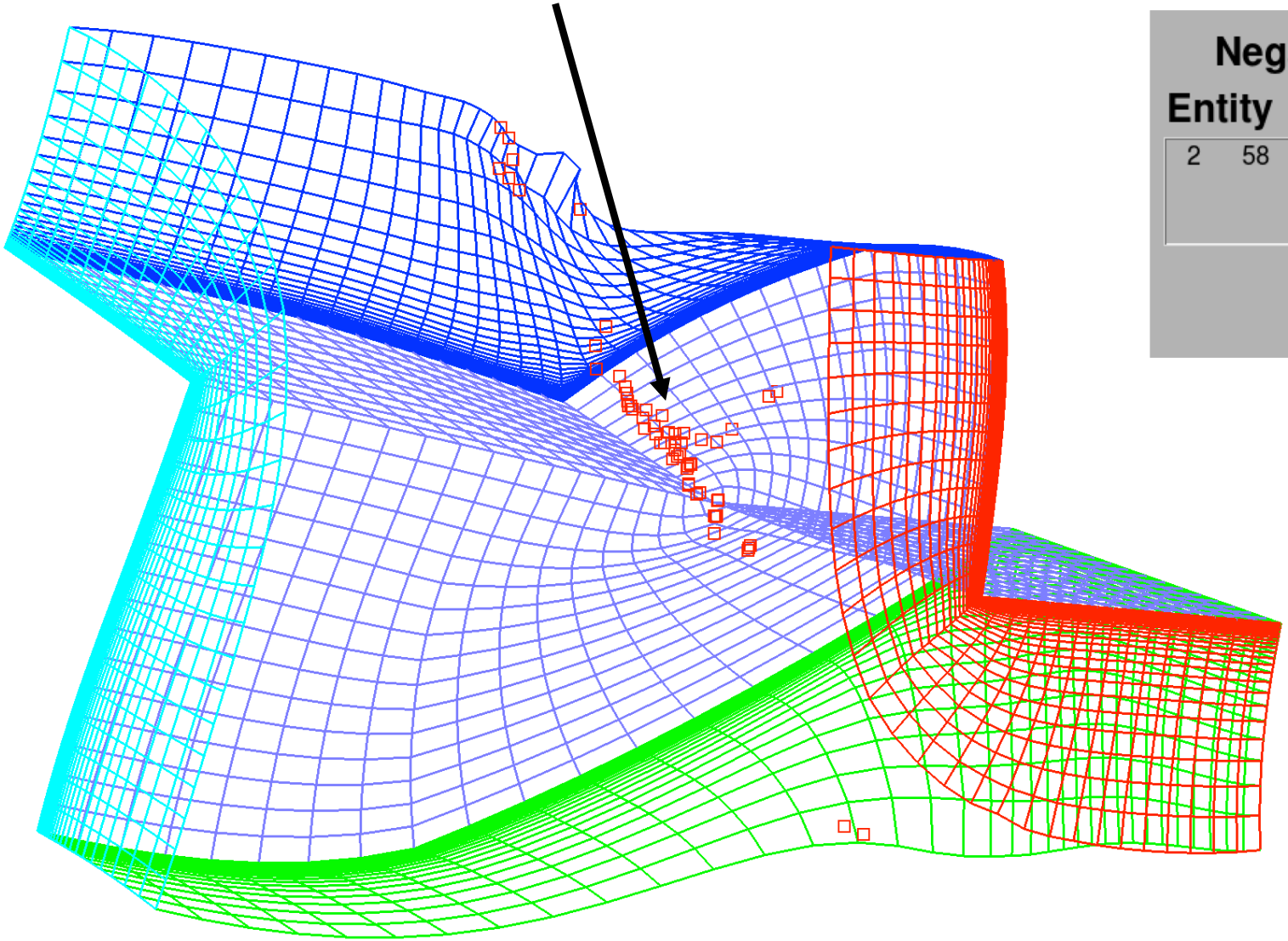
- Type “overgrid” on command line to launch window below
- Select STEP or IGES
- Auto call to egads2srf
- Auto load triangulation file

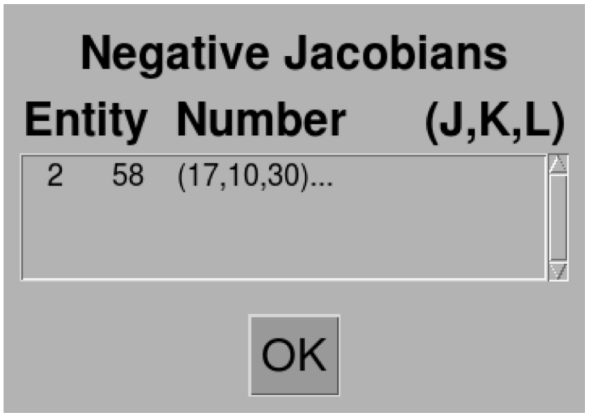


Control: maximum
- dihedral angle
- cell size
- chordal deviation

GRID QUALITY CHECKS (1)
Must-Pass: Jacobians (OVERGRID, MINMAX)

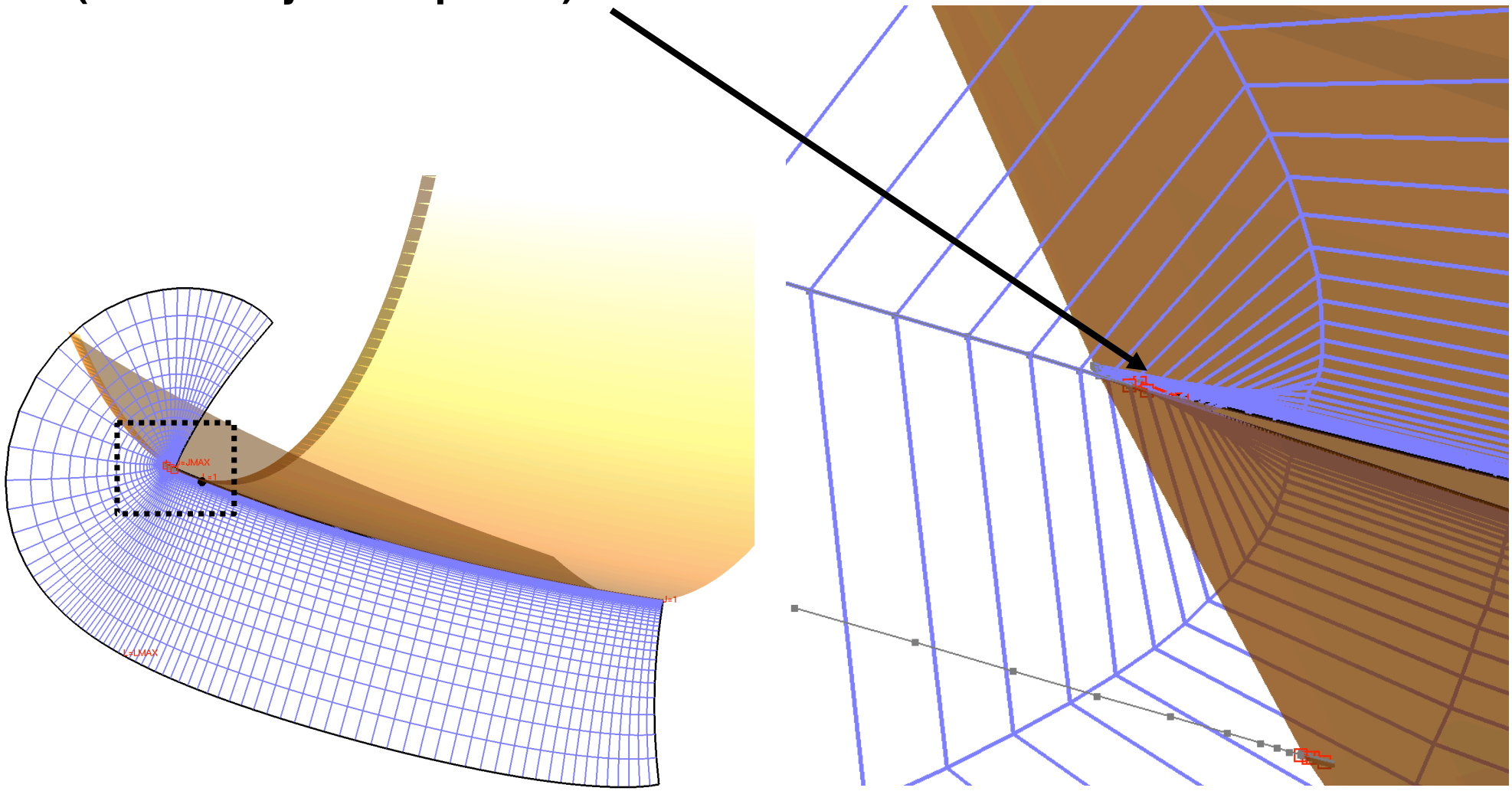
Jacobian computed using same subroutine as in target flow solver (negative Jacobian locations marked by red squares)





GRID QUALITY CHECKS (2)
Must-Pass: Self-Intersections (OVERGRID, GRIDED)

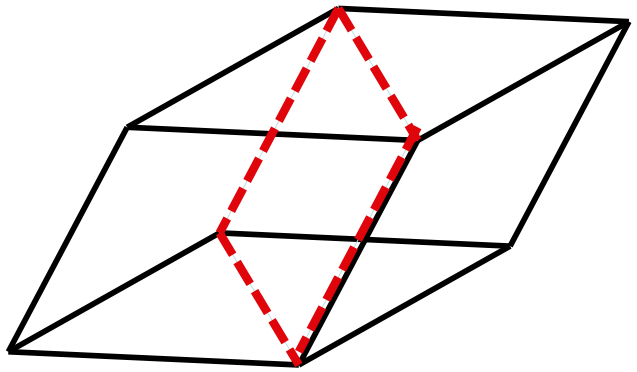
Self-intersection of volume grid points against surface grid (marked by red squares)



OVERGRID: GRID QUALITY CHECKS (2)
Mostly-Pass: Cell Volumes

Cell volume computed by hexahedral decomposition into 6 tetrahedrons

OVERGRID Diagnostic

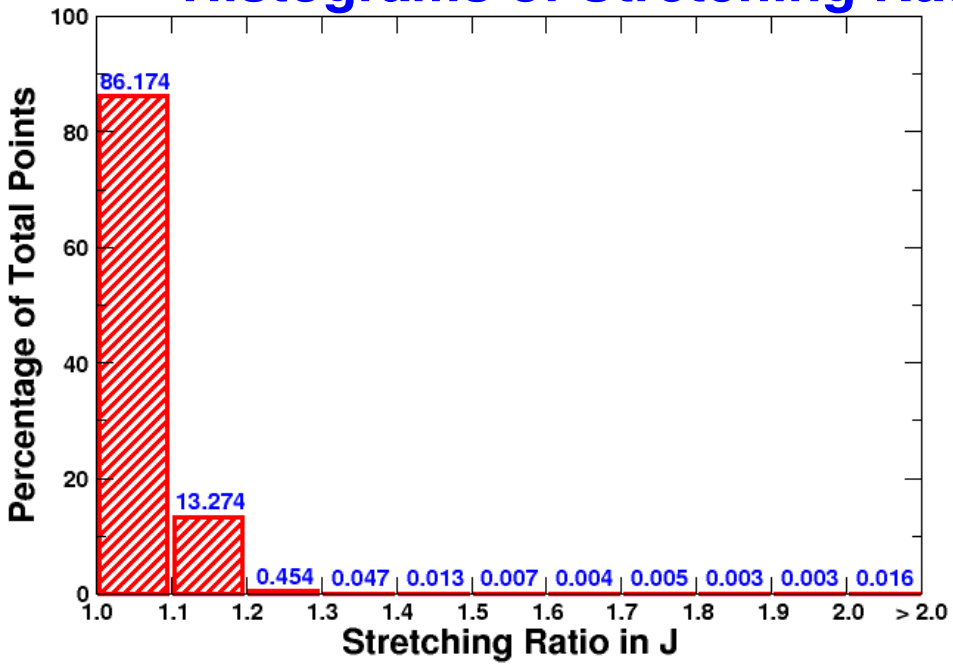


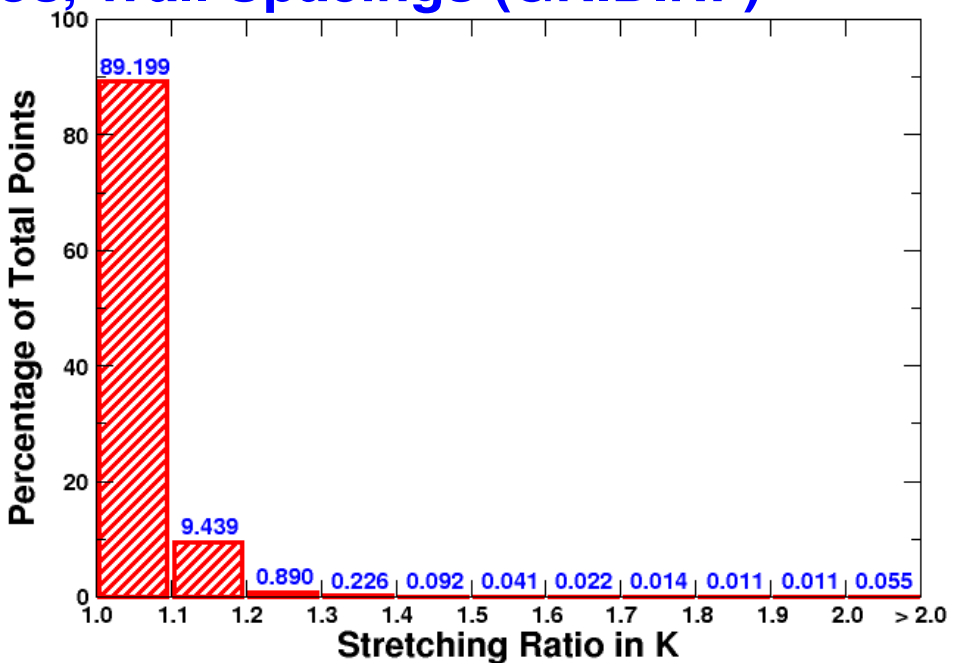
- Cut into 2 prisms
- Cut each prism into 3 tets
- Bad cell if
  1. any tet volume < 0
  2. sum of 6 tet volumes < 0

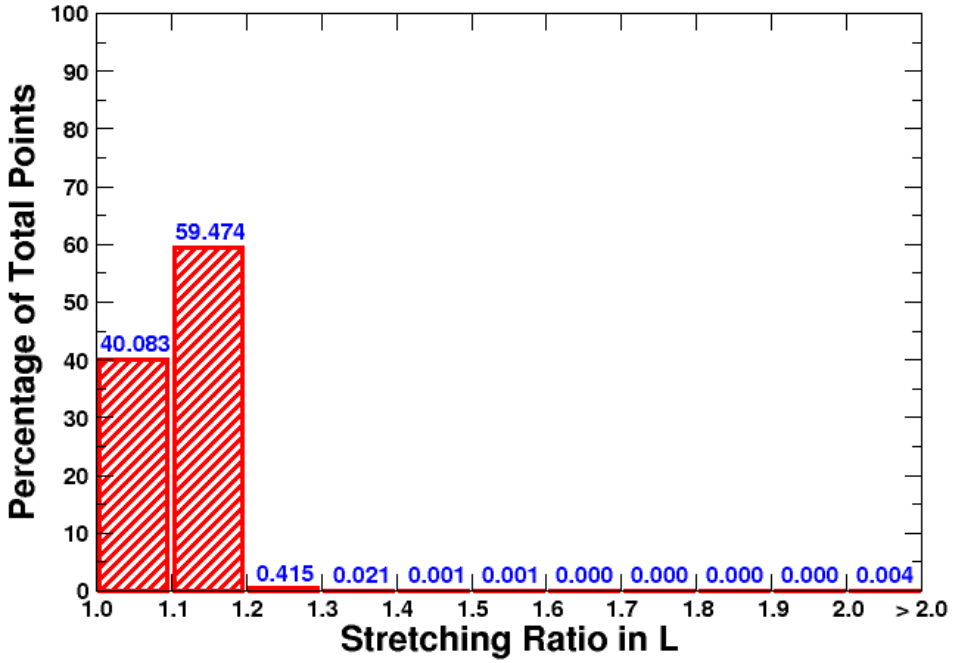
Cell Volume Check

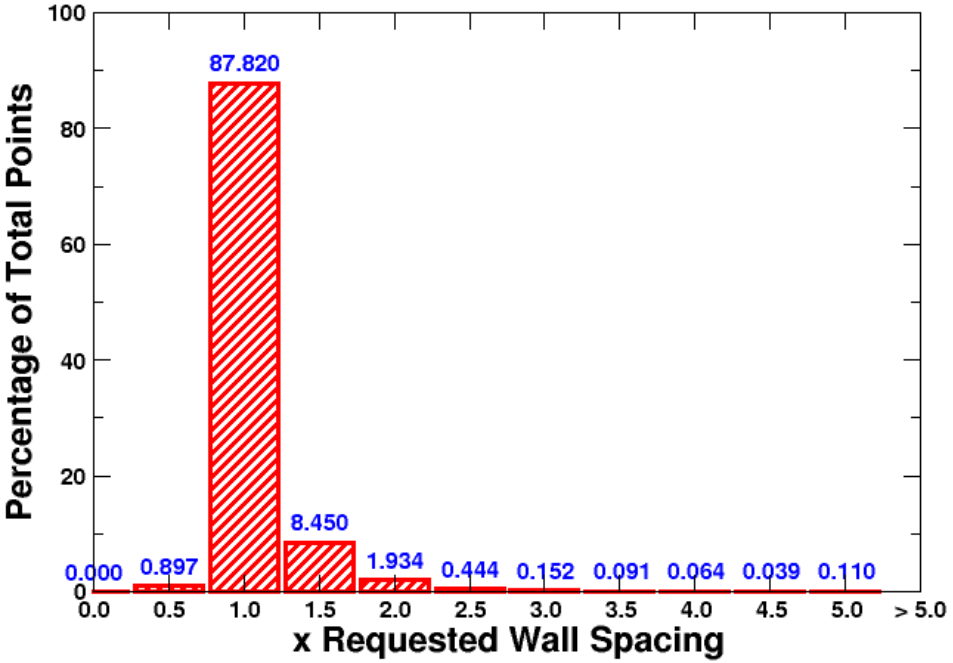
	Sum 6 tets			One or more tets	
	Negative sum			Negative vol	
Entity	# Cells	(J,K,L)	Min Vol	# Cells	Min Tet Vol
1	0				
2	0				
3	0		2.526e-04	9	-2.719e-06
4	0				
5	0		9.463e-04	186	-2.195e-04
6	0				
7	0		4.672e-04	59	-2.892e-04
8	0		3.594e-05	12	-4.785e-07
9	0		5.191e-04	6	-1.232e-07
10	1	(26,38,28)	-1.567e-03	216	-1.884e-03
11	0				
12	0				

GRID QUALITY CHECKS (3)
Histograms of Stretching Ratios, Wall Spacings (GRIDINF)

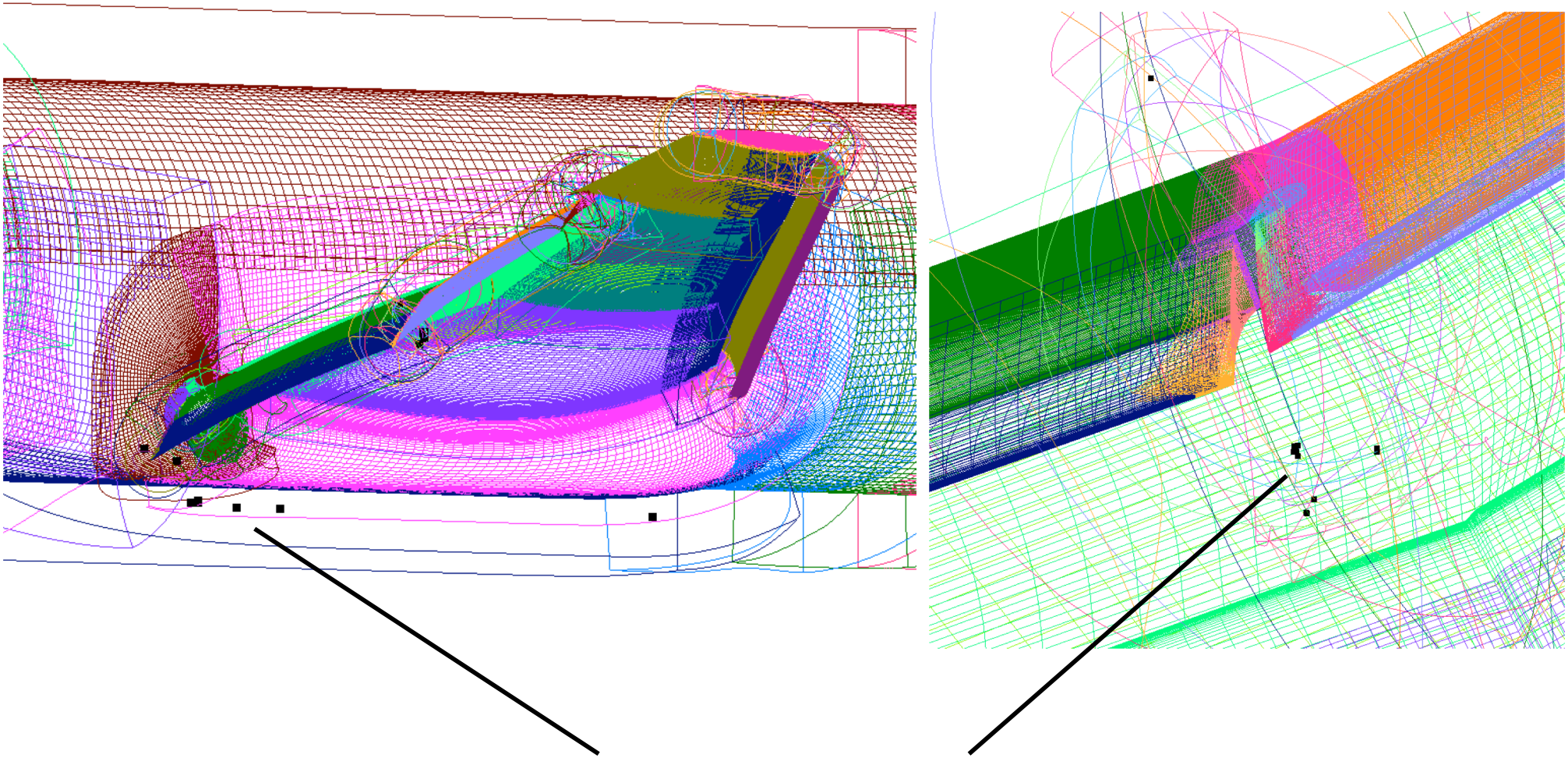








DOMAIN CONNECTIVITY QUALITY CHECKS (1)
Total number, location, and spread of orphan points (OVERGRID)

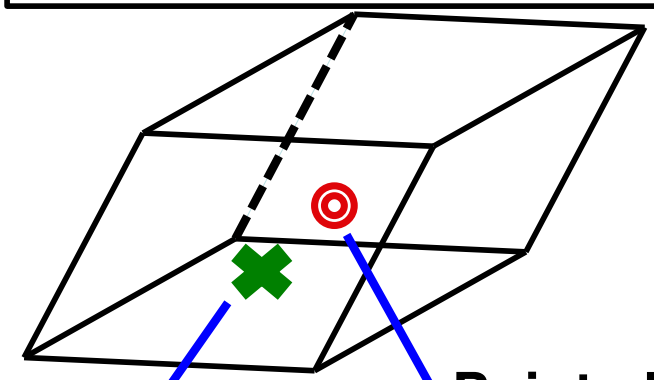


Total = 25, sparse points away from surface

DOMAIN CONNECTIVITY QUALITY CHECKS (2)
Fringe Point Donor Stencil Accuracy (OVERGRID, INTCHK)

Histogram of distance between fringe point and vertex obtained by donor stencil interpolation (intchk)

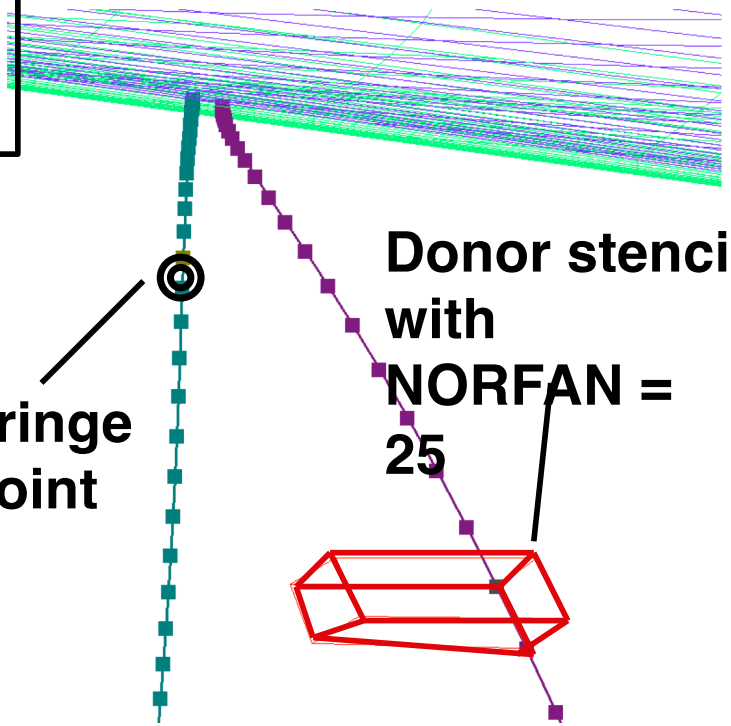
Distance	Number of pts	% Total
d < 0.0001,	2592370,	89.207
0.0001 <= d < 0.001,	127886,	4.401
0.001 <= d < 0.01,	128241,	4.413
0.01 <= d < 0.1,	47312,	1.628
0.1 <= d < 1.0,	10167,	0.350
1.0 <= d < 10.0,	49,	1.7E-03
10.0 <= d,	0,	0.0



Fringe point

Point obtained using interpolation coefficients on 8 corners of donor cell

Set NORFAN carefully in OVERFLOW for viscous stencil repair



Fringe point

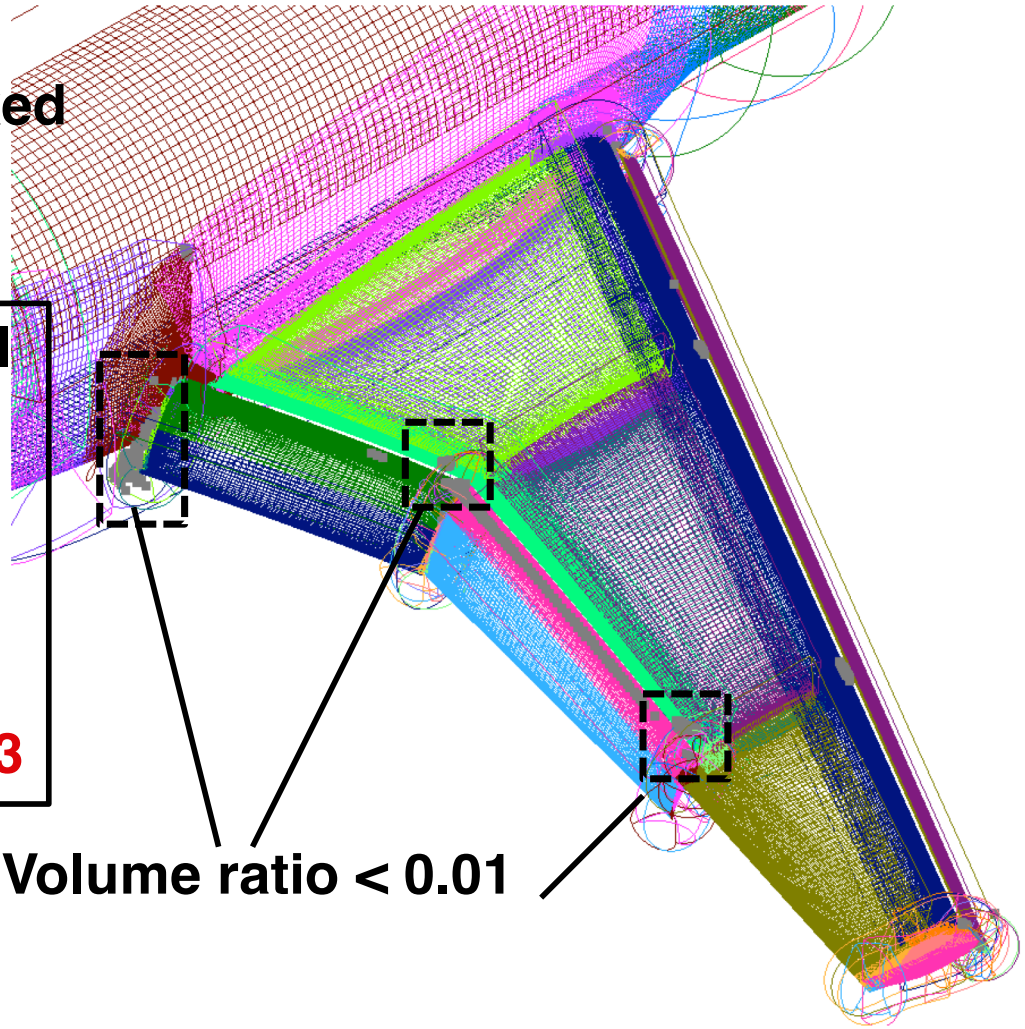
Donor stencil with NORFAN = 25

DOMAIN CONNECTIVITY QUALITY CHECKS (3)
Donor Stencil Attributes Compatibility (OVERGRID, INTCHK)

Compatibility of cell attributes between fringe point and donor stencil
- **Cell volume ratio histogram table (intchk) and location map (OVERGRID)**
- **Bad ratio => gradients cannot be transferred accurately between grids**

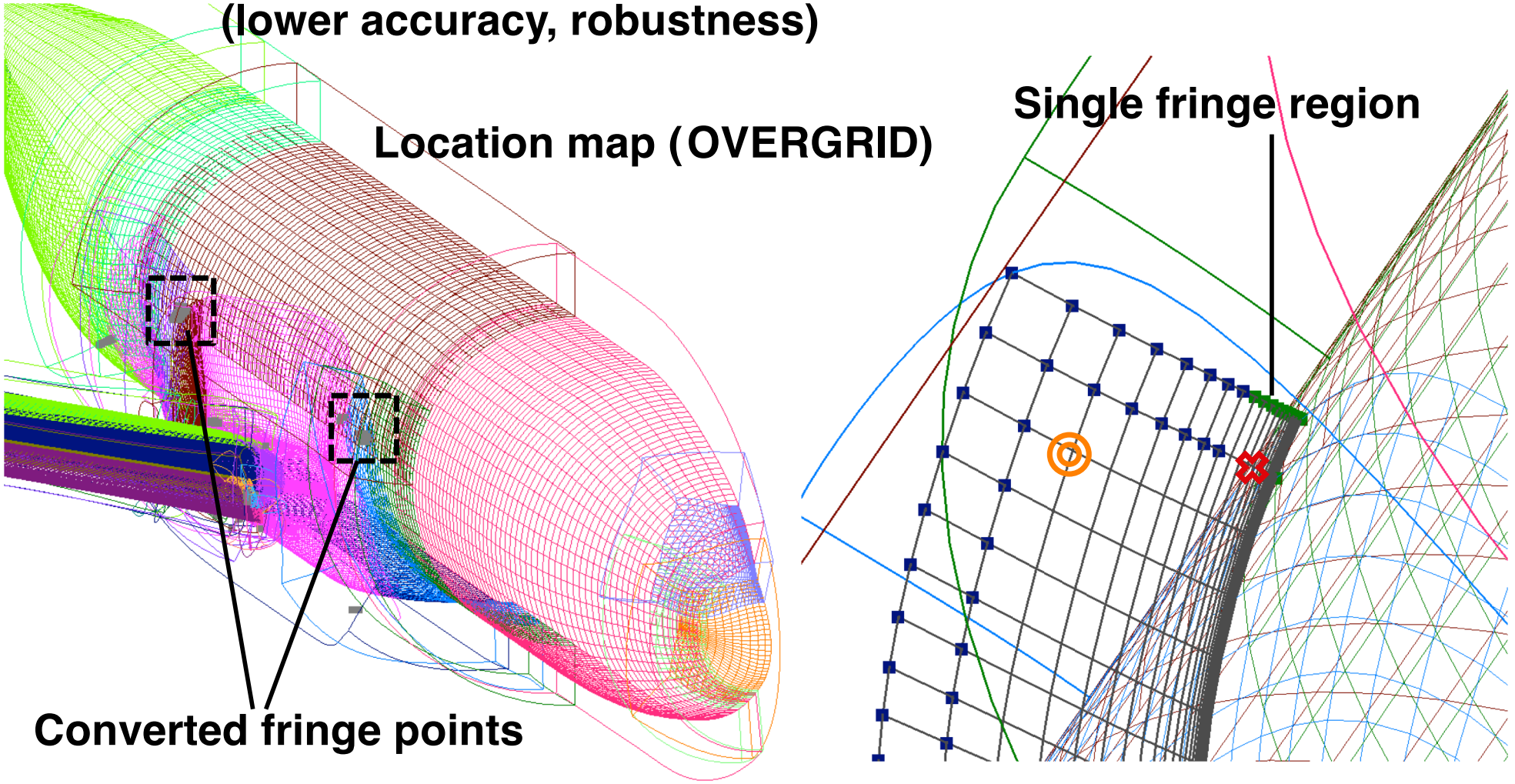
Other attributes that could be checked
- **Cell aspect ratio, orientation**

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



DOMAIN CONNECTIVITY QUALITY CHECKS (4)
Conversion to Lower Fringe Layers (OVERGRID, INTCHK)

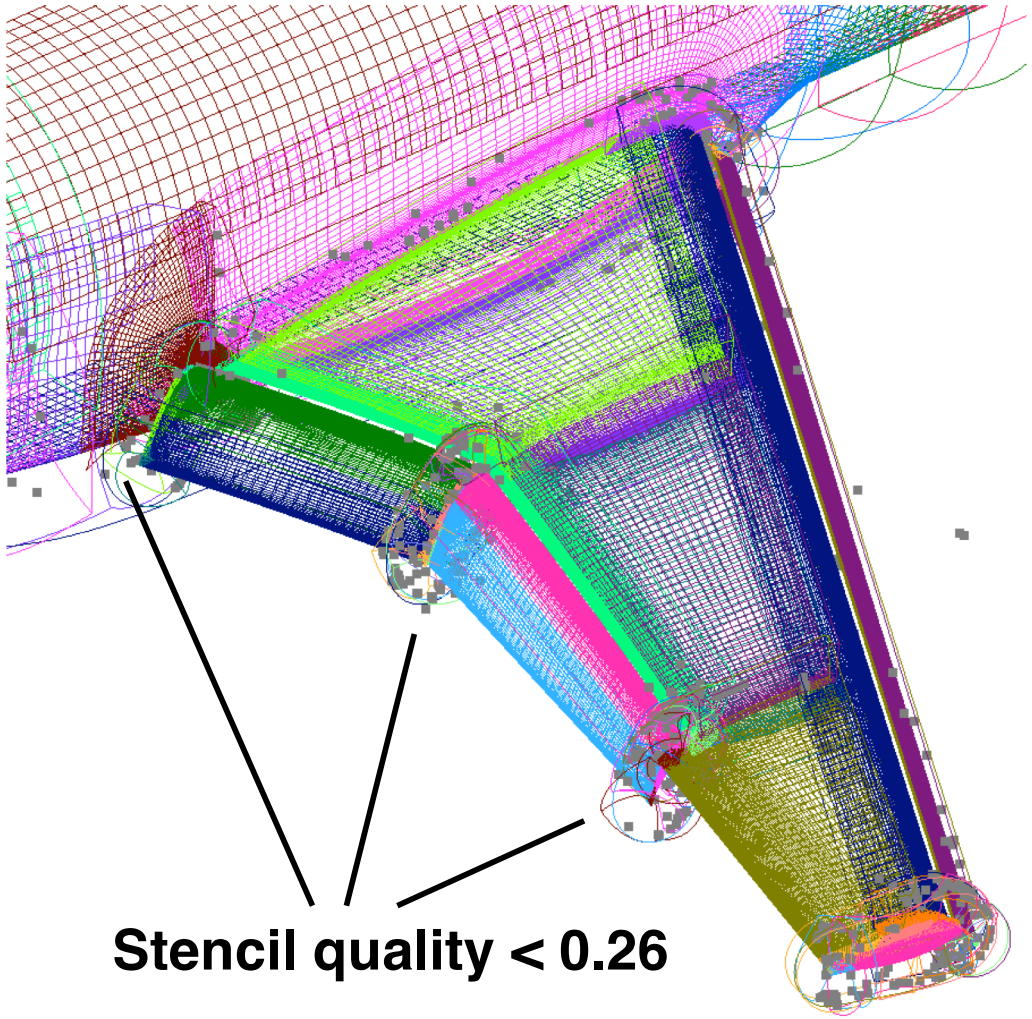
- Insufficient grid overlap to support double fringe locally
- Option to convert from double fringe to single fringe
  => full 5-point differencing stencil not supported in flow solver
  (lower accuracy, robustness)



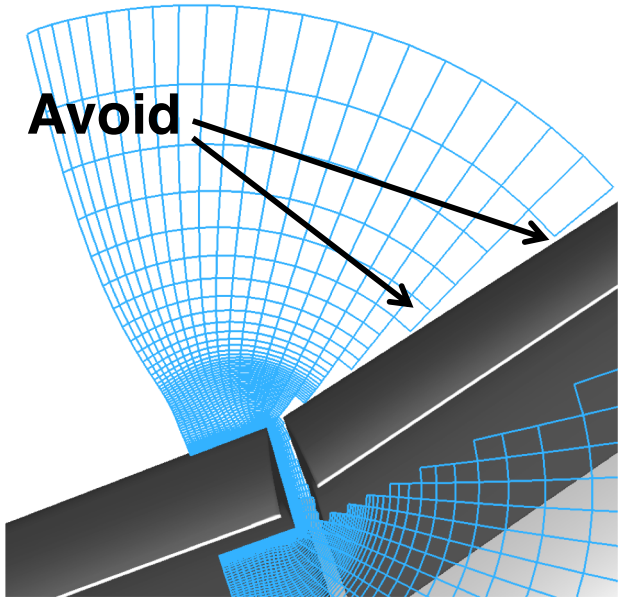
DOMAIN CONNECTIVITY QUALITY CHECKS (5)
Donor Stencil Quality (OVERGRID, INTCHK)

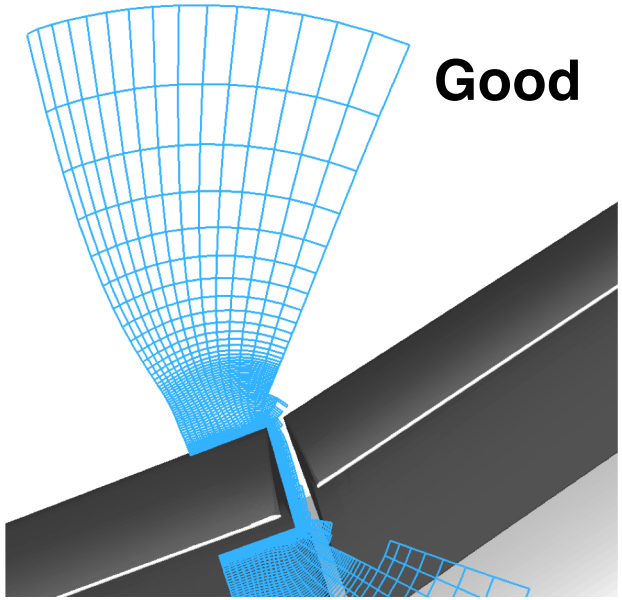
Histogram table (intchk) and location map (OVERGRID)

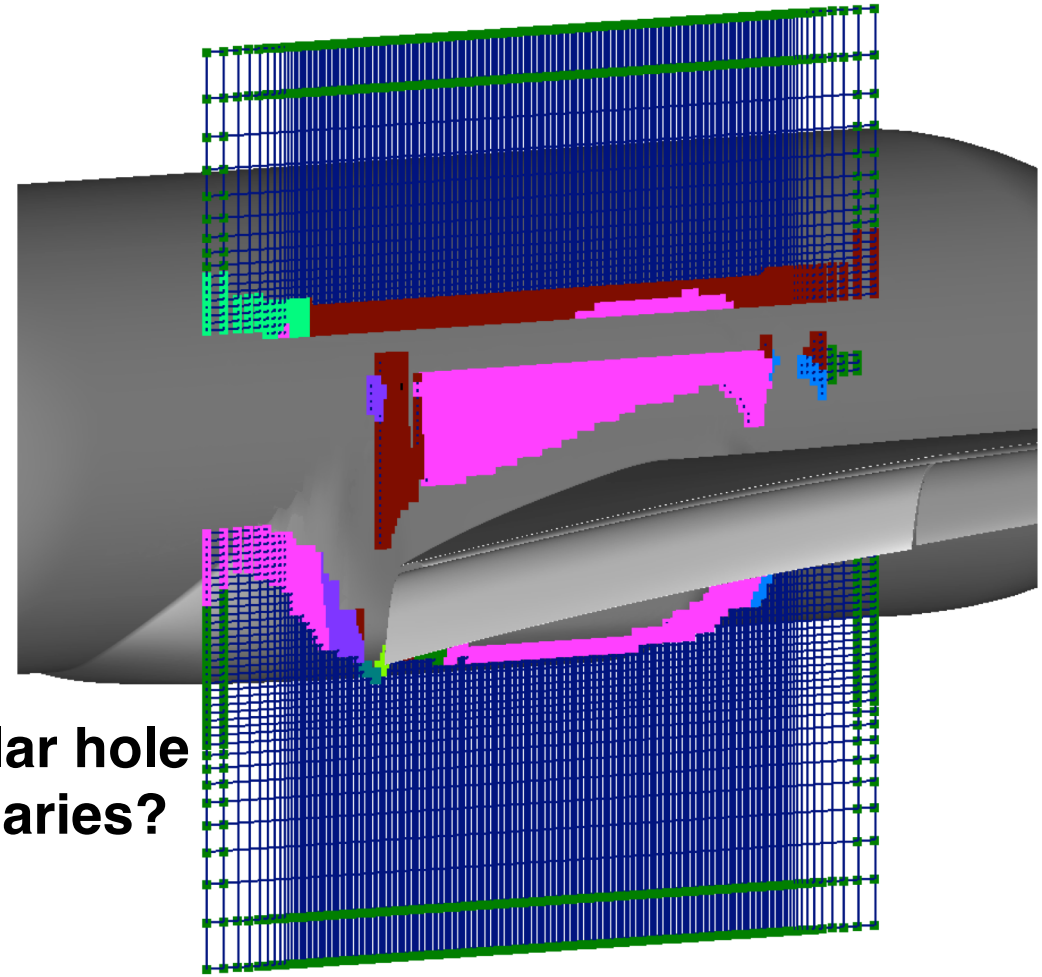
Stencil Quality	Number	% Total
Q = 0.0	0	0.0000
0.0< Q < 0.1	0	0.0000
0.1<= Q < 0.2	0	0.0000
0.2<= Q < 0.3	4858	0.1672
0.3<= Q < 0.4	12120	0.4171
0.4<= Q < 0.5	14660	0.5045
0.5<= Q < 0.6	14054	0.4836
0.6<= Q < 0.7	19504	0.6712
0.7<= Q < 0.8	24788	0.8530
0.8<= Q < 0.9	23280	0.8011
0.9<= Q < 1.0	45317	1.5594
Q = 1.0	2573858	88.5697



DOMAIN CONNECTIVITY QUALITY CHECKS (6)
Hole Boundary Location & Smoothness (OVERGRID)



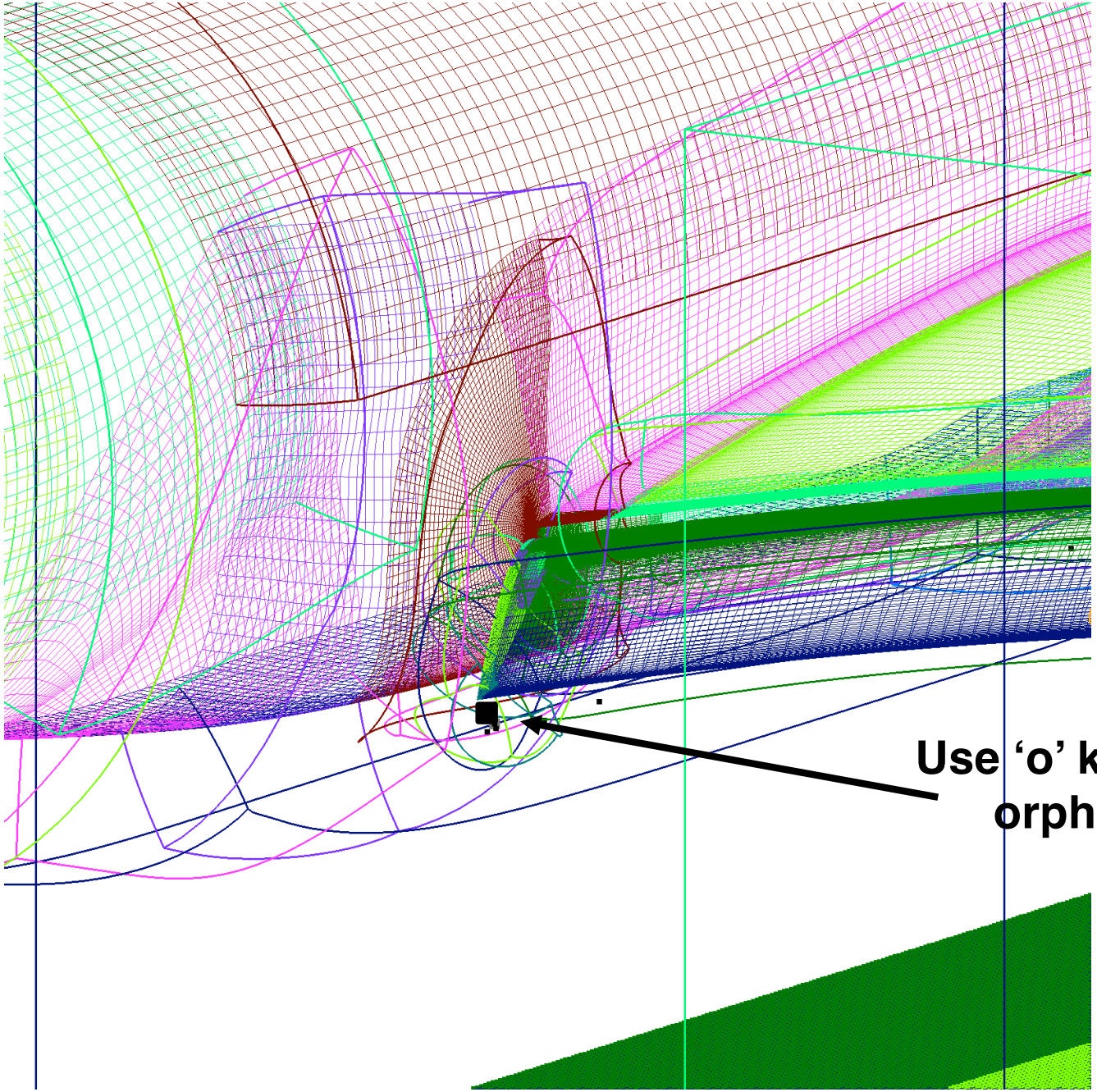




Irregular hole boundaries?

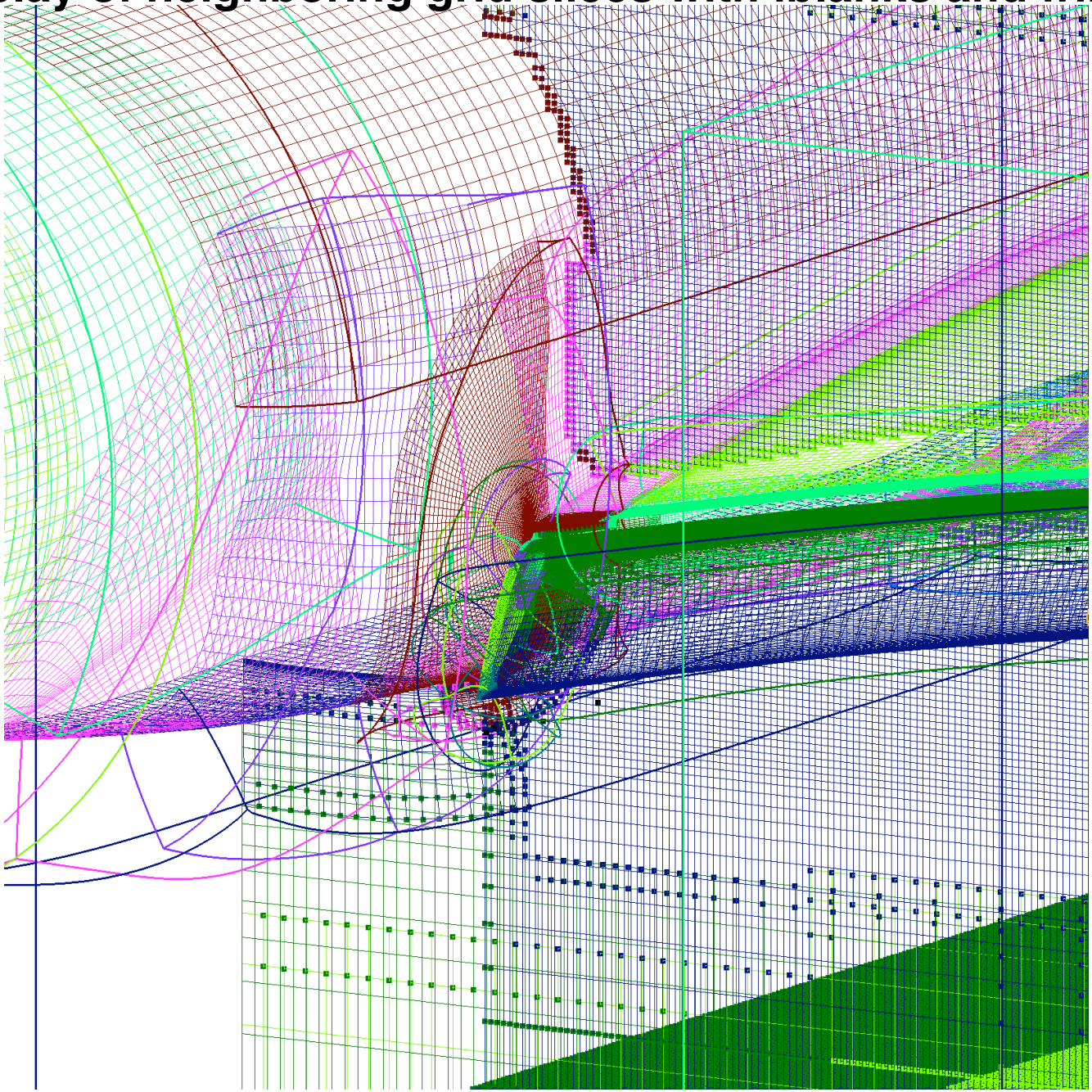
Chan, Pandya, Rogers, Efficient Creation of Overset Grid Hole Boundaries and Effects of Their Locations on Aerodynamic Loads, AIAA Paper 2013-3074, 2013.

ORPHAN POINTS REDUCTION / ELIMINATION IN OVERGRID (1)



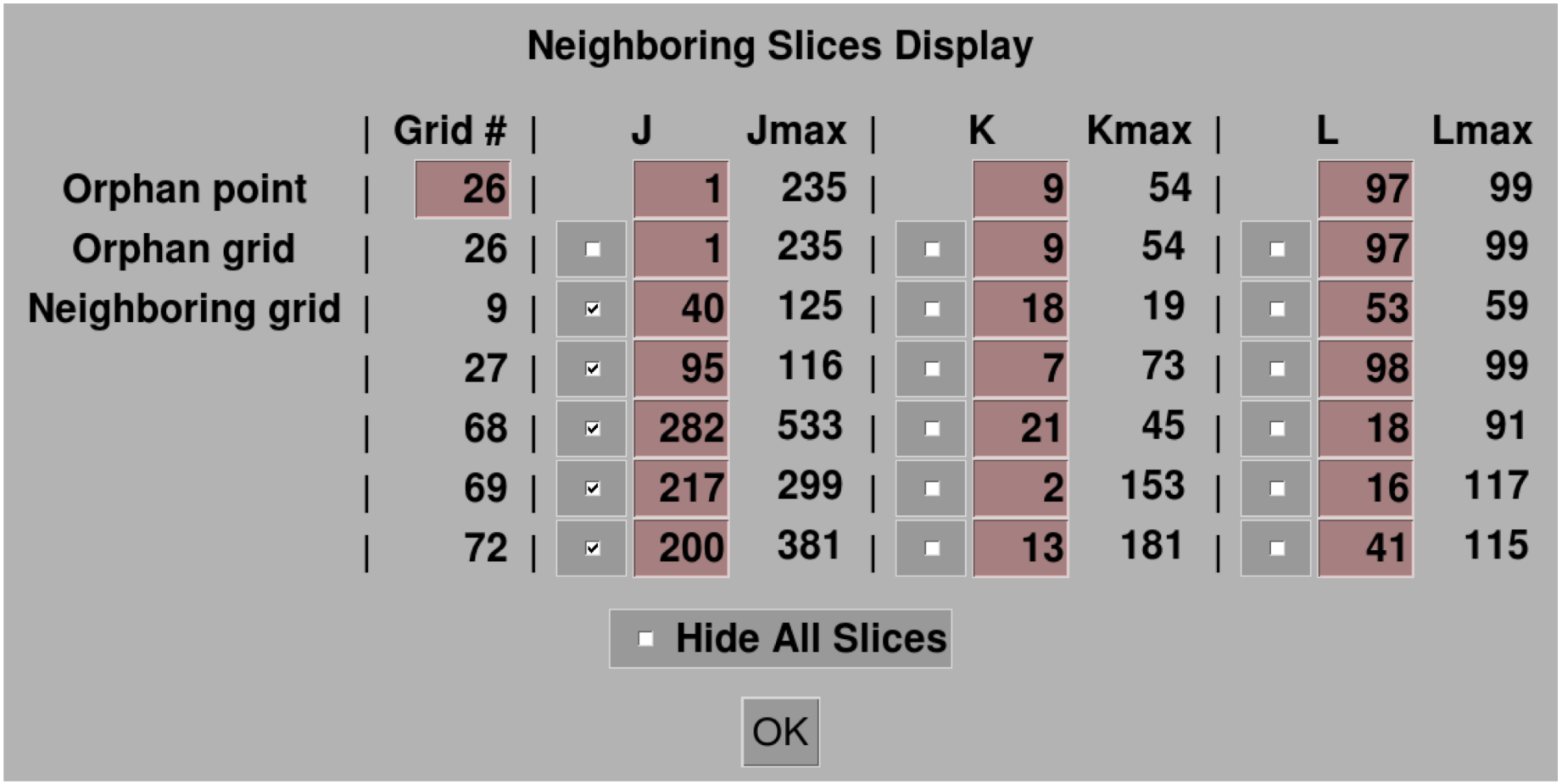
ORPHAN POINTS REDUCTION / ELIMINATION IN OVERGRID (2)

Auto display of neighboring grid slices with iblanks and fringe points



ORPHAN POINTS REDUCTION / ELIMINATION IN OVERGRID (3)

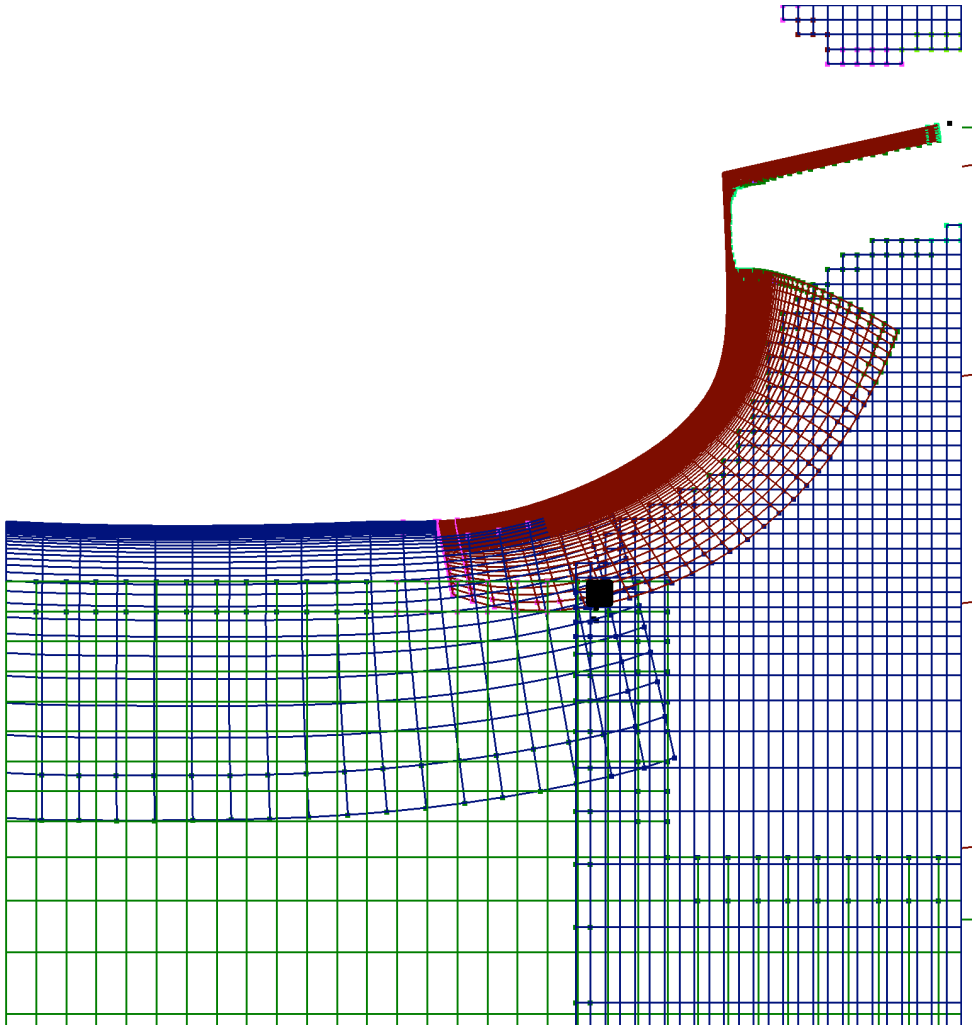
Widgets for toggling display of all neighboring grid slices that may contain selected orphan point

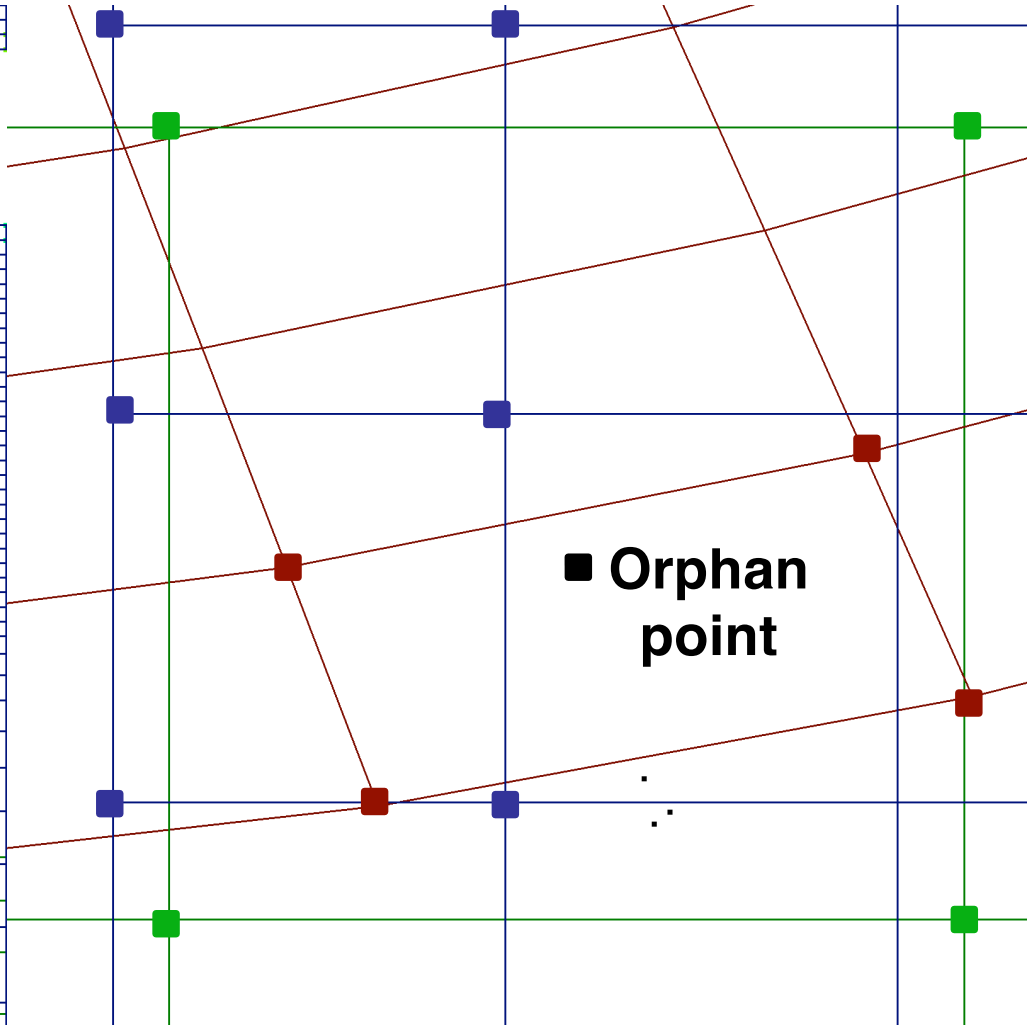


ORPHAN POINTS REDUCTION / ELIMINATION IN OVERGRID (4)

Zoomed-in view

Even more zoomed-in view showing fringe point locations of neighboring slices



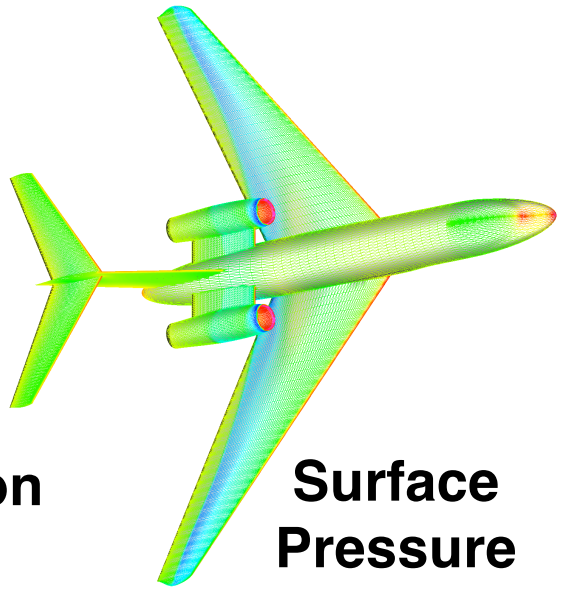


VISUALIZATION OF SURFACE TRIANGULATIONS IN .TRIX FORMAT IN OVERGRID

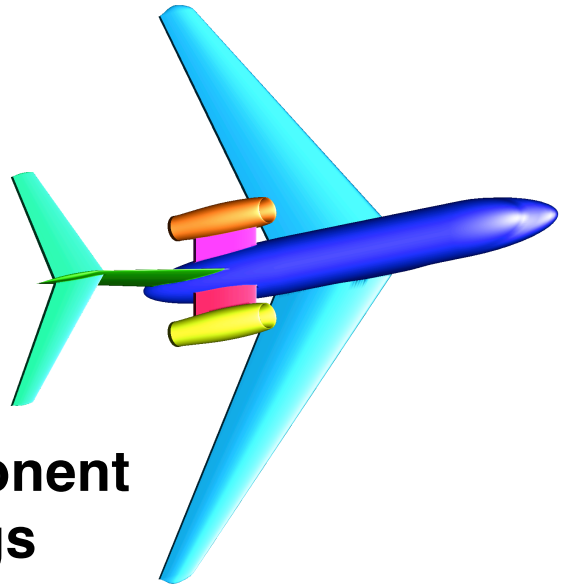
CART3D trix file with vertex-centered and cell-centered scalars



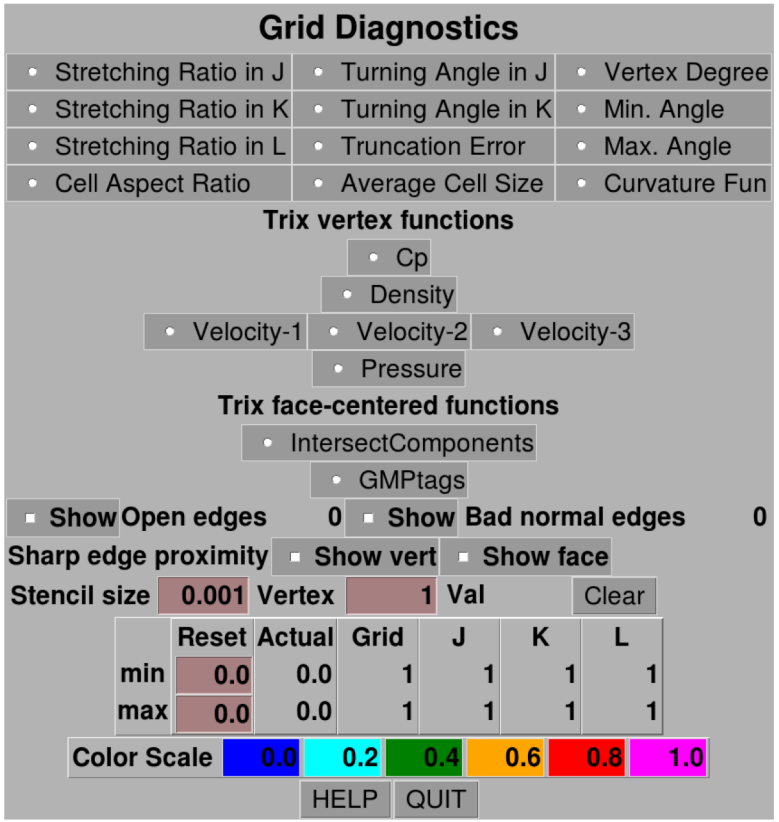
Triangulation Mesh

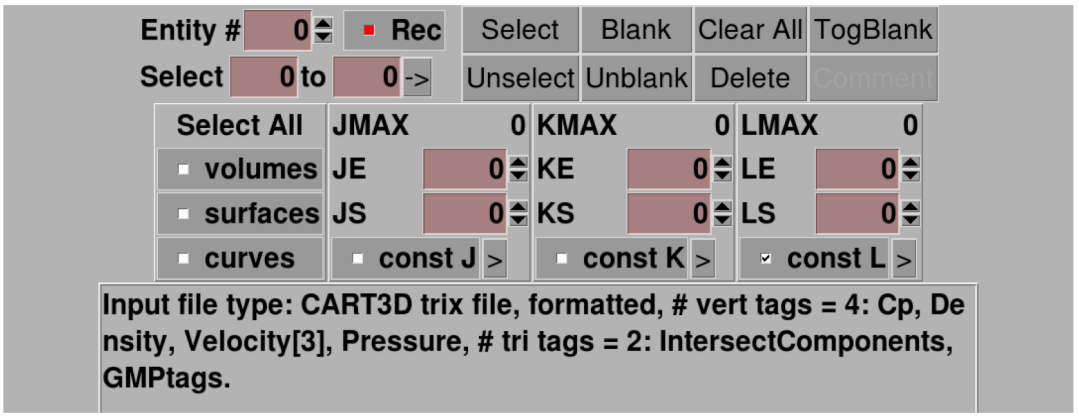


Surface Pressure



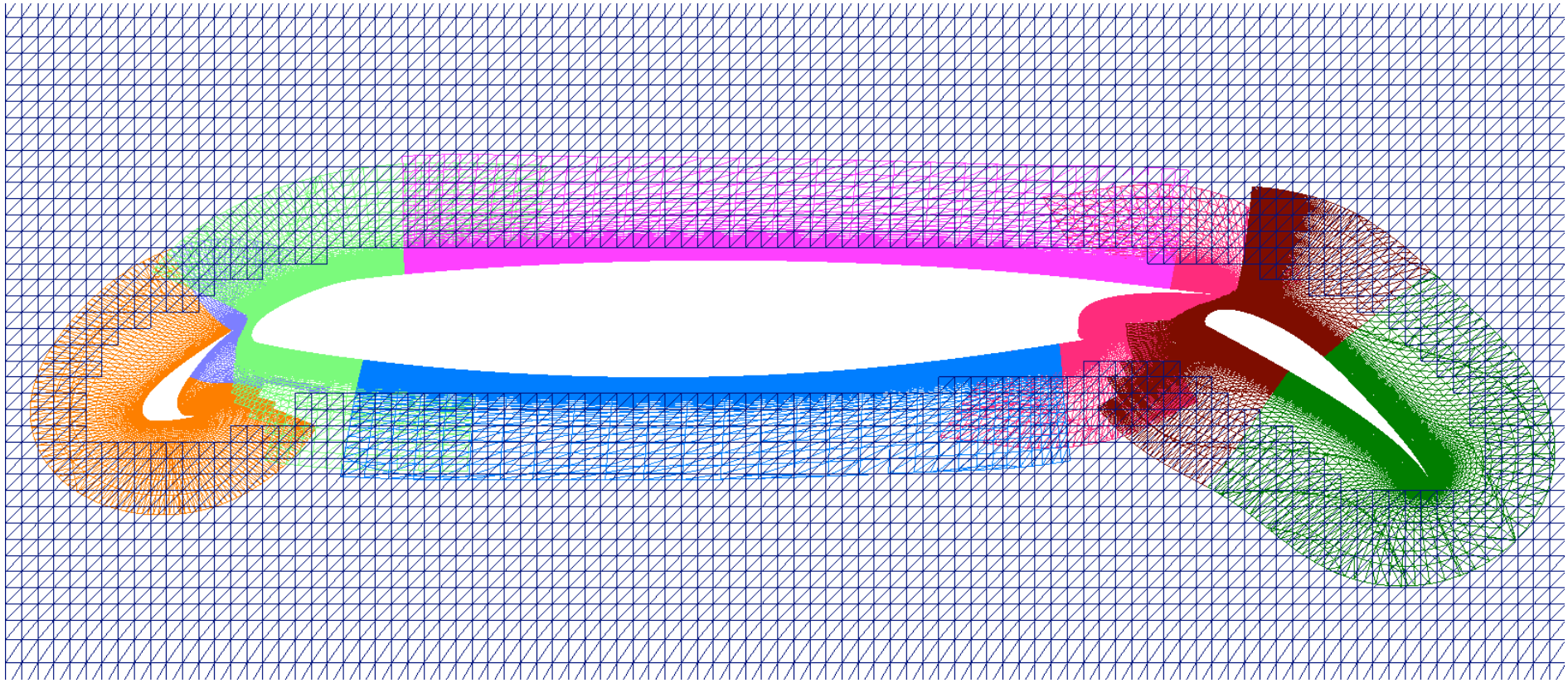
Component Tags





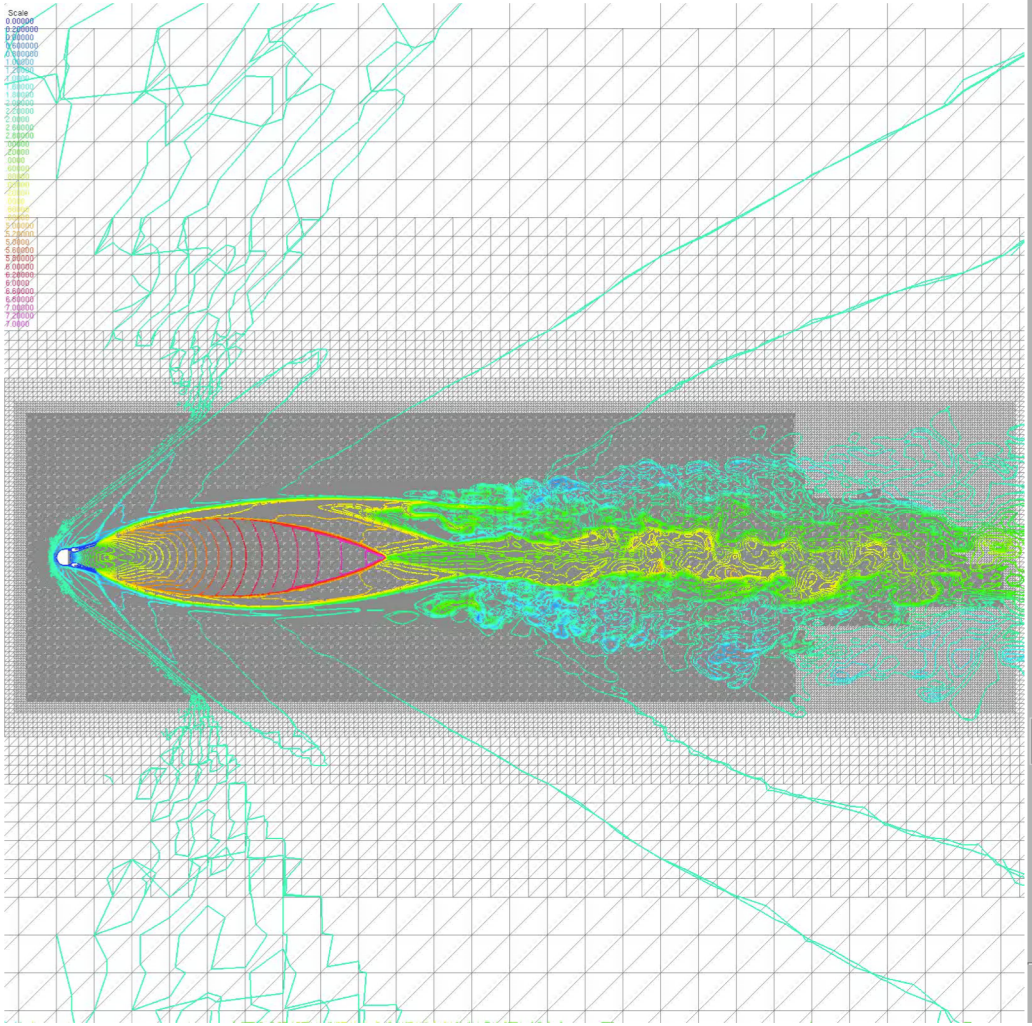
CUT PLANE GENERATION IN CVA

- Generate cut plane through multiple structured overset curvilinear grid and solution file -> .triq file
- Cut
  - constant x/y/z
  - arbitrary defined by Ax + By + Cz + D = 0
- Command line mode and scriptable
- Long term goal of performing control volume analysis



CUT PLANE VISUALIZATION IN OVERGRID (LINE CONTOURS)

Visualize single or multiple frames of .triq files generated by
- **cut-plane option in OVERFLOW**
- **external sources (read from files)**



Solution Viewer for Static and Dynamic Surfaces

Number of near-body grids 1

Surface Specification | Auto subset reset | Adaptive grids

Grid: Show

Q: Frames single multiple

Filenames

Root Extension

FT_BF start 002550 end 004750

inc frame time 1

Read Files read 0 Show

Frame # 0 Filename extension REC PLAY

Slow frame play by factor of 1

Scalar Functions

rho | rho u | rho v | rho w | e

u | v | w | velocity magnitude | Mach number

pressure | pressure coefficient | sound speed

temperature | internal energy | total enthalpy | entropy

Log10

Vector Functions

velocity

Show arrow head | Scale vector length | Scale factor 0.1

Display Options

Wireframe | Line Contours | Shaded Surface

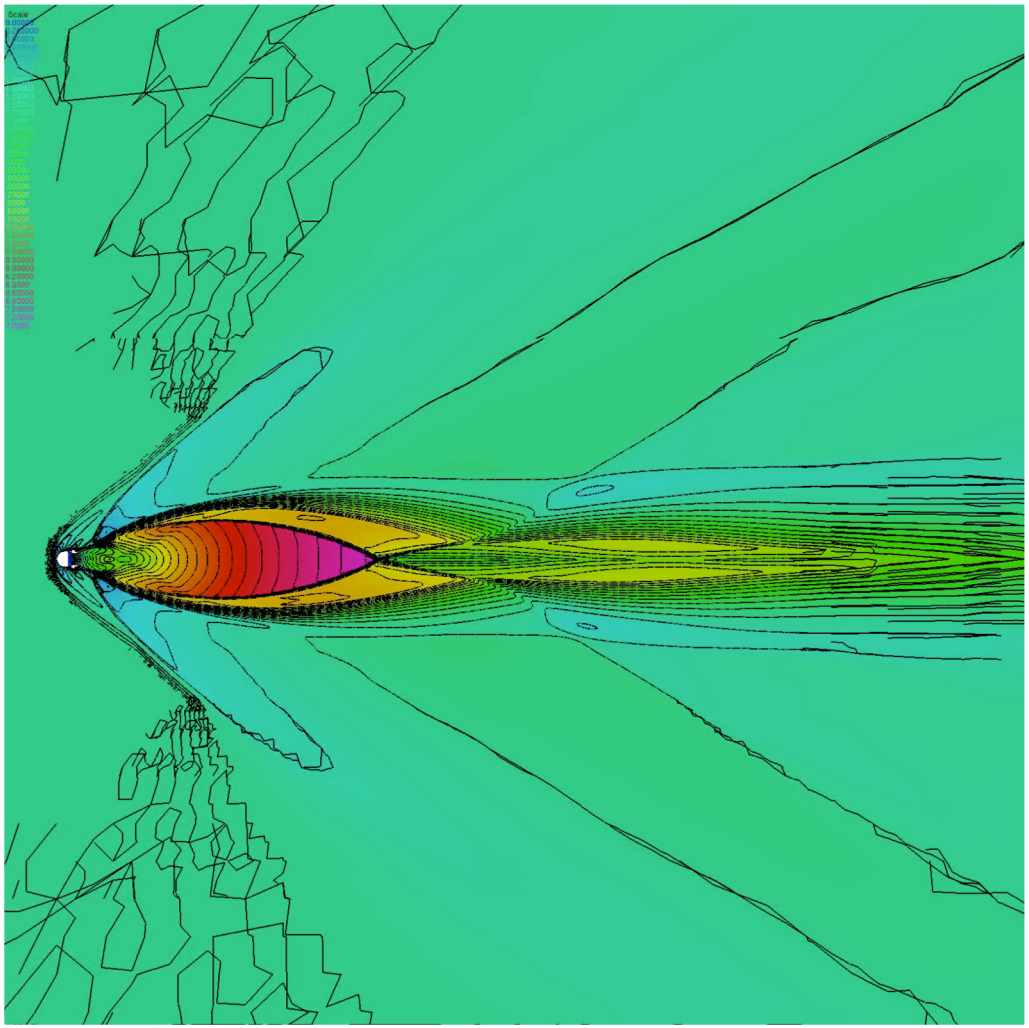
Color scale

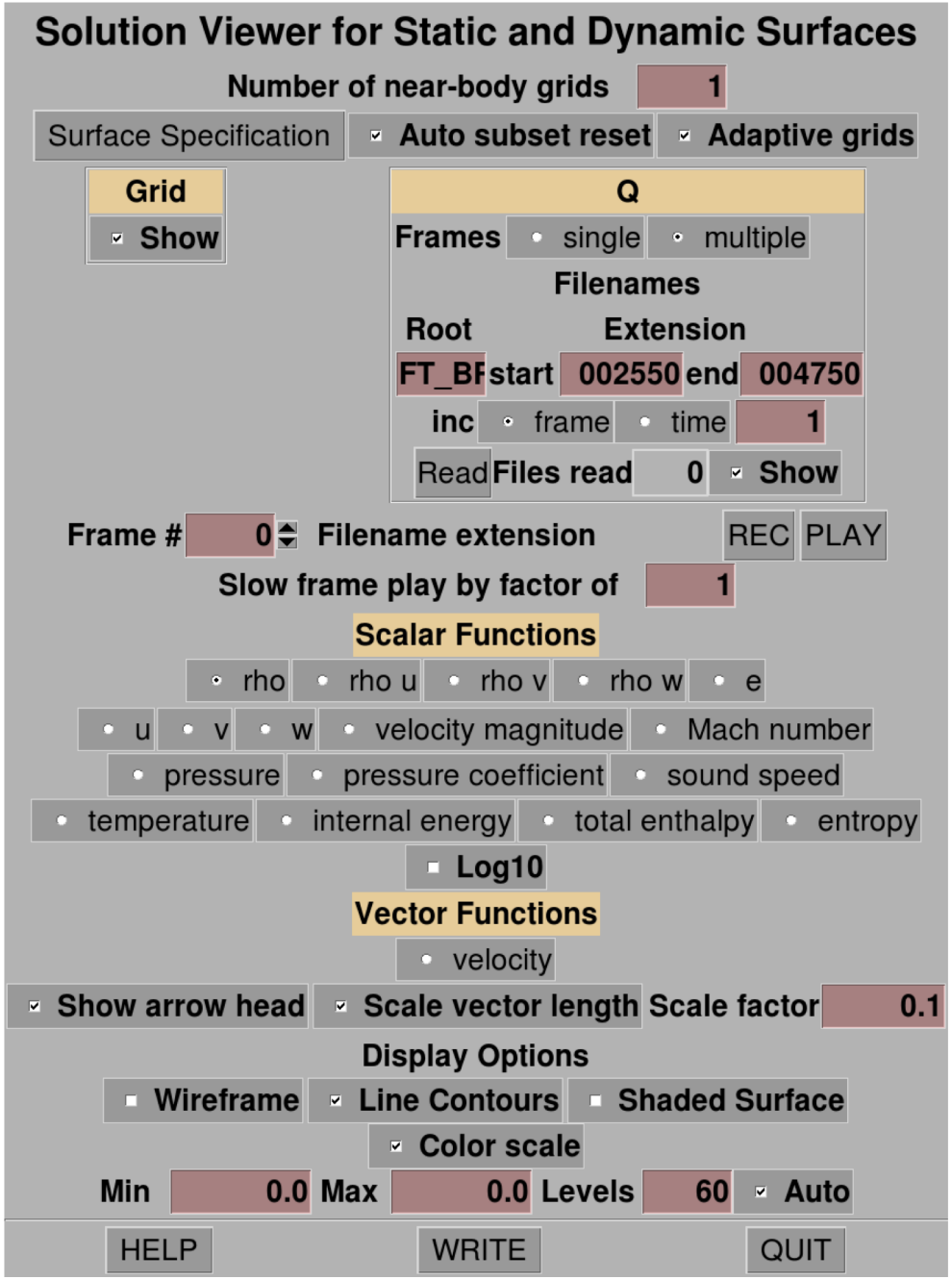
Min 0.0 Max 0.0 Levels 60 Auto

HELP | WRITE | QUIT

CUT PLANE VISUALIZATION IN OVERGRID (SHADED CONTOURS)

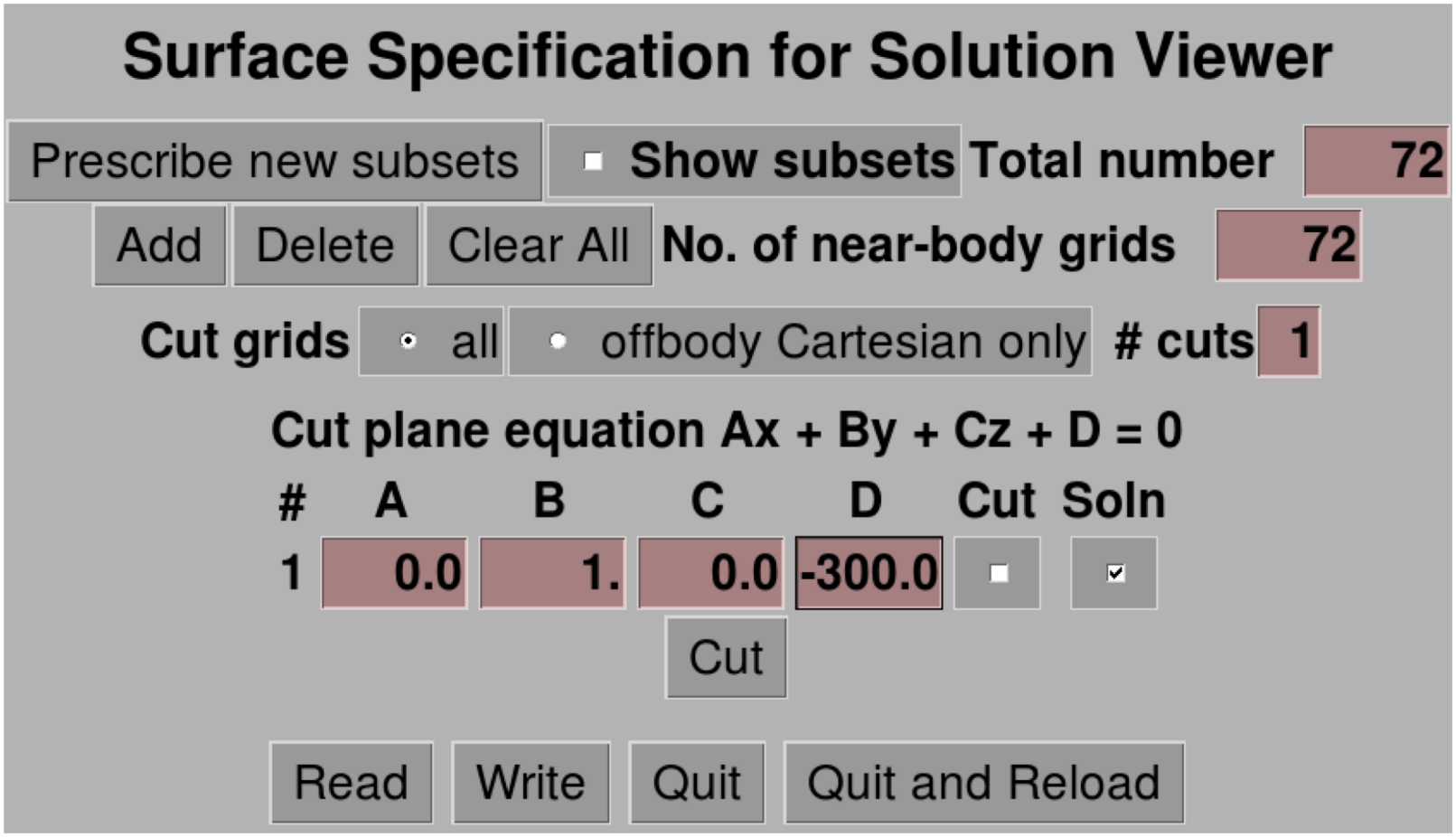
Visualize single or multiple frames of .triq files generated by
- **cut-plane option in OVERFLOW**
- **any other means**



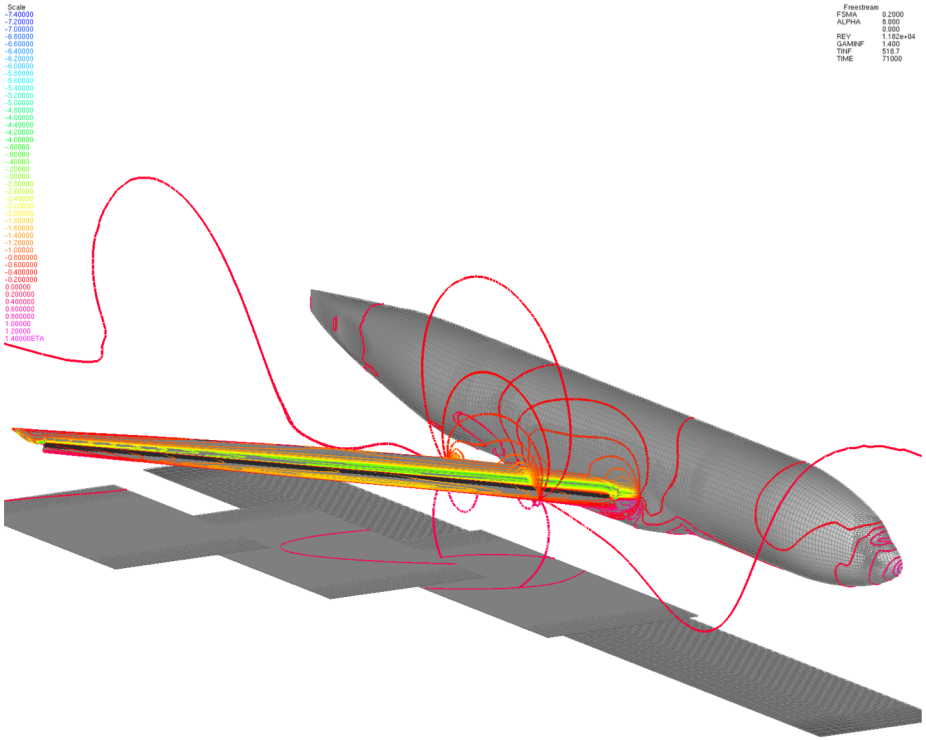


CUT PLANE GENERATION AND VISUALIZATION IN OVERGRID (1)

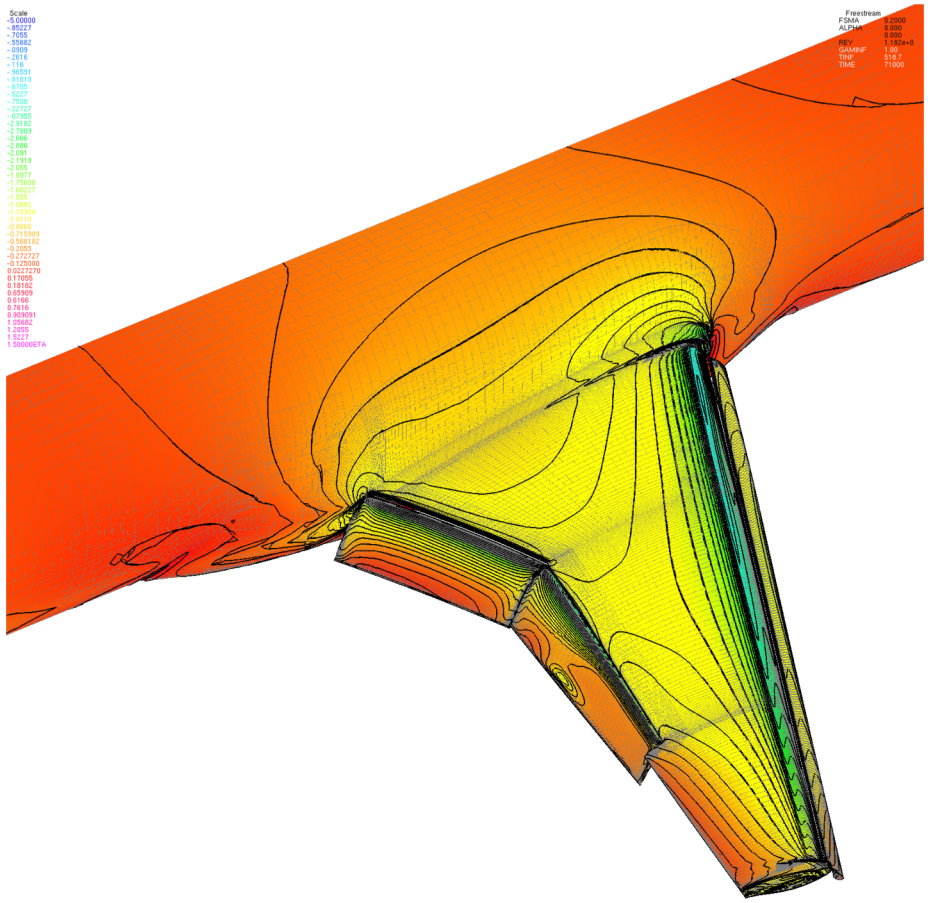
Generate cut planes through multiple structured overset meshes from GUI



CUT PLANE GENERATION AND VISUALIZATION IN OVERGRID (2)



Colored line contours on L=1 surfaces and cut planes

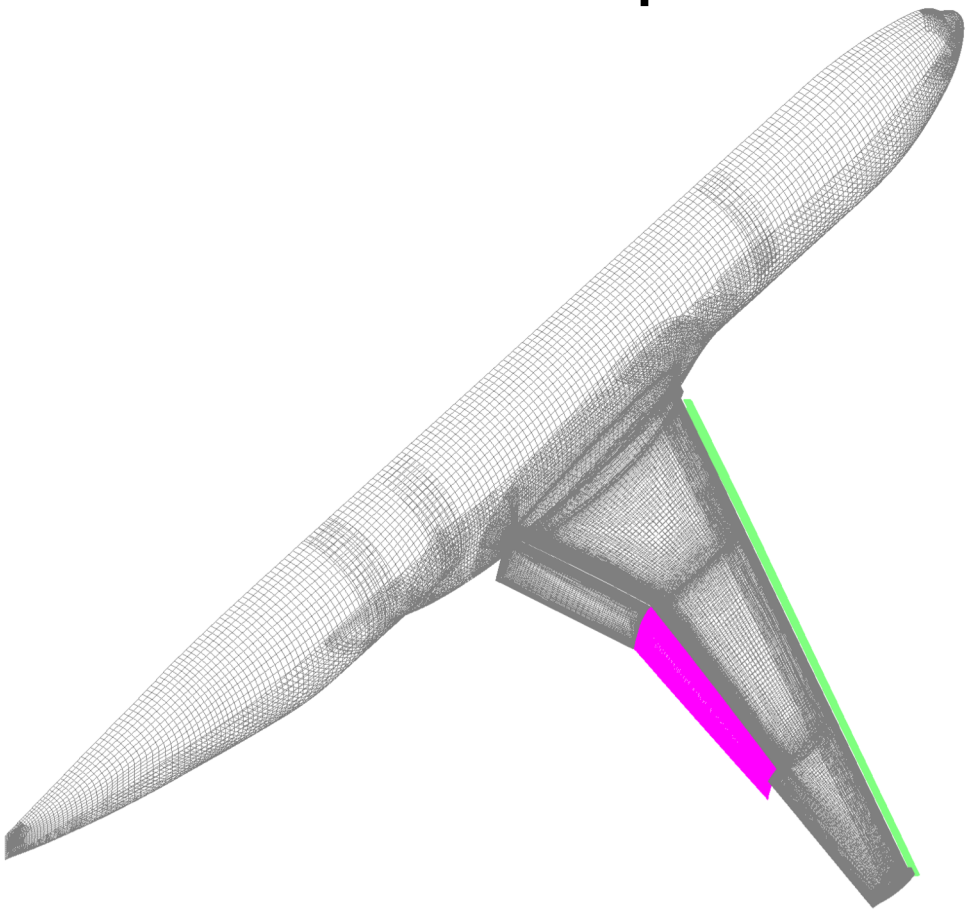


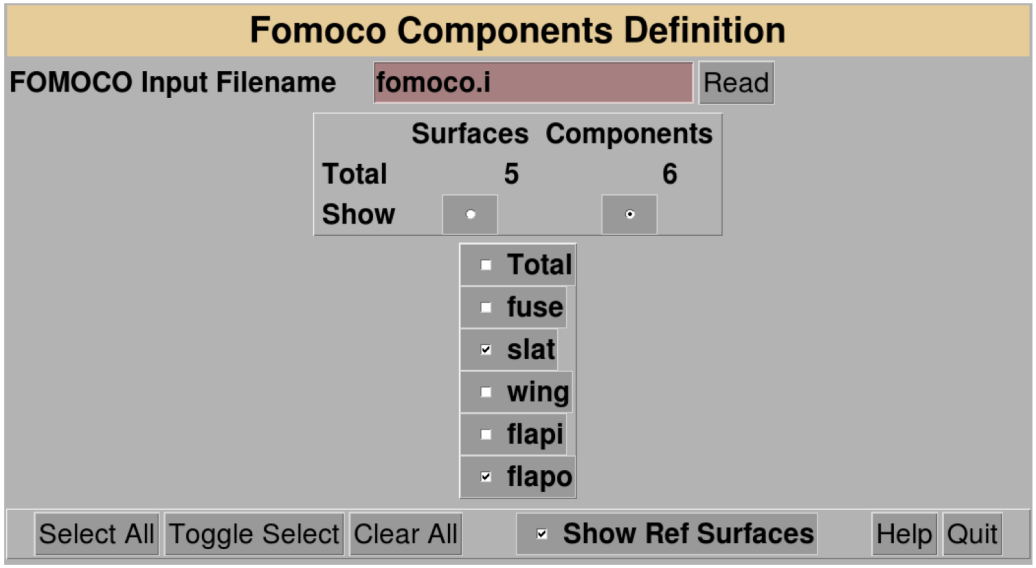
Shaded colored contours with overlayed line contours

OVERGRID: VISUALIZATION OF COMPONENTS DEFINED FOR FORCES/MOMENTS COMPUTATION

- Recent complex configuration applications: 100+ components, each component may contain from a few to 100+ surface subsets

- Need visual check of grid indices used to define components for forces/moments computation



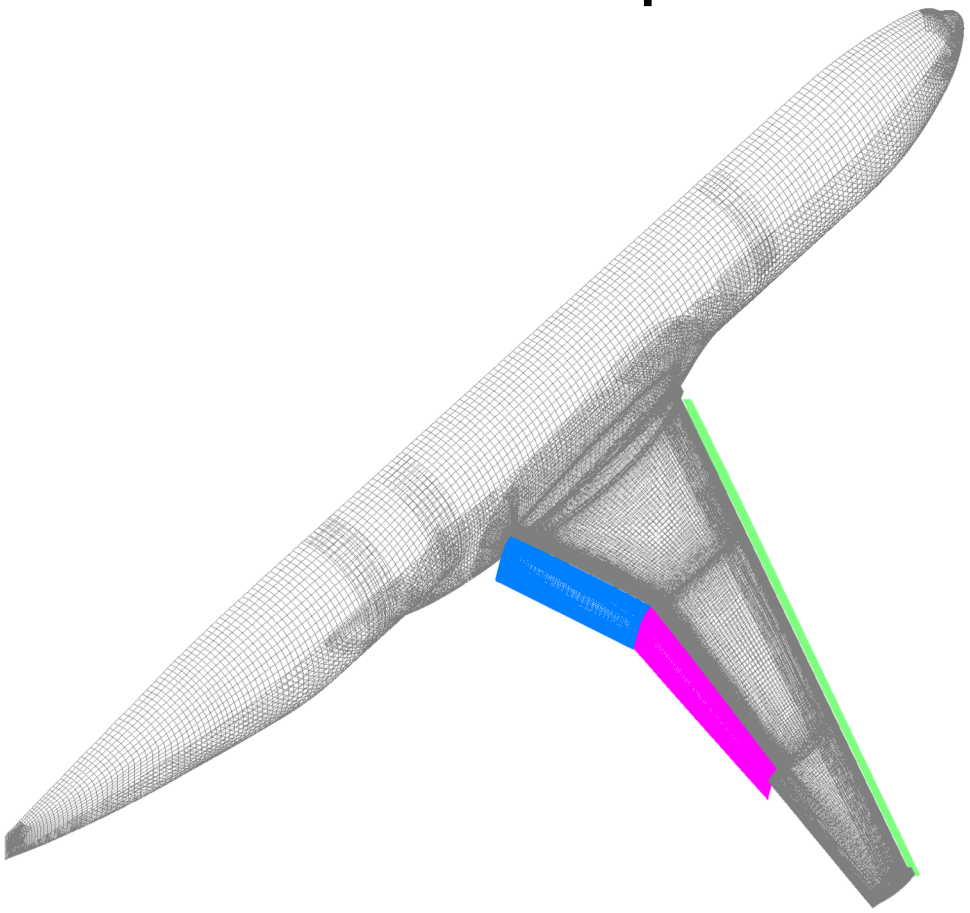


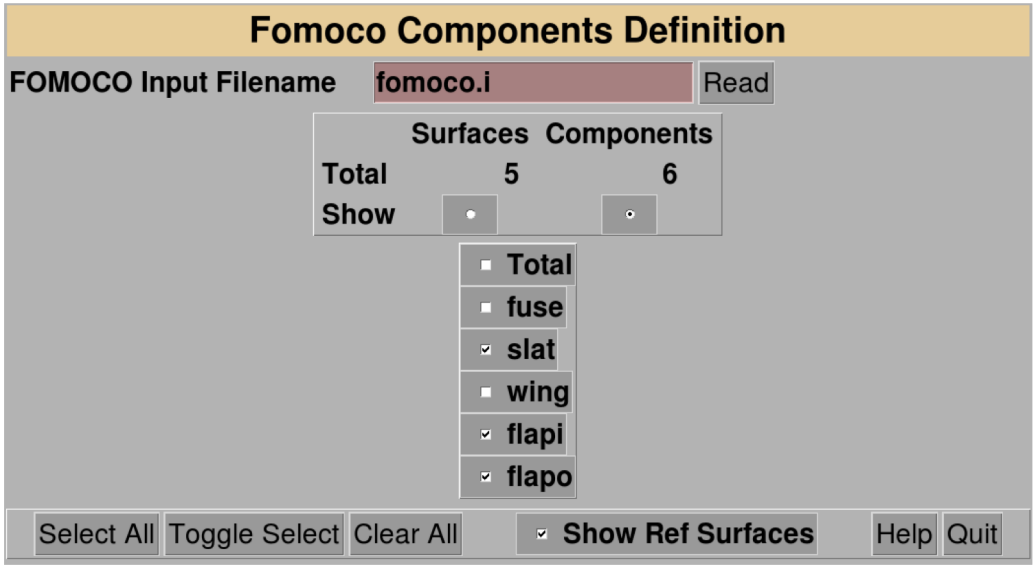
Toggle display of each component in different colors

OVERGRID: VISUALIZATION OF COMPONENTS DEFINED FOR FORCES/MOMENTS COMPUTATION

- Recent complex configuration applications: 100+ components, each component may contain from a few to 100+ surface subsets

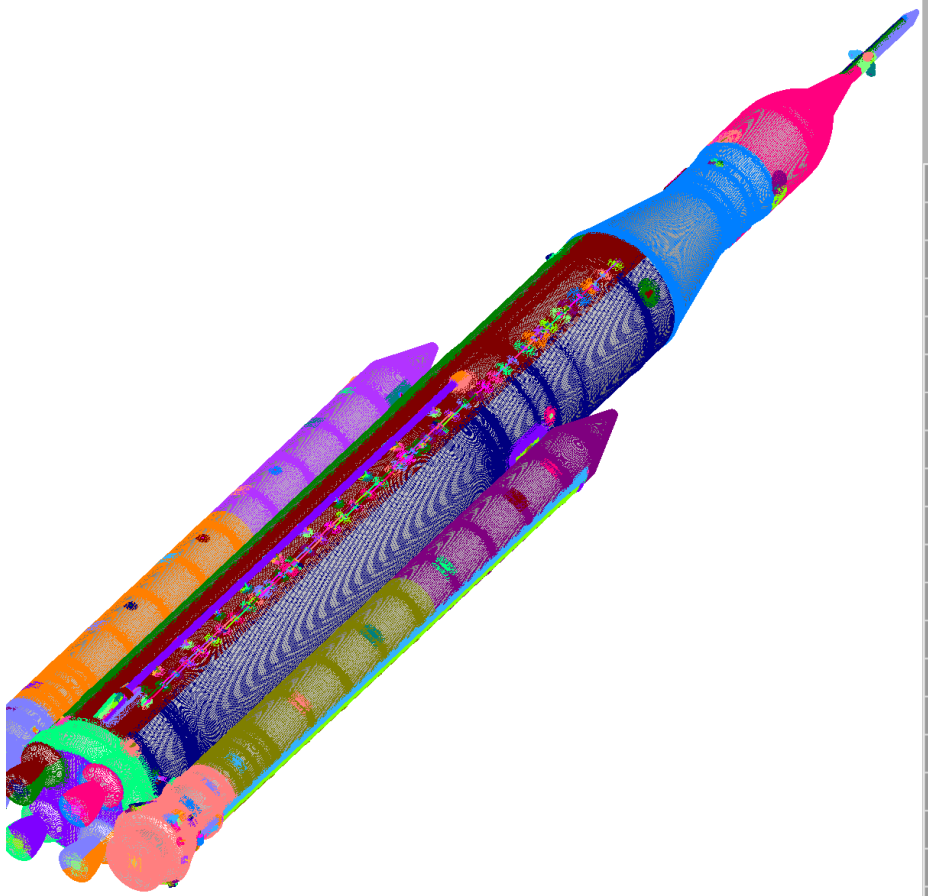
- Need visual check of grid indices used to define components for forces/moments computation





Toggle display of each component in different colors

OVERGRID: VISUALIZATION OF COMPONENTS DEFINED FOR FORCES/MOMENTS COMPUTATION (BIG CASE)



Click to second panel to see components 76-147

Fomoco Components Definition

FOMOCO Input Filename: mixsur.i [Read]

	Surfaces	Components
Total	142	147
Show	•	•

ALL	CORE_LOXLineSeal	CORE_PressLineBracketG02
CORE_No_Base	CORE_LOXLineFwdFairing	CORE_PressLineBracketG03
LSRB_No_Base	CORE_LOX1Brackets	CORE_PressLineBracketG04
RSRB_No_Base	CORE_LOX2Brackets	CORE_PressLineBracketG05
STACK_No_Base	CORE_LOXLineAftFairing1	CORE_PressLineBracketG06
MPCV_Body	CORE_LOXLineAftFairing2	CORE_PressLineBracketG07
CORE_Body	CORE_PressLineLong	CORE_PressLineBracketG08
CORE_SystemTunnel	CORE_PressLineShort	CORE_PressLineBracketG09
CORE_Base	CORE_PressLineBracketA01	CORE_PressLineBracketG10
MPCV_AbortNoz1	CORE_PressLineBracketB01	CORE_PressLineBracketG11
MPCV_AbortNoz2	CORE_PressLineBracketB02	CORE_PressLineBracketG12
MPCV_AbortNoz3	CORE_PressLineBracketB03	CORE_PressLineBracketG13
MPCV_AbortNoz4	CORE_PressLineBracketB04	CORE_PressLineBracketG14
ICPS_Tunnel1	CORE_PressLineBracketB05	CORE_PressLineBracketG15
ICPS_Tunnel2	CORE_PressLineBracketB06	CORE_PressLineBracketG16
ICPS_UmbConnector	CORE_PressLineBracketB07	CORE_PressLineBracketG17
MPCV_Umbilical_ramp	CORE_PressLineBracketC01	CORE_PressLineBracketG18
MPCV_Umbilical	CORE_PressLineBracketE01	CORE_PressLineBracketG19
CORE_FwdCamera	CORE_PressLineBracketE02	CORE_PressLineBracketG20
CORE_Stabilizer	CORE_PressLineBracketE03	CORE_PressLineBracketG21
MPCV_PanelHinge	CORE_PressLineBracketE04	CORE_PressLineBracketG22
MPCV_Camera	CORE_PressLineBracketE05	CORE_PressLineBracketG23
MPCV_TowerTunnel	CORE_PressLineBracketD01	CORE_PressLineBracketH01
CORE_LOXLine1	CORE_PressLineBracketF01	CORE_PressLineBracketH02
CORE_LOXLine2	CORE_PressLineBracketG01	CORE_PressLineBracketI01

< 1 - 75 >

Select All | Toggle Select | Clear All | Show Ref Surfaces | Help | Quit

OVERGRID: COMMAND LINE OPTIONS

Scripted dumping of image files in non-interactive mode enabled by command line options

-2 : dual screen
-l/-r : location of smaller screen for horizontal stack (l=left, r=right)
+x/+y : x and y shifts for window placement
-cmd : read command line arguments from specified file
-cntrfun/-shadfun/-wirefun : 0/1 turn off or on contour/shaded/wireframe display for solution function
-dp : use double precision mode to read ascii structured grid files
-fun : plot function *fun_name* in solution viewer, valid *fun_name* include q1,q2,...,u,v,w,velocity magnitude,Mach number,pressure,Cp, sound speed,temperature,internal energy,total enthalpy,entropy
-img : dump image to specified filename (non-interactive mode)
-maxval/-minval : set max/min value of contours to specified value
-nlevel : set number of contour levels
-noax/-nogrid : do not display axis/grid wireframe
-nolog : do not write *overgrid.log* file
-qfile : load structured grid solution from specified *solution* file
-sub : load solution subsets from specified *subsets* file
-vp : load view point from specified *viewpoint* file

FORTRAN FILE I/O (FFIO) LIBRARY AND OVERCONVERT

Auto detection of type and attributes of files encountered in overset CFD analysis process using number and size of record markers

File types
- **PLOT3D grid, solution, and function**
- **OVERFLOW solution (one or two time levels)**
- **CART3D grid and solution files (.tri, .i.tri, .triq)**
- **X-ray map**
- **Interpolation stencil data (INTOUT/XINTOUT)**

File attributes
- **ASCII / unformatted single / unformatted double**
- **Big / little endian**
- **PLOT3D grid (single/multiple grid, with/without iblanks, 2D/3D)**
- **Solution (PLOT3D/OVERFLOW, with/without 2nd order restart)**

Commonly used FFIO enabled CGT modules
- **GRIDED, TRIGED, SRAP, SURGRD, HYPGEN, BOXGR, GEN_X, GRIDINF MINMAX, LSECT, COMBINEMX, COMBINEMQ, TRILOADCMV, QINFO**

Use overConvert to report/check file type and attributes, and to convert between different attributes

OVERCONVERT SAMPLE OUTPUT

overConvert -i filename -v -h -s

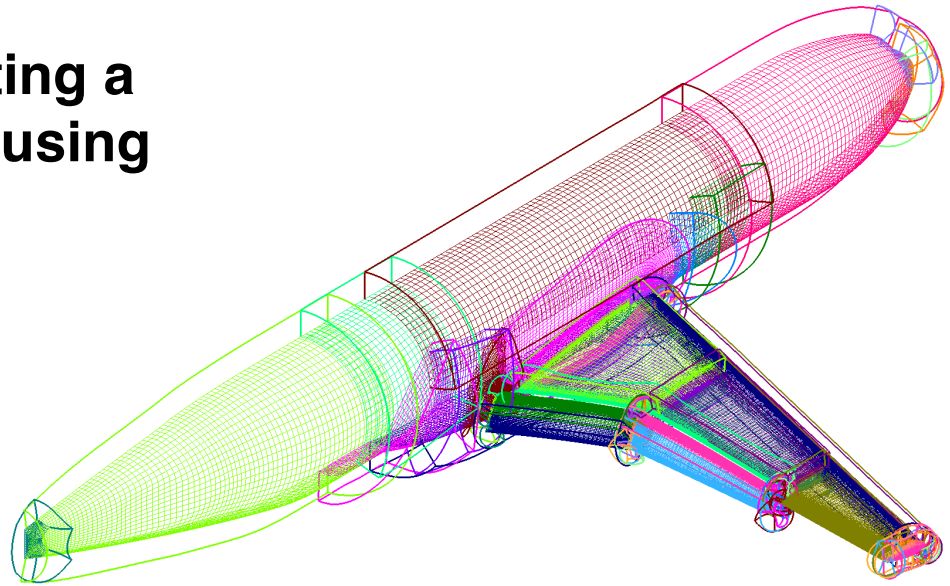
```
unformatted file
Machine is Little Endian
File is Big Endian
74 records found in input file
Number of Grids in multiple grid file: 72
Double Precision, no IBlanks
Data is 3D

Grid 3: 15x27x59 (23.9K Points)
Grid 25: 17x41x54 (37.6K Points)
Grid 13: 35x19x59 (39.2K Points)
Grid 20: 17x43x54 (39.5K Points)
...
Grid 69: 289x159x117 (5.4M Points)
Grid 58: 386x153x98 (5.8M Points)
Grid 72: 381x181x115 (7.9M Points)
Grid 30: 215x538x97 (11.2M Points)

Total points in file: 72.92M
Total cells in file: 70.93M
```

MULTI-THREADED TCL SCRIPT FOR VOLUME MESH GENERATION

Script library procedure for generating a system of hyperbolic volume grids using multiple Tcl threads



```
GenHypVolThread  [list grid1.sur grid1.vol $strlist1 $bclist1 $smulist1] \
                 [list grid2.sur grid2.vol $strlist2 $bclist2 $smulist2] \
                 ...
                 [list gridN.sur gridN.vol $strlistN $bclistN $smulistN]
```

where

- grid{i}.sur = input surface grid filename
- grid{i}.vol = output volume grid filename
- strlist{i} = stretching function parameters list
- bclist{i} = boundary conditions parameters list
- smulist{i} = smoothing parameters list

} Inputs for grid{i}

OVERPLOT: SOLUTION CONVERGENCE DIAGNOSTICS

Residual history plots for components defined for forces/moments computation

GRAPHICAL USER INTERFACE FOR OVERFLOW LINE PLOTS

Plot Type: Force & Moment; Residual; Min. density/pressure; Dynamics; Sectional

XTERM: ON; OFF

Plotting Package: xmgrace; gnuplot; xyplot

Output Options: Screen; PostScript; File

PLOT DATA

Max number of curves per plot: 500

Ctrl-q to quit

Residual History Plot Options

Residual history filename: run.resid

OVERFLOW input filename: run.01.inp

Type: Grids; Components

X-axis Options: Time Step Number; Show every 1 point; Show all subiterations

Y-axis Options: L2 of RHS; Linf of RHS; L2 of delta Q; Linf of delta Q; Drop in log of L2 of RHS for sub-iterations; Drop in log of Linf of RHS for sub-iterations; Drop in log of L2 of delta Q for sub-iterations; Drop in log of Linf of delta Q for sub-iterations; CPU time; Number of grid points

Components # 6: Total; fuse; slat; wing; flapi; flapo

Select All

Plot Component Grids

Grids in component # 12: 'Slat Main Front-14'; 'Slat Main Back-15'; 'Slat In Cap 1-16'; 'Slat In Cap 2-17'; 'Slat In Cap 3-18'; 'Slat In Cap 4-19'; 'Slat In Cap 5-20'; 'Slat Out Cap 1-21'; 'Slat Out Cap 2-22'; 'Slat Out Cap 3-23'

Convergence Analysis

Convergence for curve #

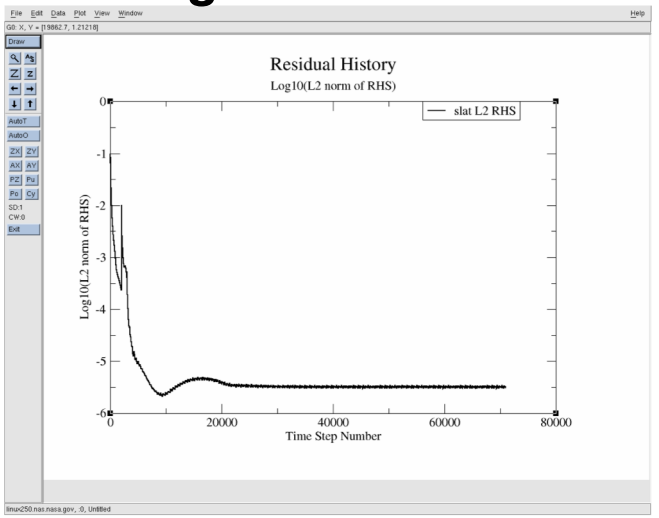
X from -0.1 to -1

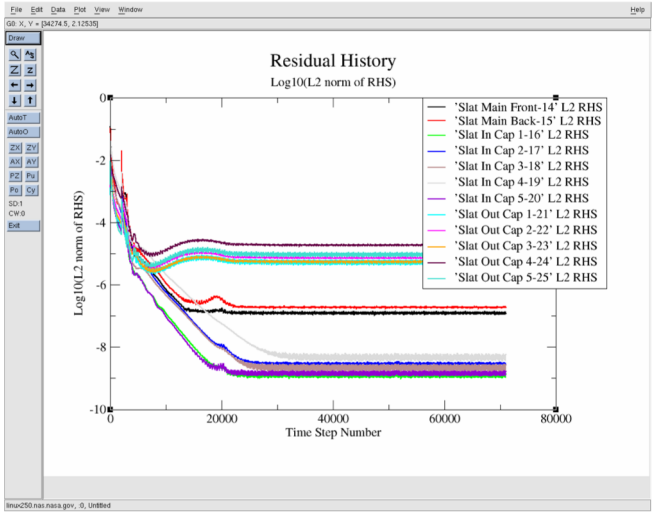
Final Value

	Value	Slope
Minimum		
Maximum		
Average		
Standard Dev.		

HELP QUIT

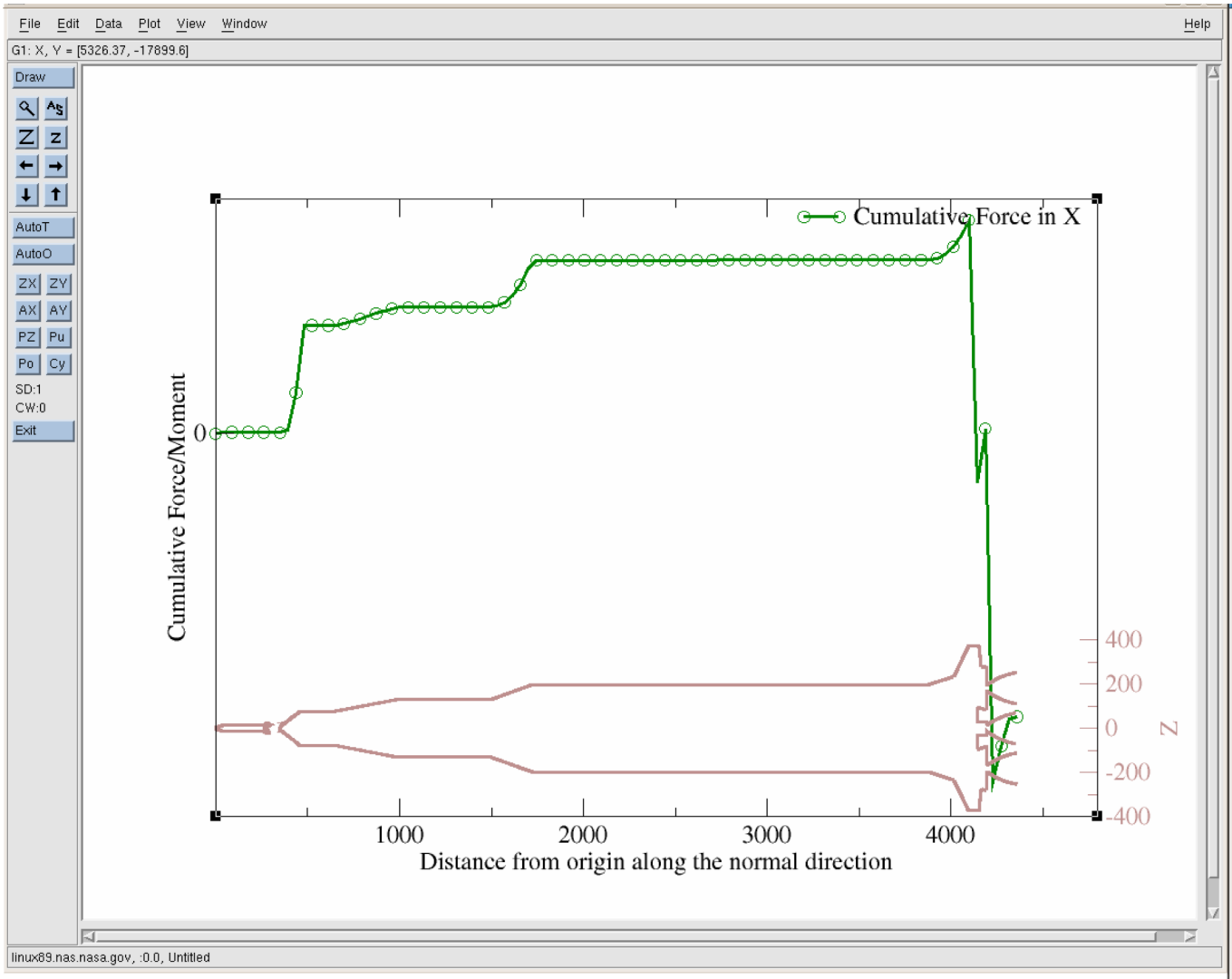
Easier to analyze convergence of grid systems with large number of grids

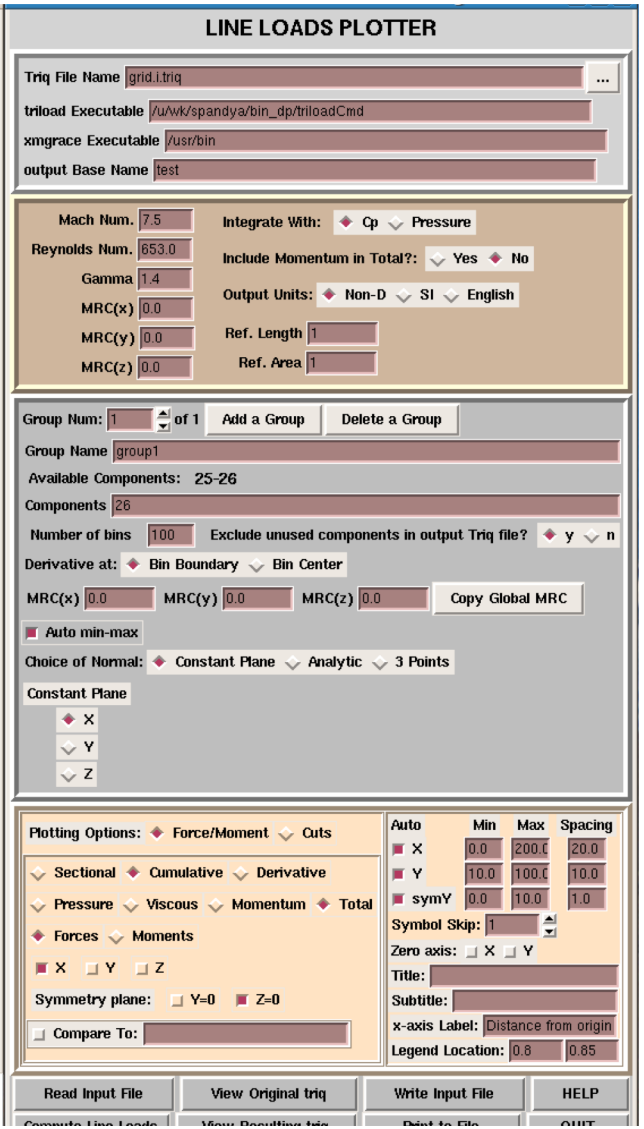




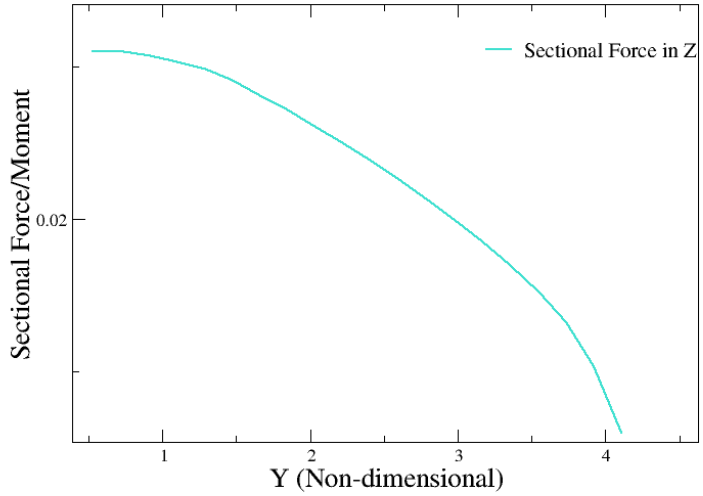
LINE LOADS COMPUTATION AND Cp CUTS IN TRILOAD (1)

- Computation of sectional loads and Cp along specified cuts
- Modes of operation
  - command line
  - GUI

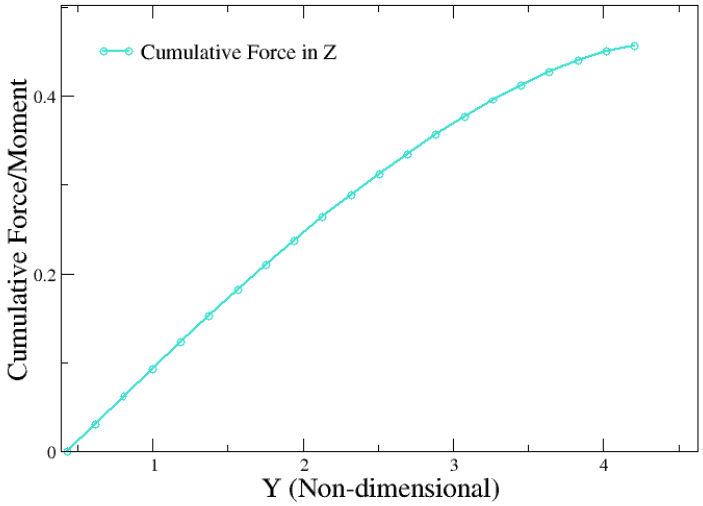




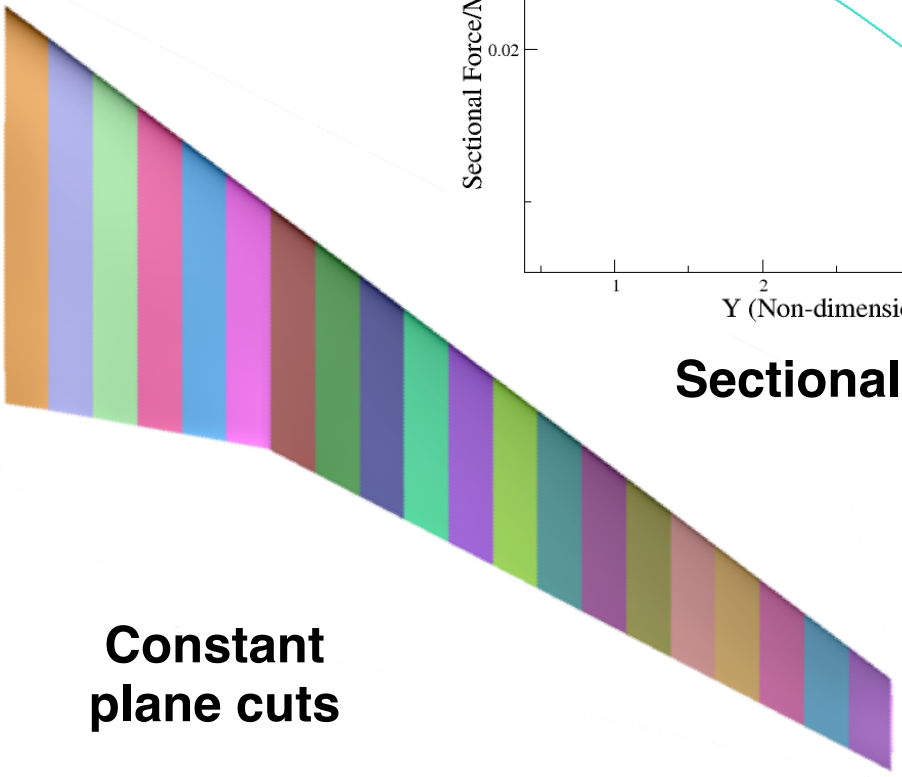
LINE LOADS COMPUTATION AND Cp CUTS IN TRILOAD (2)



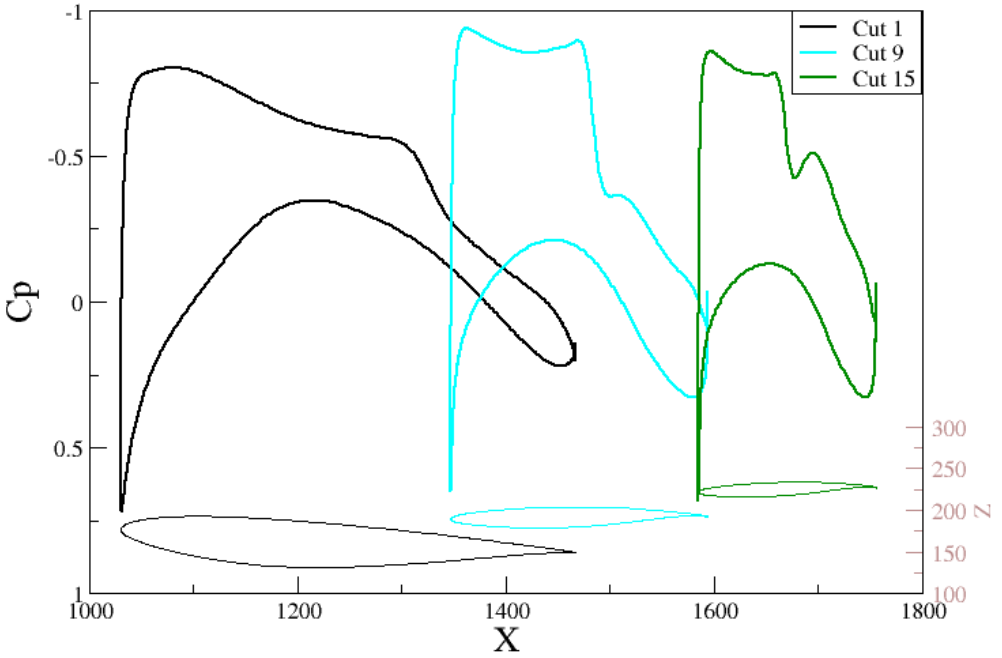
Sectional loads



Cumulative loads



Constant plane cuts



Cp on various cut planes

MISCELLANEOUS NEW FEATURES FROM DIFFERENT MODULES

DIFFXQ – compute differences between two structured mesh files in
- **grid coordinates**
- **solution values**
- **iblank values (connectivity)**

TRIGED – triangulation editing tool
- **read .stl, .fro files (in addition to .tri, .triq, .ucd, .fst)**
- **report bounding box and edge length statistics**
- **fast search for duplicated vertices**
- **perturb vertices along local surface normal by specified distance**
- **compute differences between two .triq files (different nvert, ntri)**

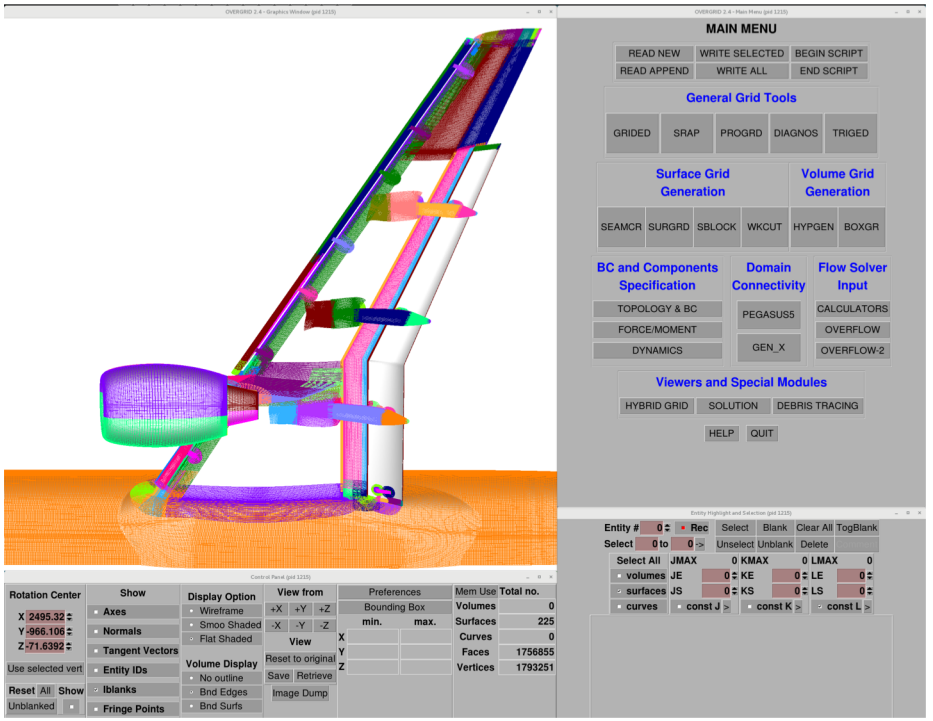
QINFO - solution file header info tool
- **report min/max of each Q**

QED – perform editing of solution files
- **swap J/K, K/L, J/L indices**
- **reverse J, K, K indices**
- **mirror velocity vector about x/y/z=0 plane**
- **rotate velocity vector**

TUTORIALS IN CGT 2.2: OVERGRID

- Under chimera2.2/tutorials/gui

- Updated for OVERGRID version 2.4



A detailed OVERGRID demo is available at:
The OVERGRID Graphical User Interface in Chimera Grid Tools (Parts 1, 2, 3)
http://www.nas.nasa.gov/publications/ams/2014/05-13-14.html
http://www.nas.nasa.gov/publications/ams/2014/05-20-14.html
http://www.nas.nasa.gov/publications/ams/2014/05-29-14.html

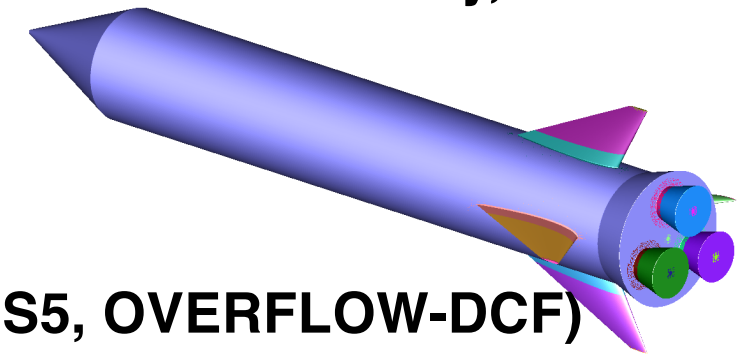
TUTORIALS IN CGT 2.2: SCRIPTING

- General Script Library procedures (chimera2.2/tutorials/scriptlib)

- Script development using the configuration (Build) scripts (chimera2.2/tutorials/scripts)

- James' rocket (JCLV) scripting example (chimera2.2/tutorials/jclv)

  - Complete process includes geometry creation, surface and volume mesh generation, input preparation for domain connectivity, flow solution, forces/moments computation



  - Grid-centric approach (Build scripts)
    - Each grid file contains 1 grid
    - Domain connectivity options (PEGASUS5, OVERFLOW-DCF)

  - Component-centric approach
    - Each grid file contains all grids for 1 component
    - Domain connectivity options (OVERFLOW-DCF, PEGASUS5, C3P)

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Transformational Tools and Technologies (TTT) Project

Advanced Air Transport Technology (AATT) Project

Revolutionary Vertical Lift Technology (RVLT) Project

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