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# ASSESSMENT OF GRID CONNECTIVITY QUALITY AND ENHANCEMENTS ON AUTOMATIC ESTIMATES ON HOLE BOUNDARY PLACEMENT

**William M. Chan**

**Shishir Pandya**

**NASA Ames Research Center**

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# OVERVIEW

- Overset grid connectivity quality

  - Review of quality measures that point to sources of orphan points and degradation of solution accuracy
  - Visualization tools in latest OVERGRID

- Hole boundary offset from minimum hole

  - Automatic variable distance estimate (work in progress)

- Summary and conclusions

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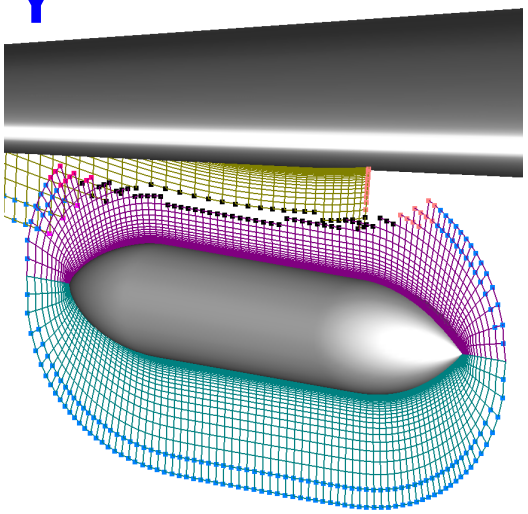
# GRID CONNECTIVITY QUALITY



**Fringe points: grid points at outer boundaries and hole boundaries that require interpolation data from another grid**

**$N_F$ = Number of layers of fringe points requested**

| Fringe point | Donor stencil | Treatment | Quality |
|---|---|---|---|
| Orphan | None | Averaged from neighbors | Poor |
| Mixed | < $N_F$ layers | Fringe points with no donor stencils converted to field points (reduced accuracy)<br>Fringe points with donor stencils get trilinear interpolation | Accepted in most standard practices if number of converted points is a small fraction of total |
| Regular | $N_F$ layers | All fringe points receive trilinear interpolation | Okay – Excellent (varies depending on fringe point / donor stencil compatibility) |

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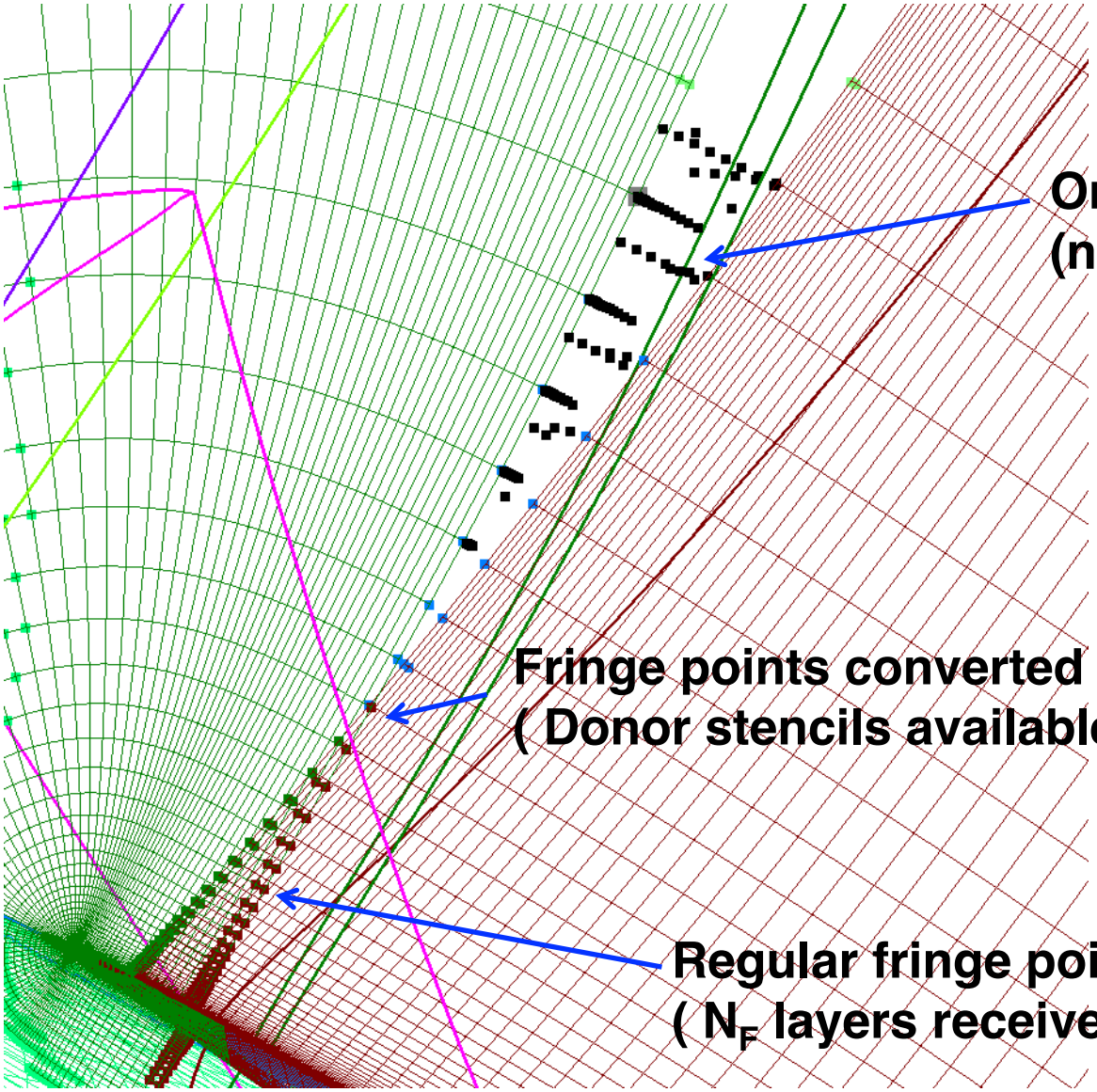
# FRINGE POINTS AND DONOR STENCILS SCENARIOS



$N_F = 2$

Orphan points
(no donor stencils)

Fringe points converted to field points
( Donor stencils available for < $N_F$ layers)

Regular fringe points
( $N_F$ layers received donor stencils)

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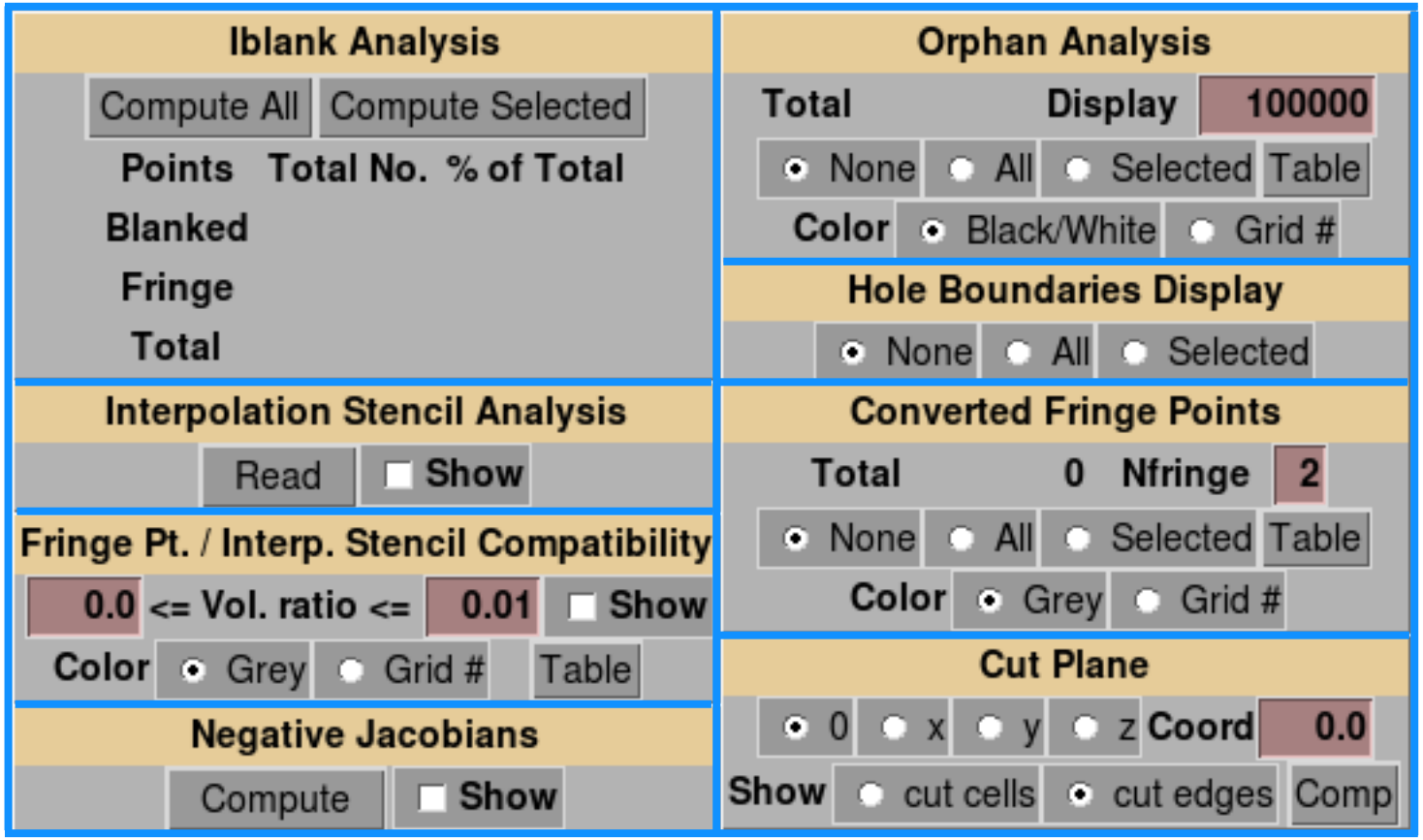
# OVERGRID (2.3t) DIAGNOSTICS MODULE




- Neighboring grid planes of selected orphan point
- 3-D hole boundaries
- Cut plane over curvilinear and Cartesian cells
- Converted fringe points
- Donor stencil compatibility

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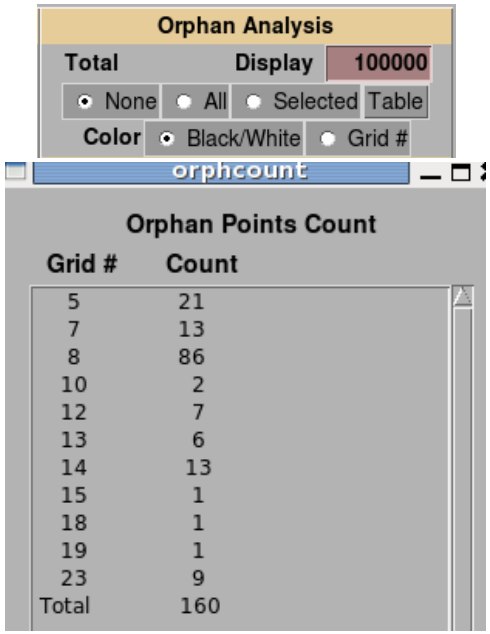
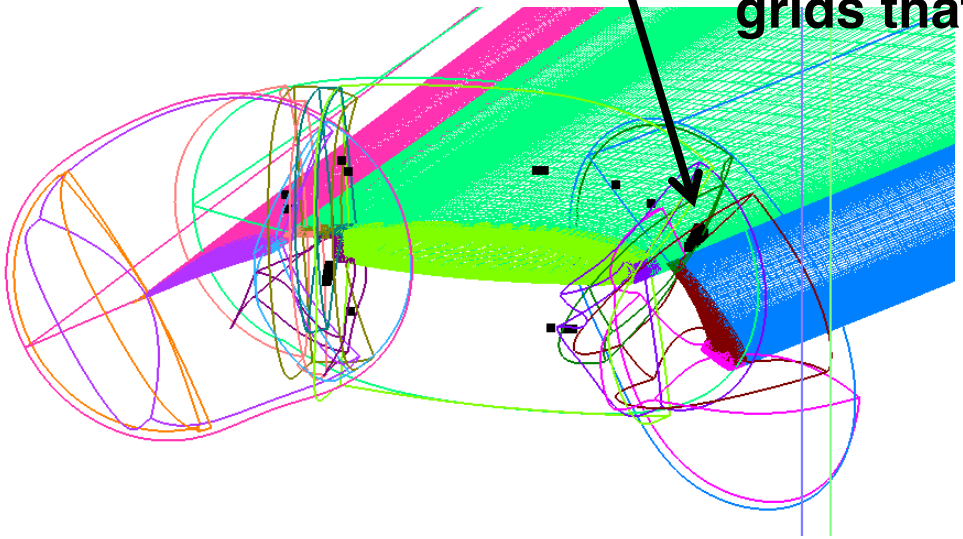
# ORPHAN POINTS ANALYSIS

## Orphan Points Display

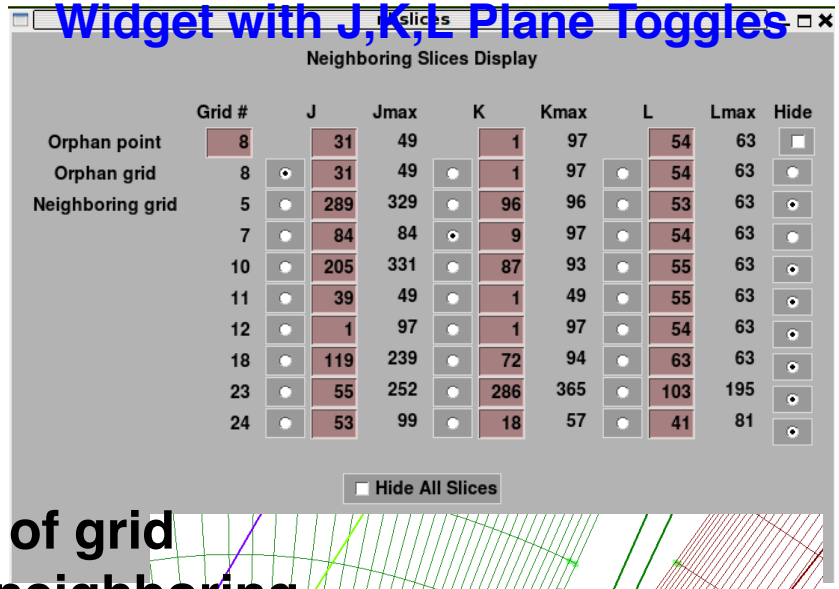



**Previous procedure: Manually select grid planes to display**

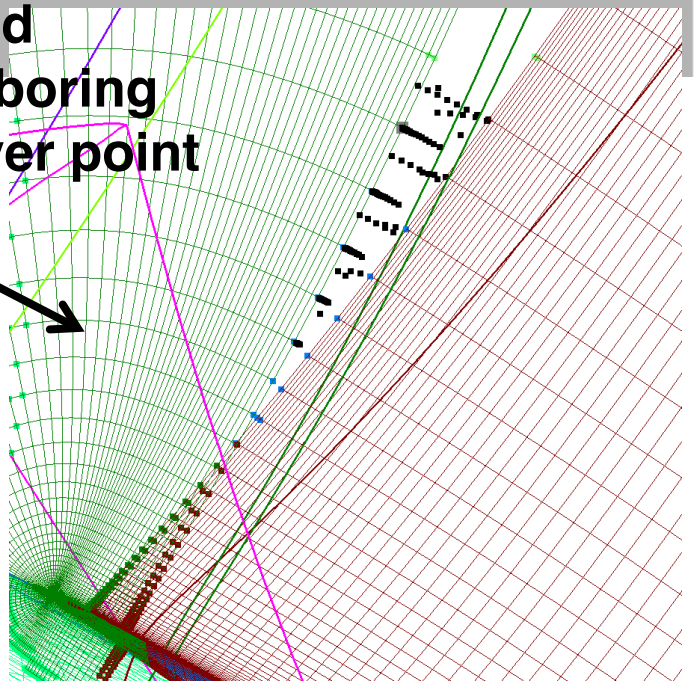
**Current procedure: Mouse pick orphan point**



## Neighboring Grid Slices Display Widget with J,K,L Plane Toggles




**Auto display of grid planes from neighboring grids that may cover point**



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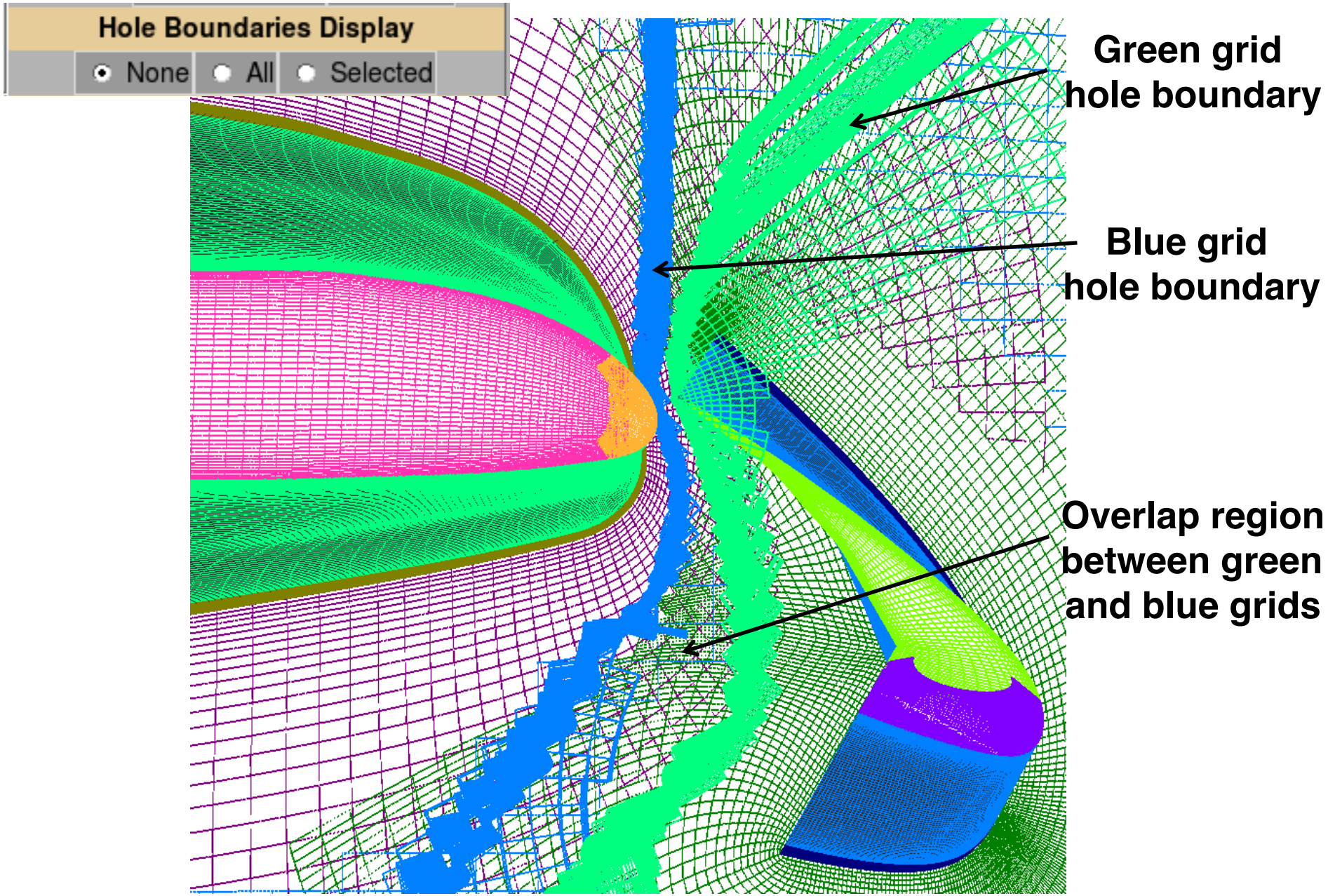
# 3-D HOLE BOUNDARIES



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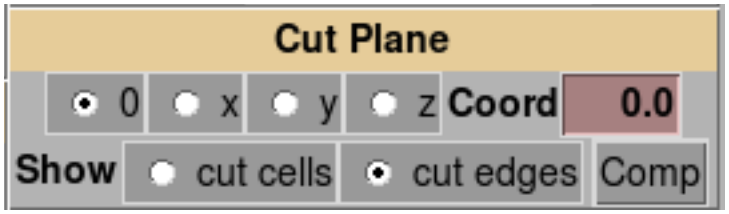
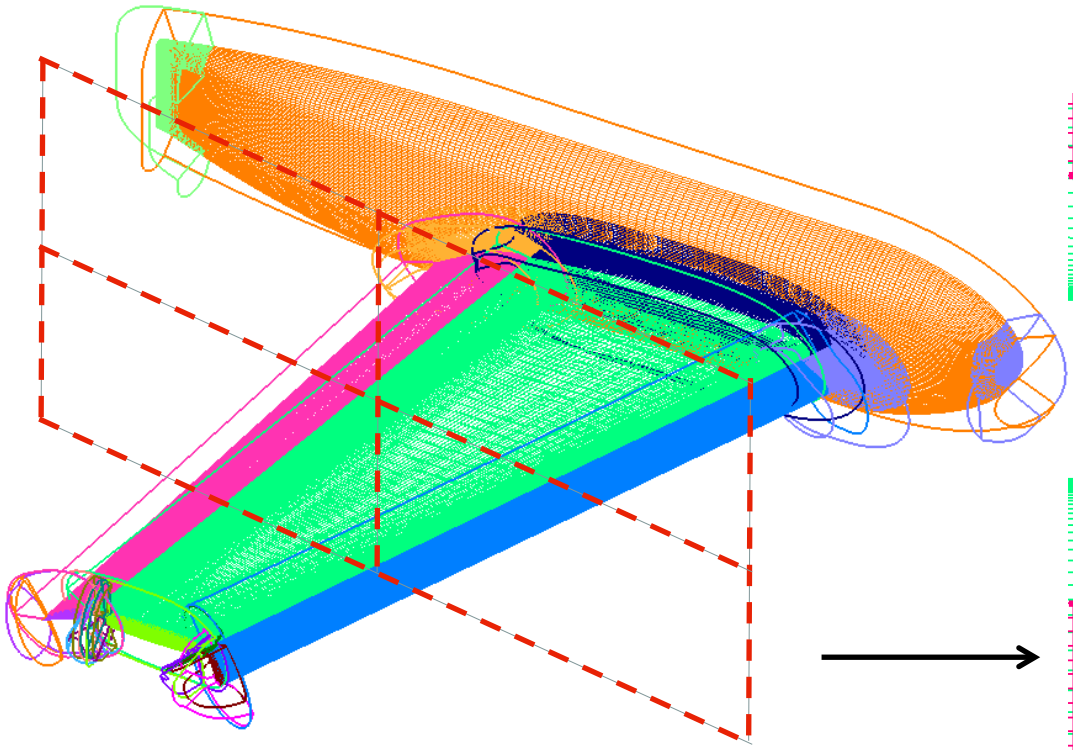
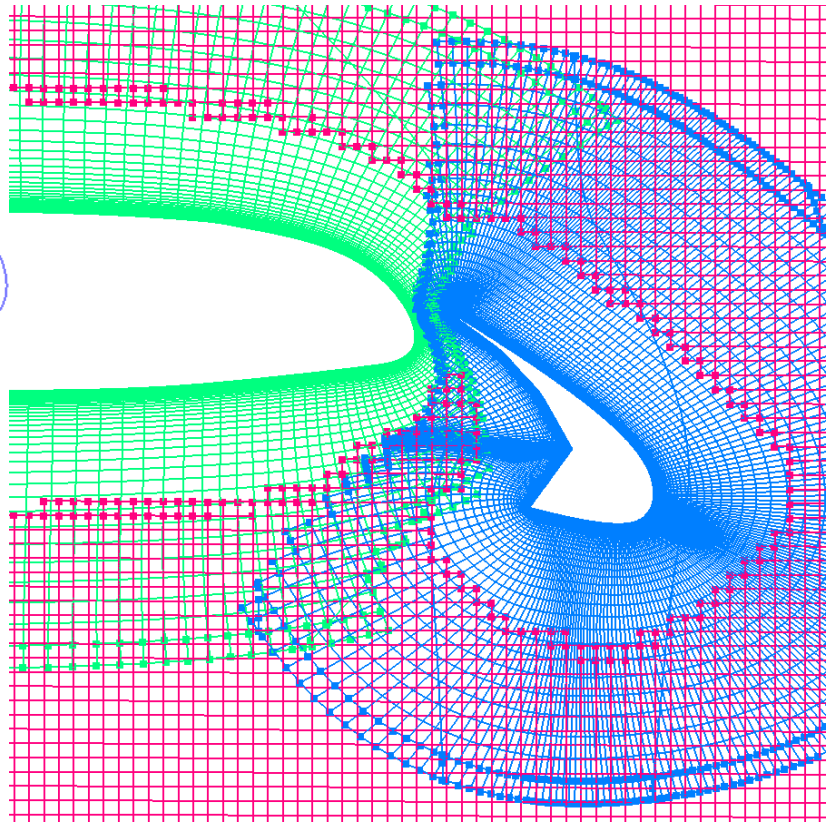
# CONSTANT CARTESIAN CUTPLANE

**Display options:**

- **Edges formed by intersection of Cartesian plane and hex cells**
- **Complete cells cut by Cartesian plane**





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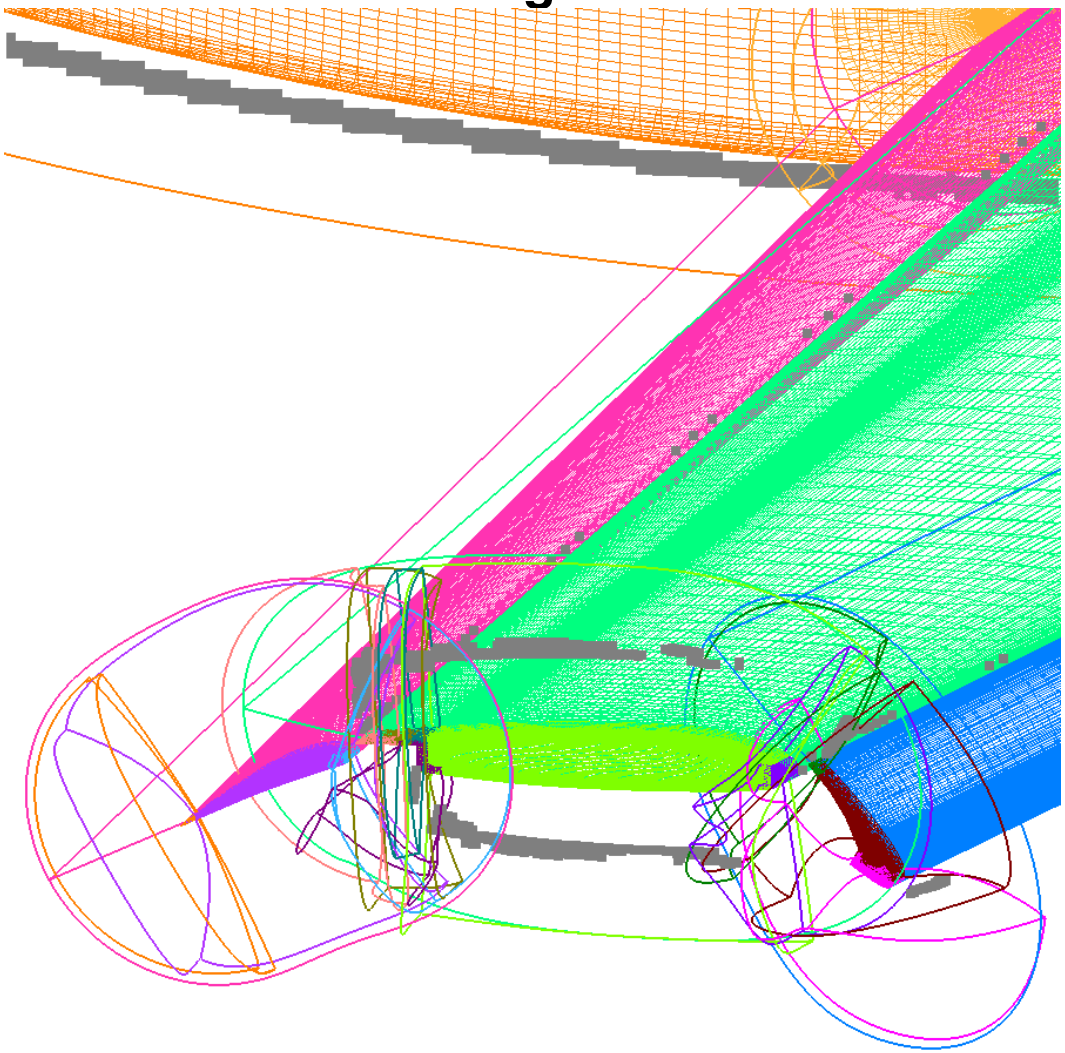
# CONVERTED FRINGE POINTS

**Display of level 2 or higher fringe points that have been converted to field points due to insufficient overlap – reduction in solution solver differencing stencil**



**Converted Fringe Points**

| | | | | |
|---|---|---|---|---|
| Total | 0 | Nfringe | 2 | |
| ◉ None | ○ All | ○ Selected | Table | |
| Color | ◉ Grey | ○ Grid # | | |

**Fringe Repair Points Count**

| Grid # | Count |
|---|---|
| 4 | 81 |
| 5 | 65 |
| 6 | 13 |
| 7 | 49 |
| 8 | 223 |
| 9 | 98 |
| 10 | 193 |
| 12 | 241 |
| 13 | 48 |
| 14 | 48 |
| 15 | 65 |
| 16 | 160 |
| 18 | 2 |
| 22 | 1119 |
| 23 | 1063 |
| Total | 3468 |

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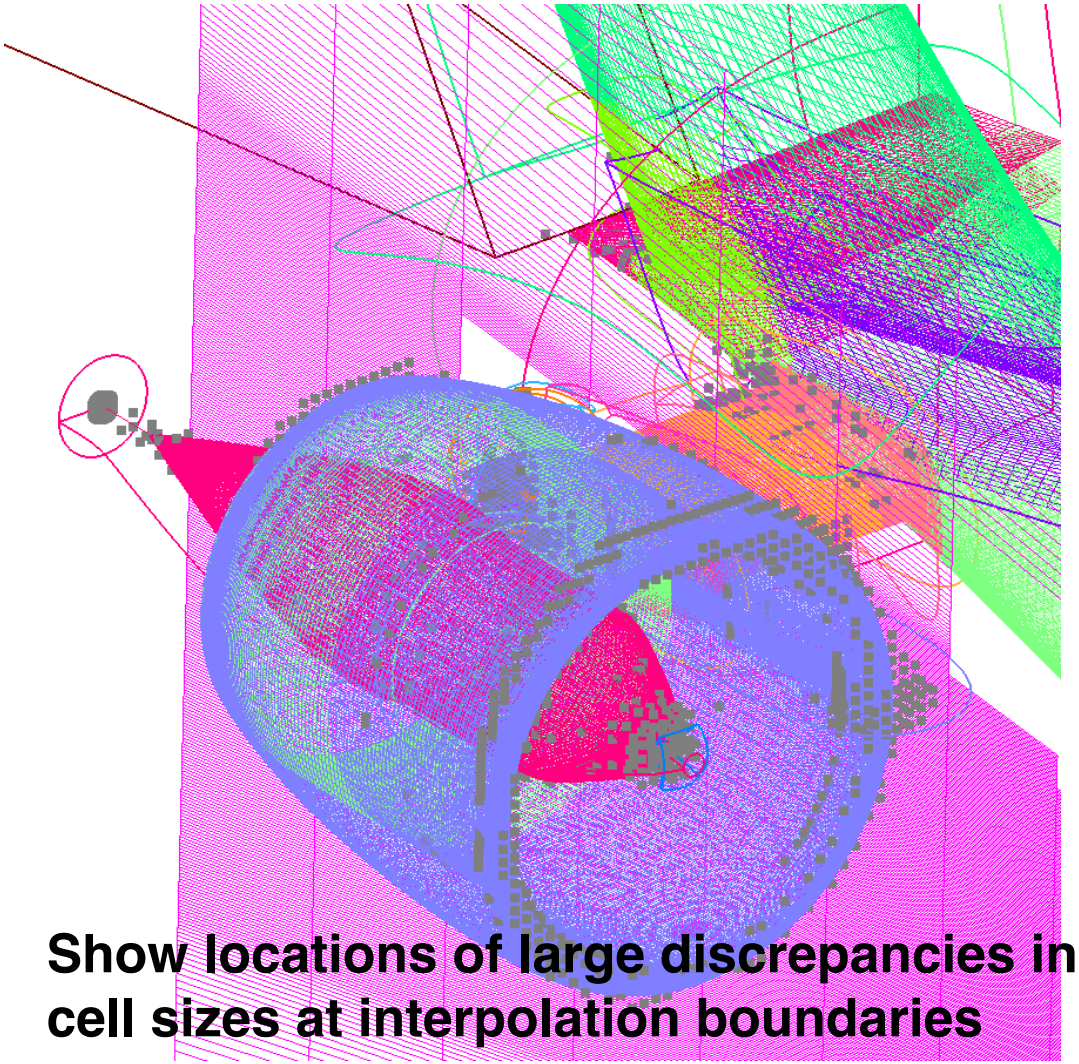
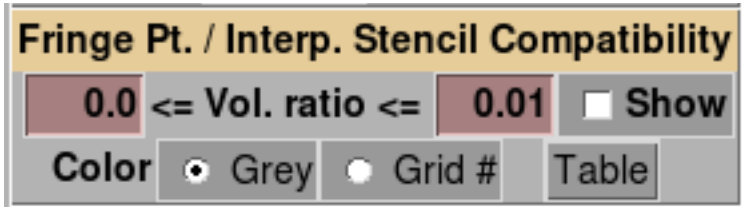
# DONOR STENCIL COMPATIBILITY

**Vr = ratio of cell volume of fringe point and cell volume of donor stencil**
**Range: 0 < Vr <= 1.0 (smaller volume / larger volume)**
**Display fringe points with Vr inside specified range**



**Show locations of large discrepancies in cell sizes at interpolation boundaries**




fcompat

Fringe Points and Interpolation Stencil Compatibility

| Grid # | 0.0 <= Vol. ratio <= 0.001 | Fraction of total |
|---|---|---|
| 3 | 271 | 0.001115 |
| 4 | 160 | 0.002431 |
| 8 | 812 | 0.007737 |
| 11 | 15 | 0.000425 |
| 12 | 122 | 0.004387 |
| 16 | 175 | 0.001214 |
| 17 | 2954 | 0.019011 |
| 18 | 513 | 0.004790 |
| 19 | 22251 | 0.205512 |
| 20 | 493 | 0.012559 |
| 21 | 1123 | 0.028608 |
| 22 | 828 | 0.003422 |
| 23 | 830 | 0.006498 |
| 24 | 12308 | 0.130355 |
| 26 | 1291 | 0.001500 |
| 30 | 28 | 0.000159 |
| 34 | 20 | 0.000173 |
| 36 | 1 | 0.000002 |
| 37 | 1 | 0.000008 |
| 38 | 198 | 0.000358 |
| 41 | 473 | 0.002026 |
| Total | 44867 | |

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# HOLE-CUTTING METHODS BEYOND MINIMUM HOLE

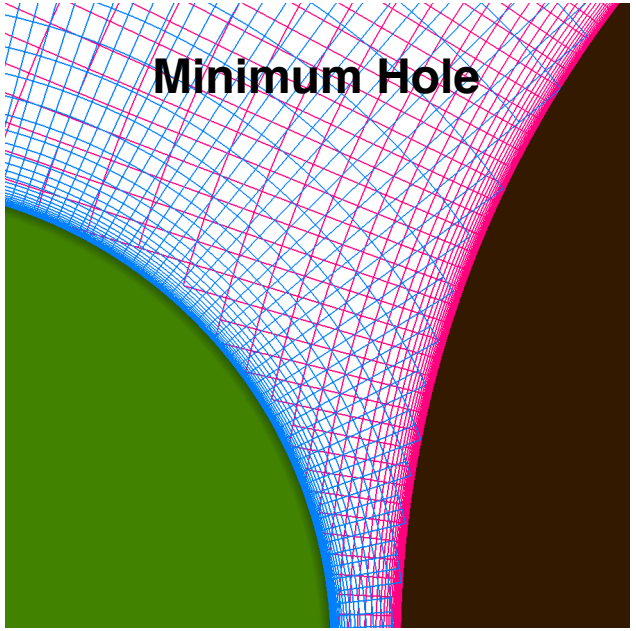
## Minimum hole

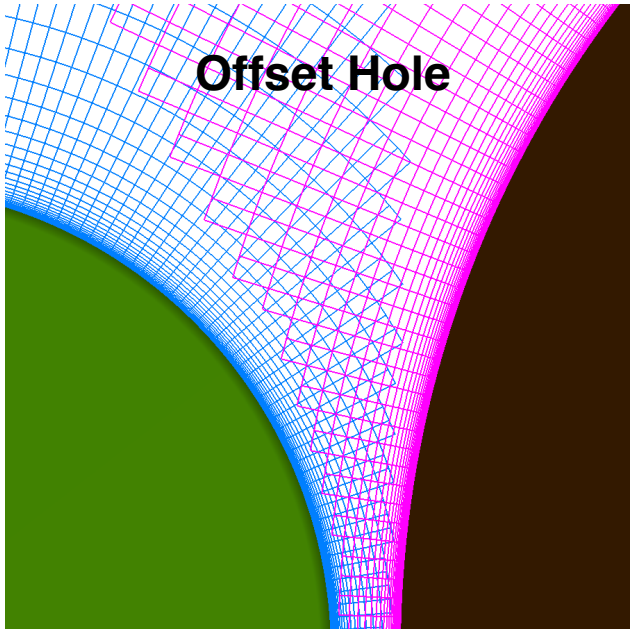
- Blank all points that are inside solid bodies

## Offset from Minimum Hole

- Perturb hole boundary points away from solid surface
- Many acceptable solutions

| Hole cut | Implicit | Explicit |
|---|---|---|
| Description | Find donor stencils for ALL points in volume grid. Use cell attribute criteria to settle on final hole boundary location | User specifies minimum hole cut and offset distance |
| User time | Low | High |
| CPU time | High | Low |



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# REVIEW OF CHIMERA COMPONENTS CONNECTIVITY PROGRAM (C3P) TECHNOLOGY

**Input:** flow solver boundary conditions, component ID on solid walls

**Automatic**

- determination of grid points to be cut by each X-ray
- generation of adaptive X-rays to cut minimum hole
- initial hole boundary offset estimates using wall distance rules
- orphan points removal iterations by adjusting hole boundaries

**Publication**

*Chan, W. M., Pandya, S. A., Rogers, S. E., Efficient Creation of Overset Grid Hole Boundaries and Effects of Their Locations on Aerodynamic Loads, AIAA Paper 2013-3074, AIAA 21st Computational Fluid Dynamics Conference, San Diego, CA, June, 2013*

**Deficiencies**

- Hole boundary offset estimate based on assumption of constant outer boundary extent of near-body grids and iblanks are ignored

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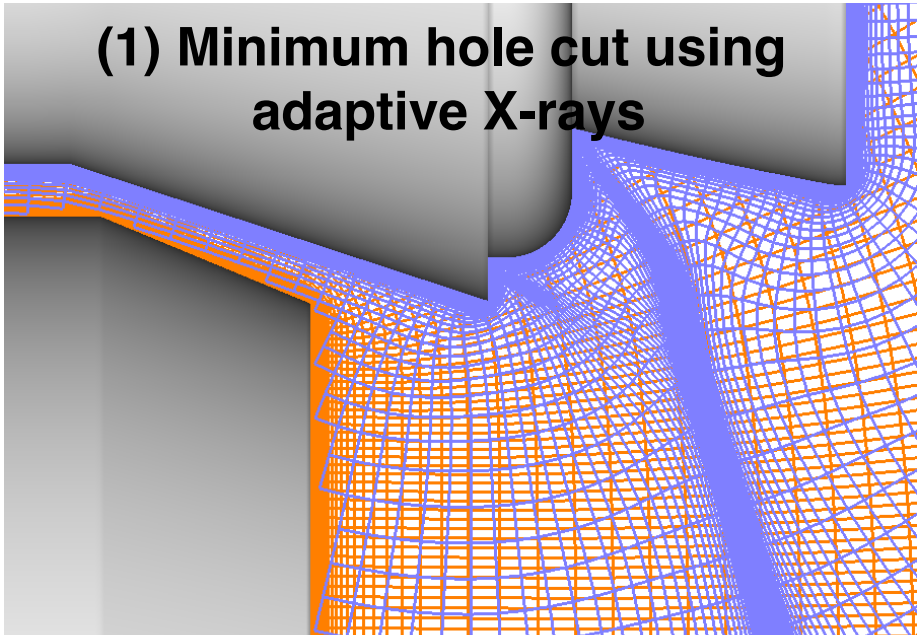
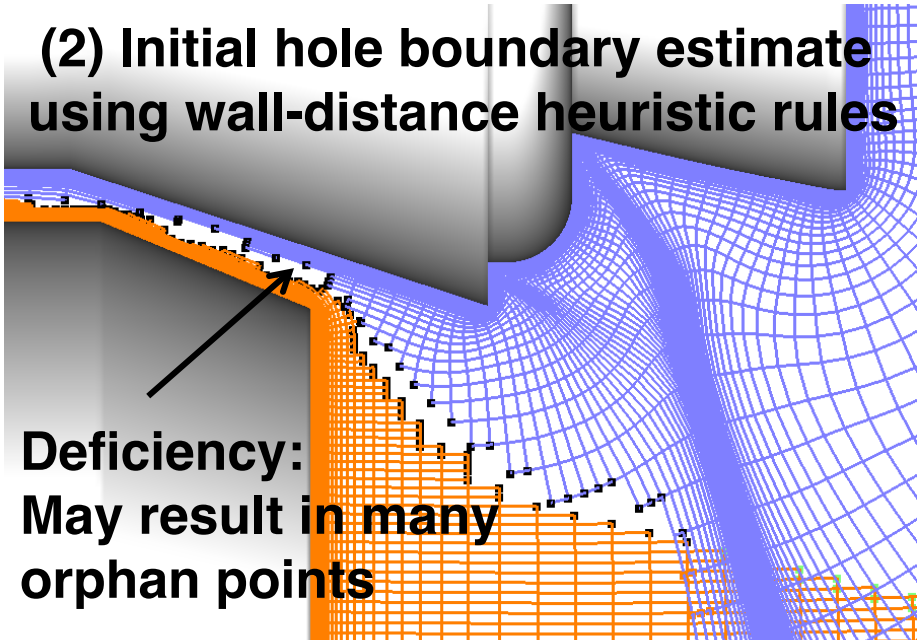
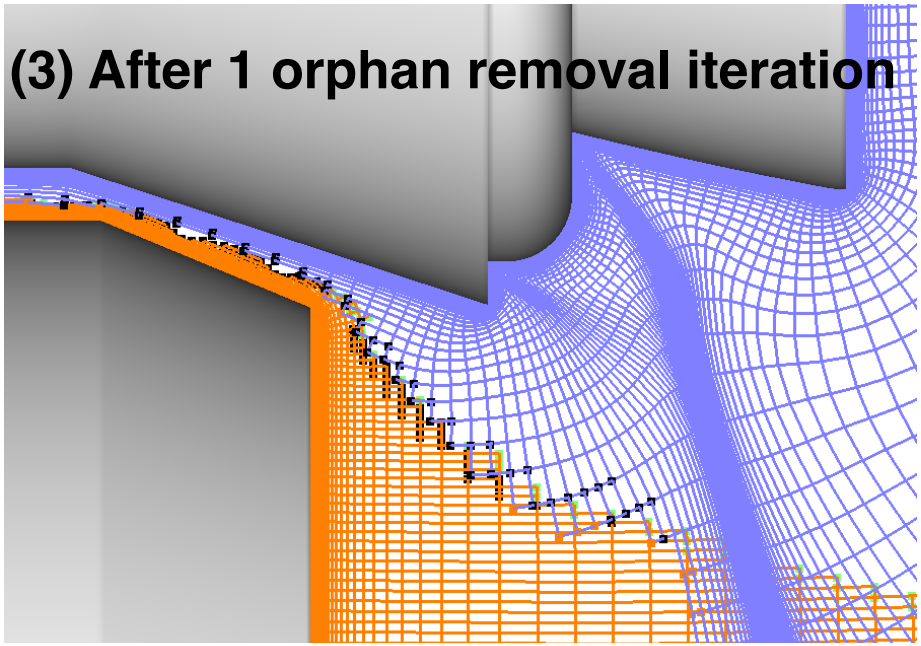
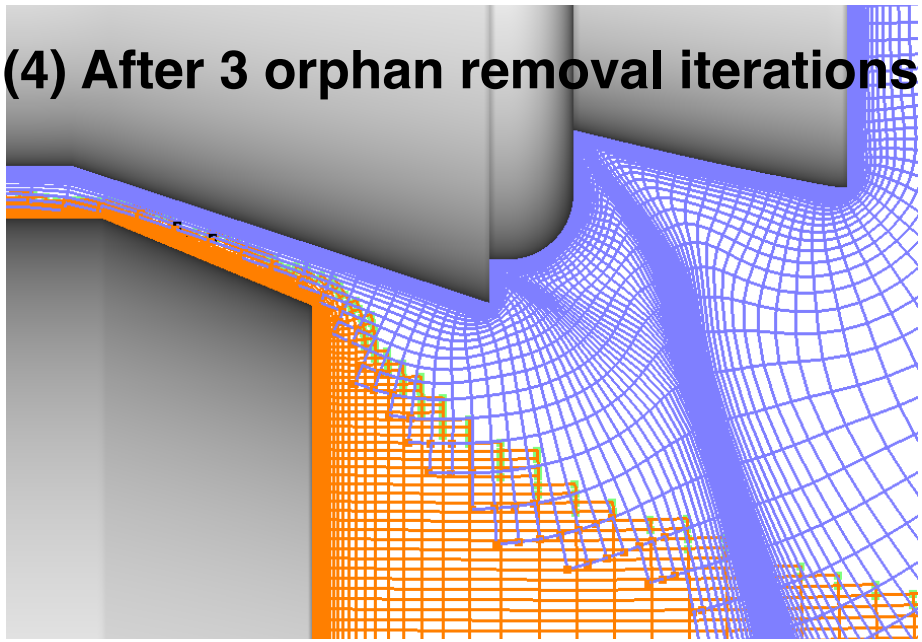
# HOLE-CUTTING PROCEDURE IN C3P



# OBJECTIVES OF CURRENT WORK

1. Given minimum hole boundary, automatically determine spatially variable offset that results in as few orphan points as possible so that orphan removal iterations can be omitted

2. CPU time for auto offset needs to be no more expensive than orphan removal iterations

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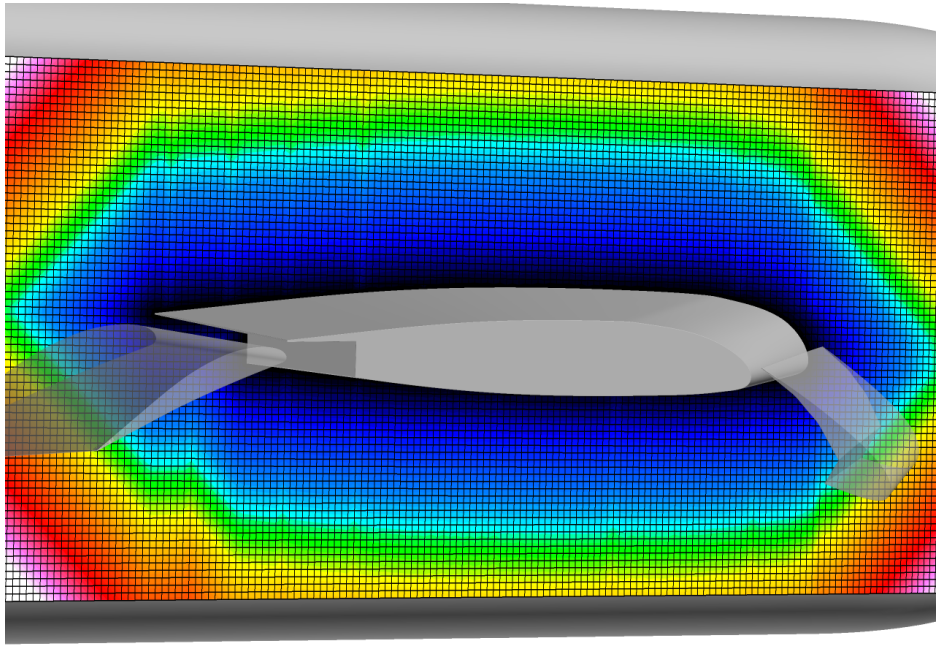
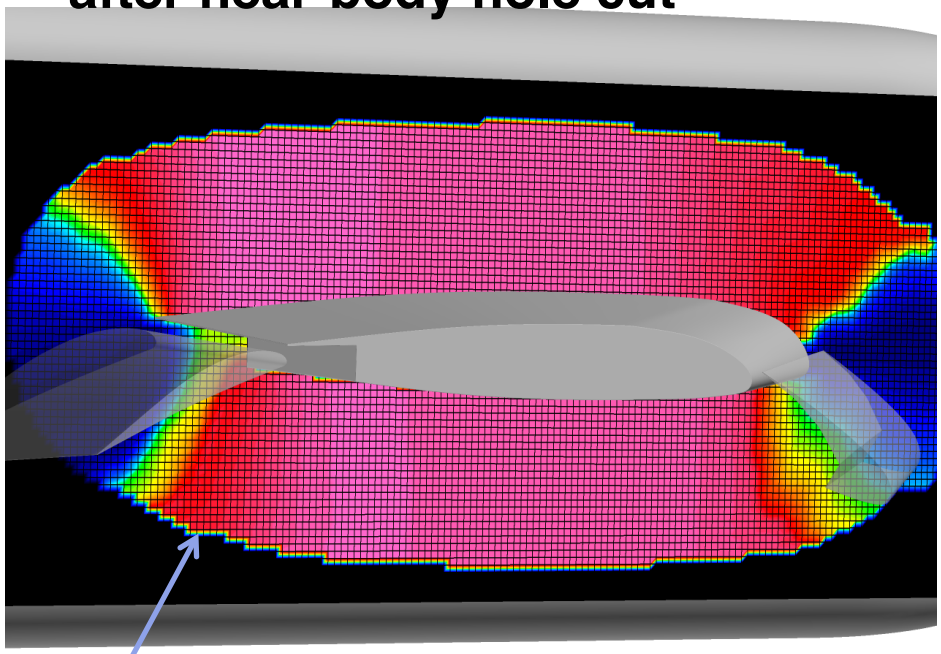
# FAST LOOK-UPS USING CARTESIAN MAPS

**For each geometric component, use Cartesian map to determine**
- **distance to component wall**
- **local outer boundary extent of component near-body grids after (1) minimum hole cut, (2) near-body hole cut estimate**

**Distance to main-wing wall**



**Local outer boundary extent of main-wing near-body grids after near-body hole cut**



**Volume grid outer boundary of main-wing**

# HOLE BOUNDARY ESTIMATE PROCEDURE (1)

## (Near-Body Grids Blanking)

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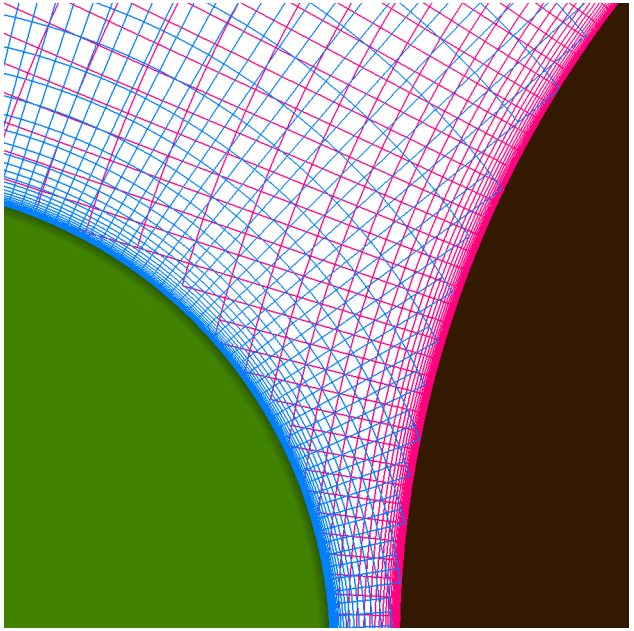
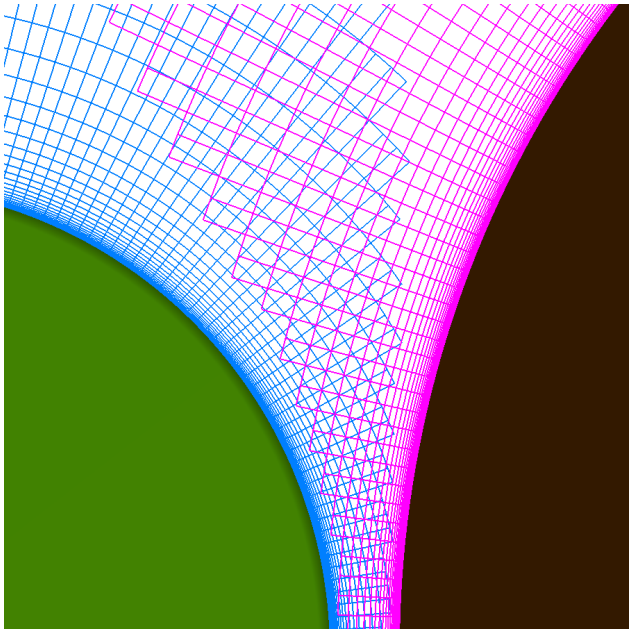




**Starting point: minimum hole**

**$D_w$ = distance to wall of another component**

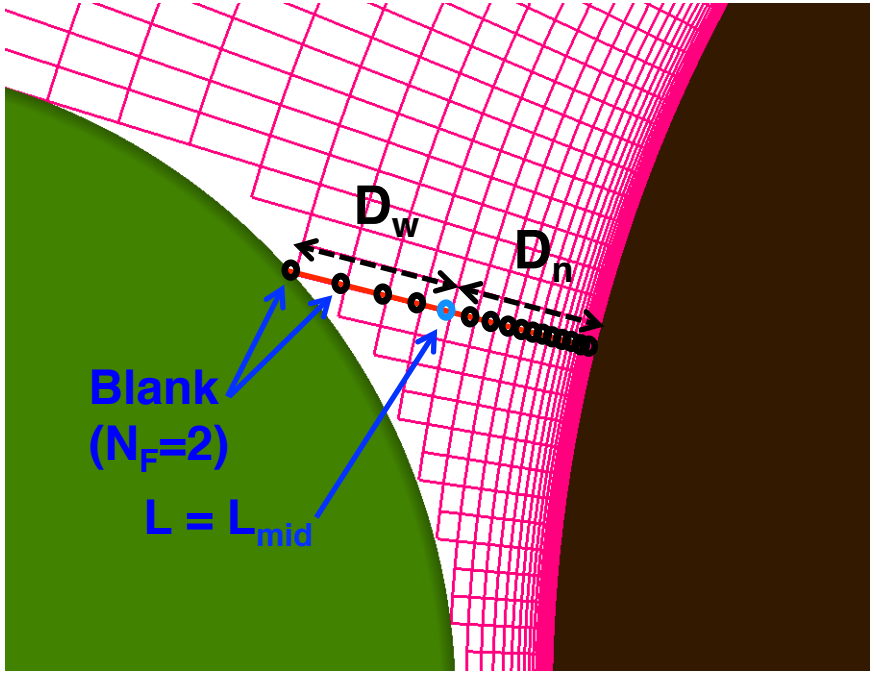
**$D_n$ = distance to wall of own component**

**$N_F$ = no. of layers of requested fringe points**

**Mid-distance rule:**

**- For each ray from surface, find first index $L_{mid}$ in normal direction L where $D_w < D_n$**

**- Blank all points $L > L_{mid} + N_F$**



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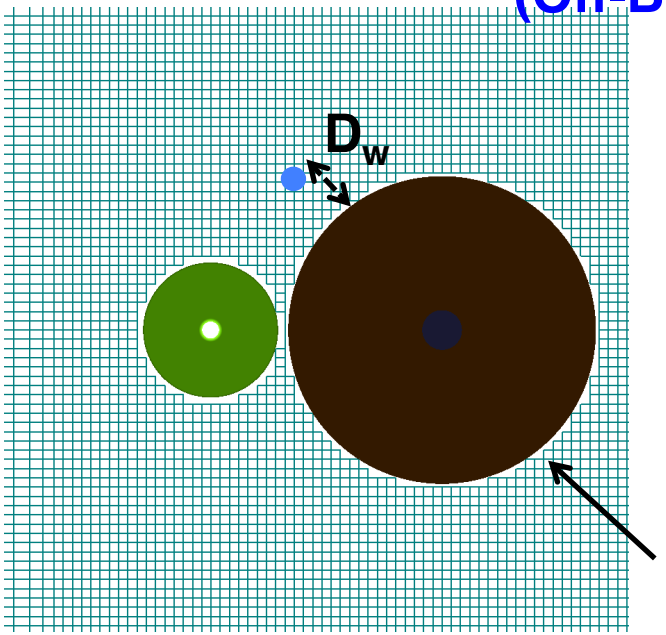
# HOLE BOUNDARY ESTIMATE PROCEDURE (2)

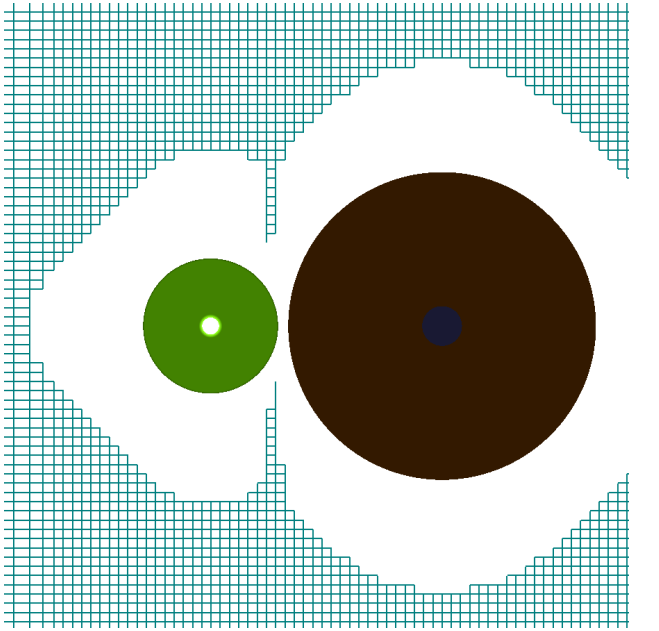
## (Off-Body Grids Treatment)



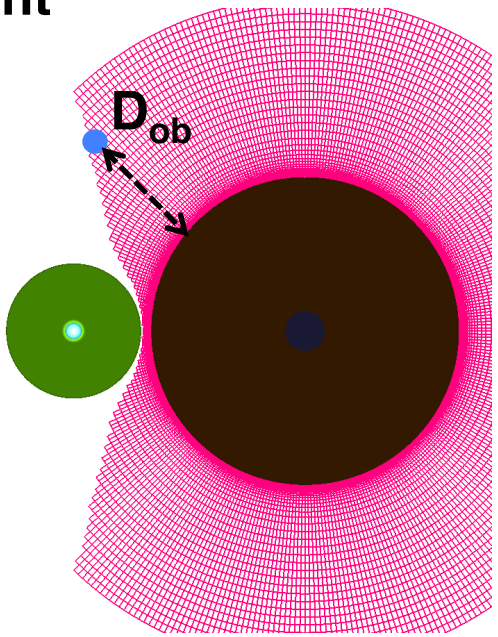

**Starting point: minimum hole**

**$D_w$ = distance to closest wall**
**$D_{ob}$ = local outer boundary extent of closest-wall component after near-body grids blanking (Cartesian map look-up)**

**Closest wall component**



**Outer boundary distance rule:**
**Blank point if**
**$D_w < \varepsilon D_{ob}$**
**where $\varepsilon \sim 0.5$**



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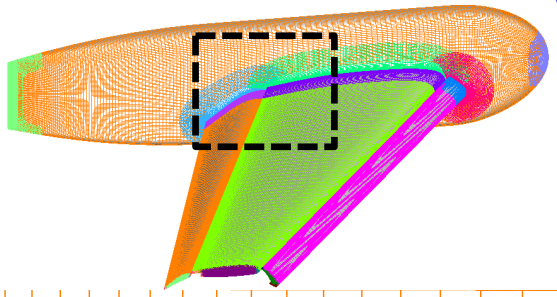
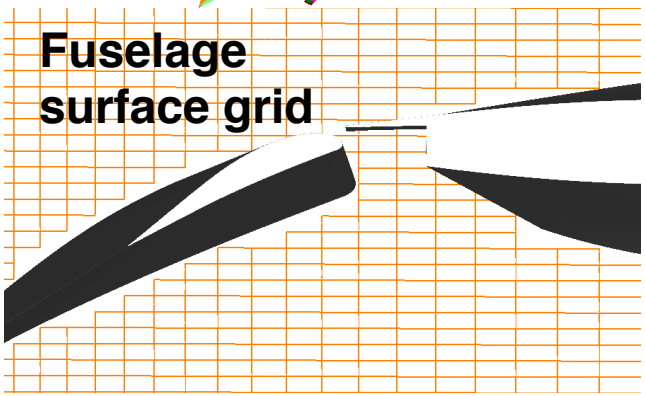
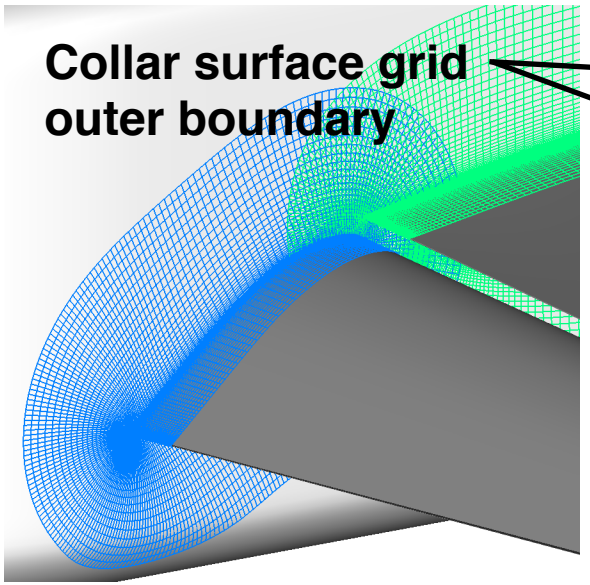
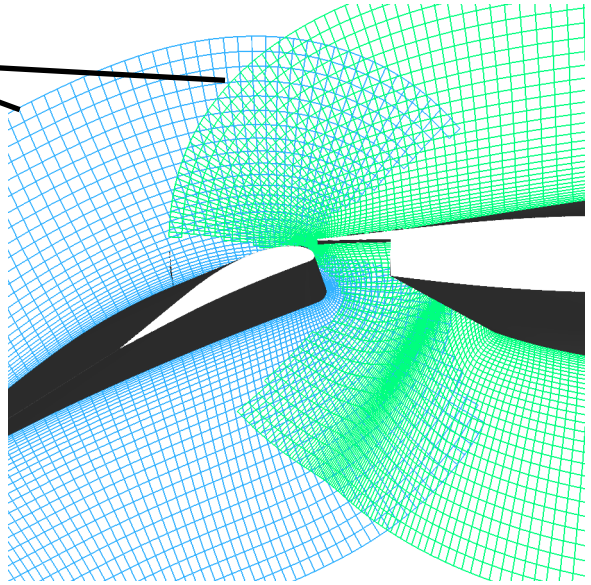
# HOLE BOUNDARY ESTIMATE PROCEDURE (3)

## (Treatment Near Collar Grids)



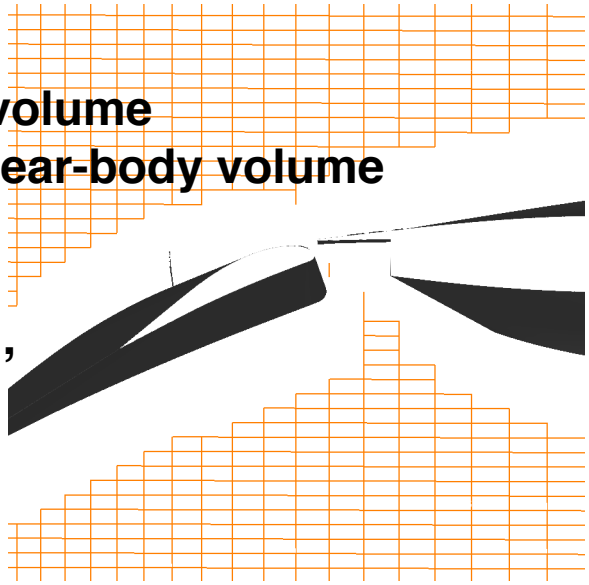


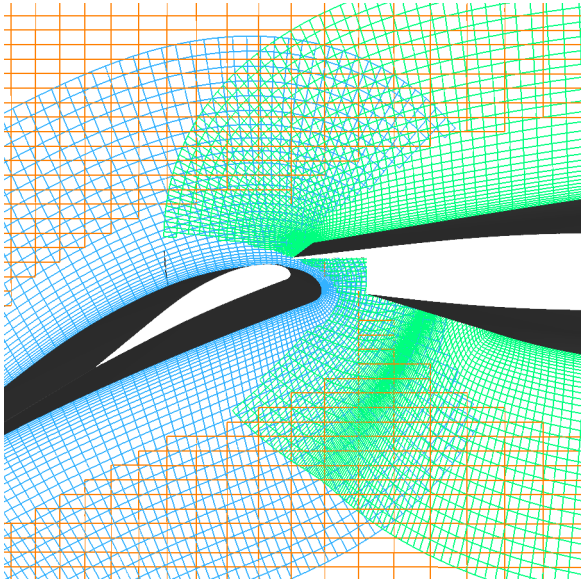



**Analogy:**
**Fuselage surface : Off-body volume**
**Collar surface on fuselage: Near-body volume**

**Outer boundary extent**
**Cartesian maps for slat, wing, and flap need to combine effects of collar grid**
**- surface outer boundary**
**- volume outer boundary**





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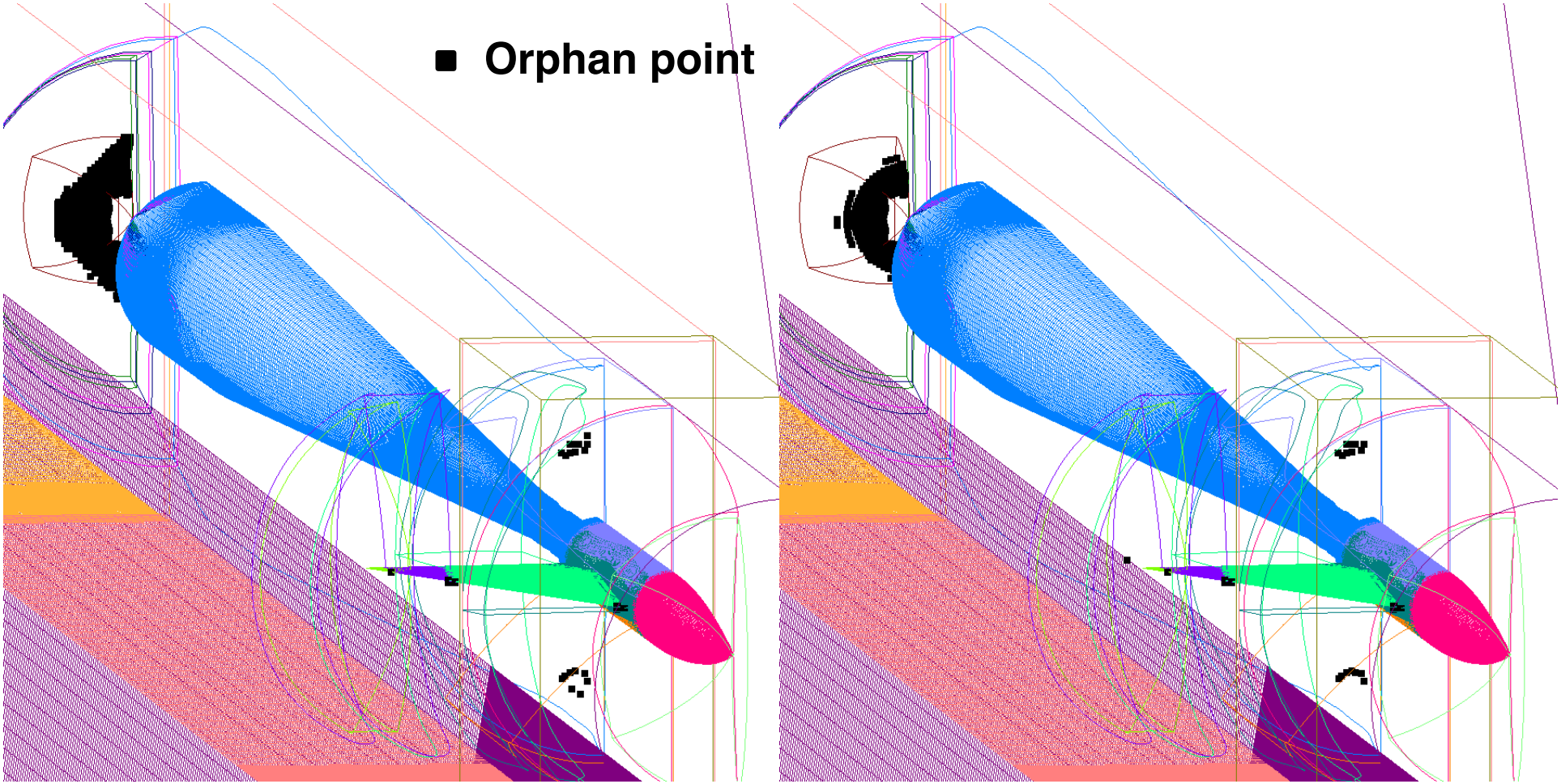
# HOLE BOUNDARY ESTIMATE TEST CASE

## 69° Delta-wing / Body / Sting (AIAA Sonic Boom Workshop)

## 32.6 million points, 17 grids

- Orphan point



**Previous: 1674 orphans**

**New: 1042 orphans**

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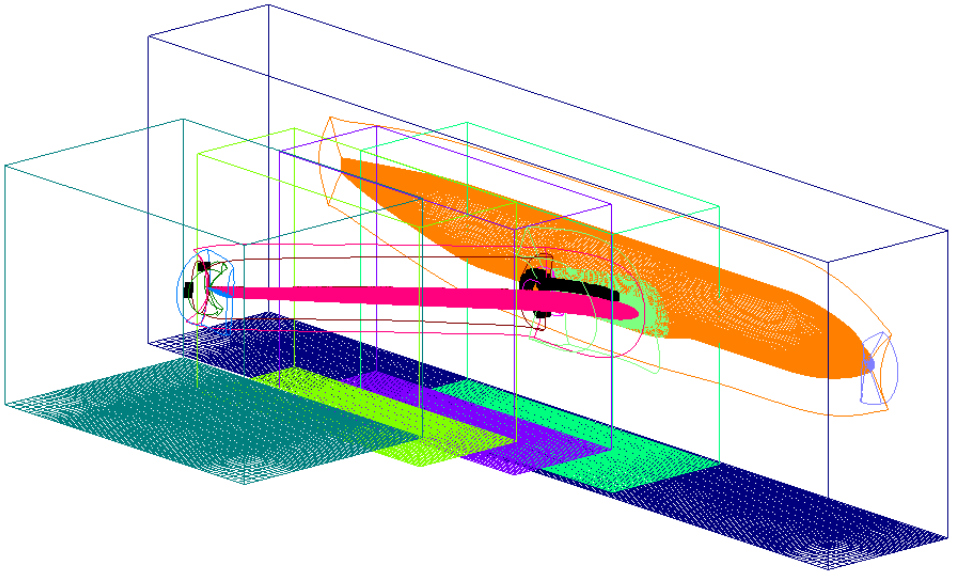
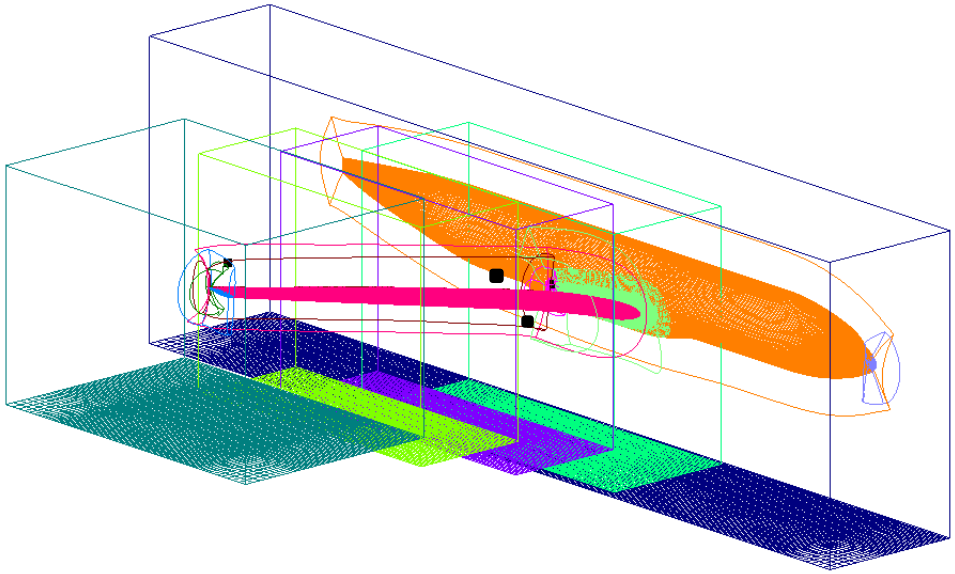
# HOLE BOUNDARY ESTIMATE TEST CASE

## Subsonic Wing/Body: Common Research Model (CRM)

## 17.8 million points, 14 grids

- Orphan point





**Previous: 513 orphans**

**New: 34 orphans**

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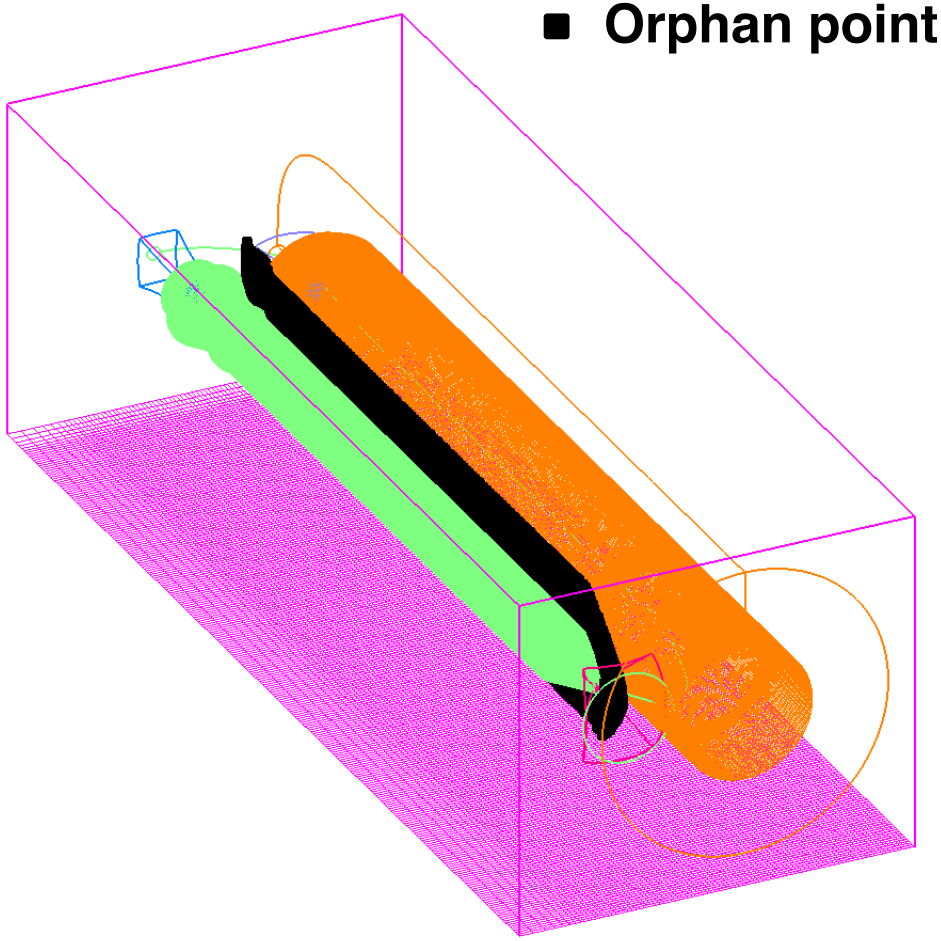
# HOLE BOUNDARY ESTIMATE TEST CASE

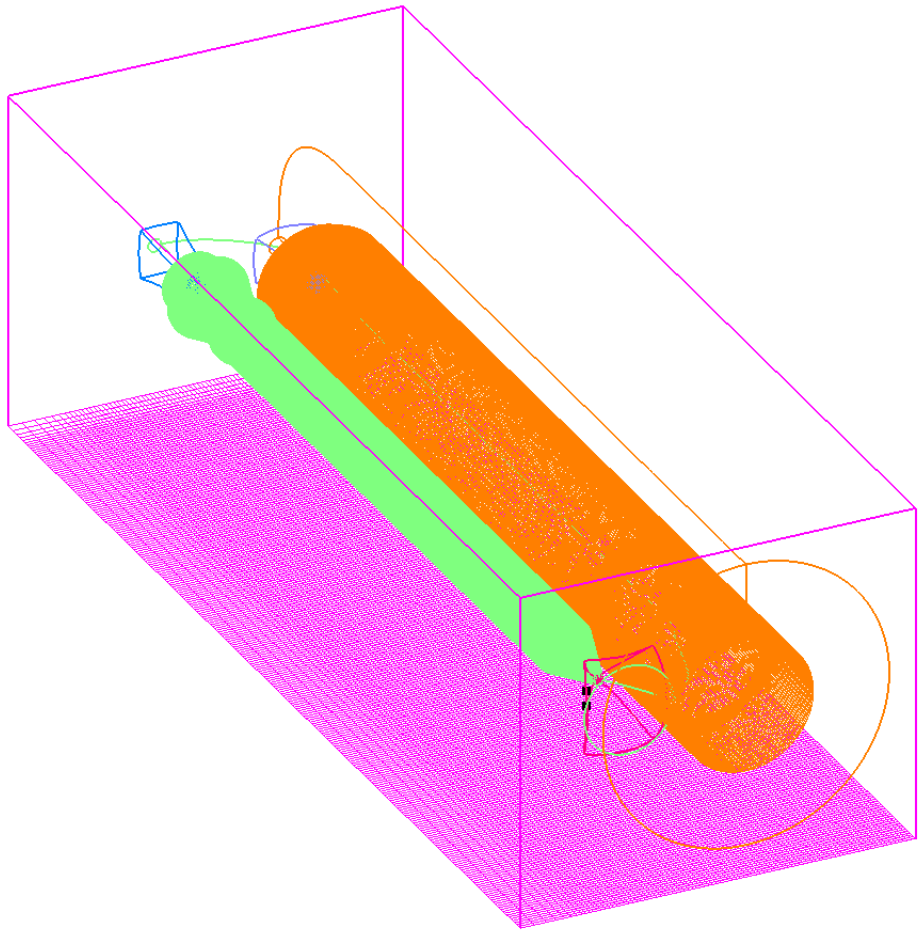
## Tank and Booster

## 28.5 million points, 6 grids

- Orphan point



Previous: 112500 orphans



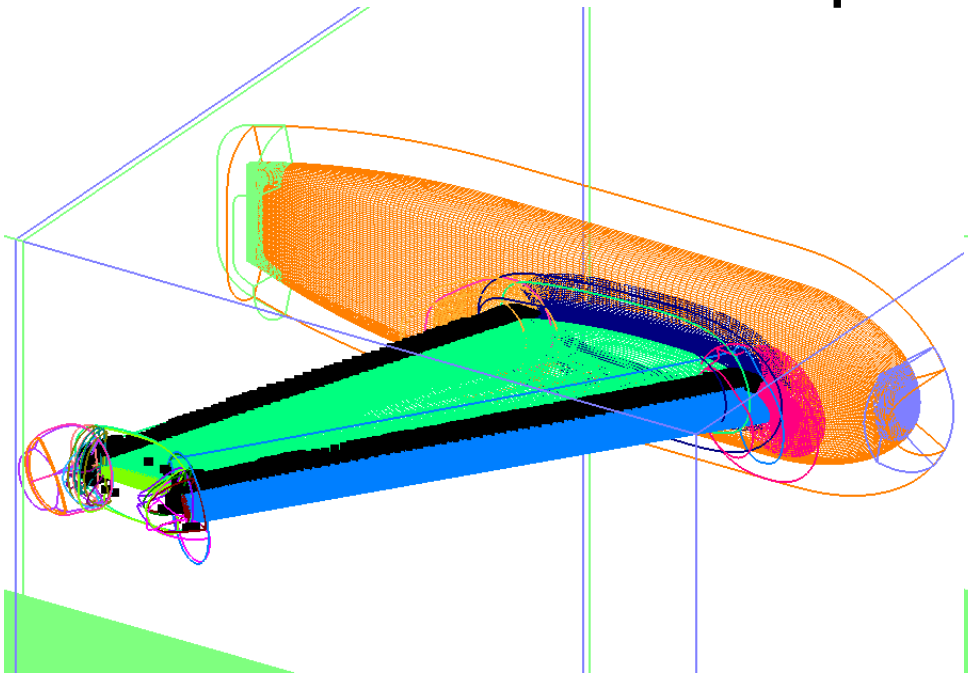
New: 2 orphans

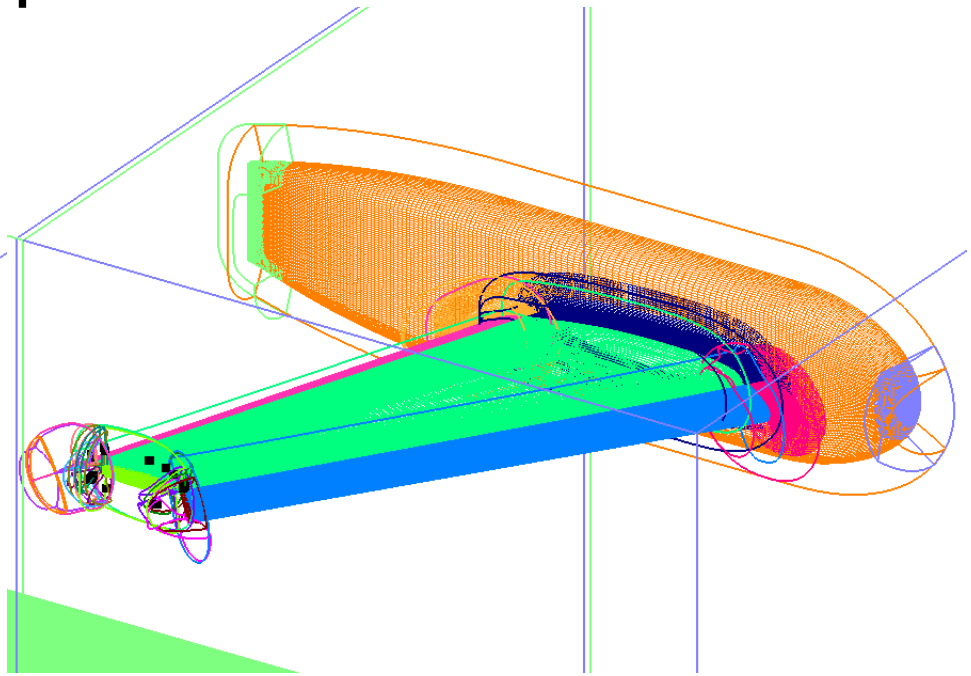
# HOLE BOUNDARY ESTIMATE TEST CASE

## Fuselage with Slat, Wing, and Flap High Lift System (Trapwing)

## 50.6 million points, 24 grids

- Orphan point





**Previous: 85000 orphans**

**New: 32 orphans**

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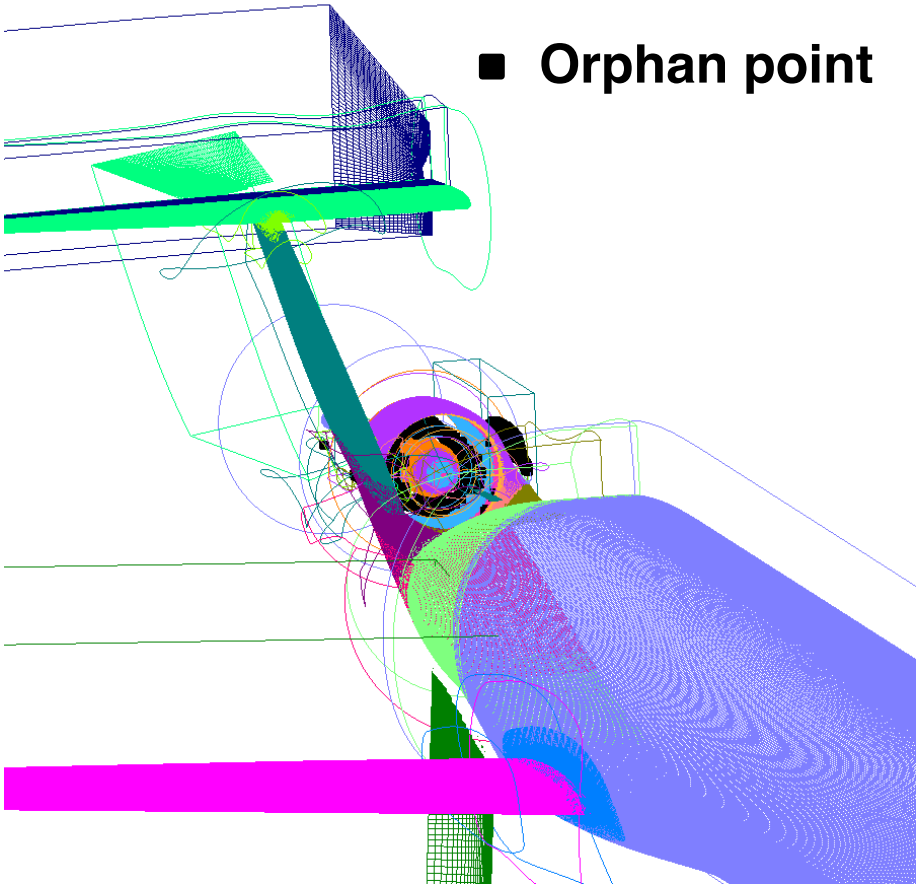
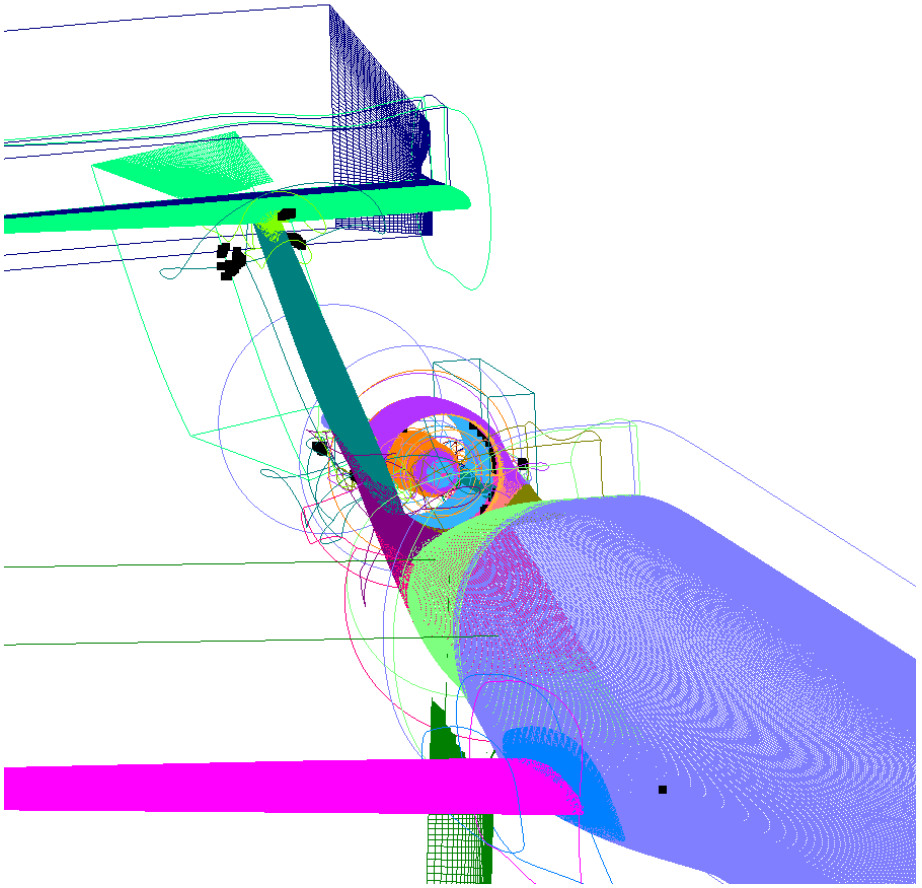
# HOLE BOUNDARY ESTIMATE TEST CASE

## D8 Double Bubble Aircraft with Blended Nacelle in Wind Tunnel
## 156.5 million points, 66 grids




Previous: 61200 orphans



New: 693 orphans

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# TEST CASES AND RESULTS

**CPU time to perform minimum hole cut, hole boundary estimate, donor stencil search, and I/O**

**Linux workstation, 8 OpenMP threads**

| Test Case | # Grid pts ($x10^6$) | Previous | | New | |
|---|---|---|---|---|---|
| | | # orphans | CPU time | # orphans | CPU time |
| Delta Wing | 32.6 | 1674 | 30s | 1042 | 26s |
| CRM | 17.8 | 513 | 25s | 34 | 24s |
| Core/SRB | 28.5 | 112500 | 46s | 2 | 36s |
| Trapwing | 50.6 | 85000 | 94s | 32 | 73s |
| D8 blend nac. | 156.5 | 61200 | 651s | 693 | 600s |

Still need to perform orphan removal iterations

Can stop here for cases 2,3,4

New time ~ 77% – 96% of previous time

# SUMMARY AND CONCLUSIONS

**Overset grid connectivity quality visualization in OVERGRID (2.3t)**

- Various displays related to grid connectivity
- Facilitate rapid location of
  - sources of orphan points
  - local degradation of solution accuracy due to reduction in differencing stencils, or large discrepancies in inter-grid cell sizes

**Improved spatially variable hole boundary offset from minimum hole**

- Successful use of distance rules requires local estimates enabled by Cartesian maps
  - Distance to wall
  - Outer boundary extent of near-body grids with iblanks accounting
- Rules for near-body grids, off-body grids, collar grids
- Compared to previous procedure
  - Significant reduction in number of orphan points (most cases)
  - Reduction in CPU time