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

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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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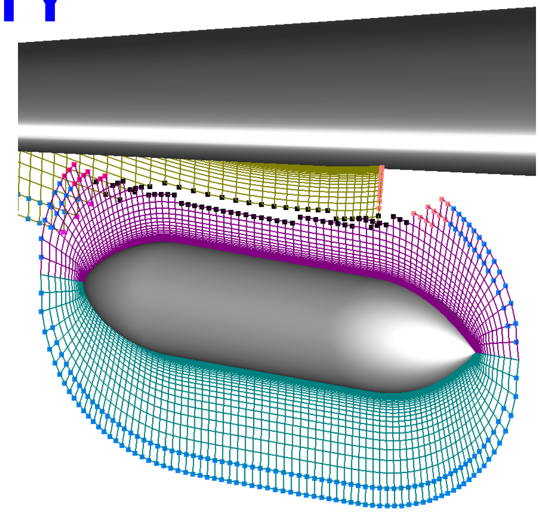
GRID CONNECTIVITY QUALITY

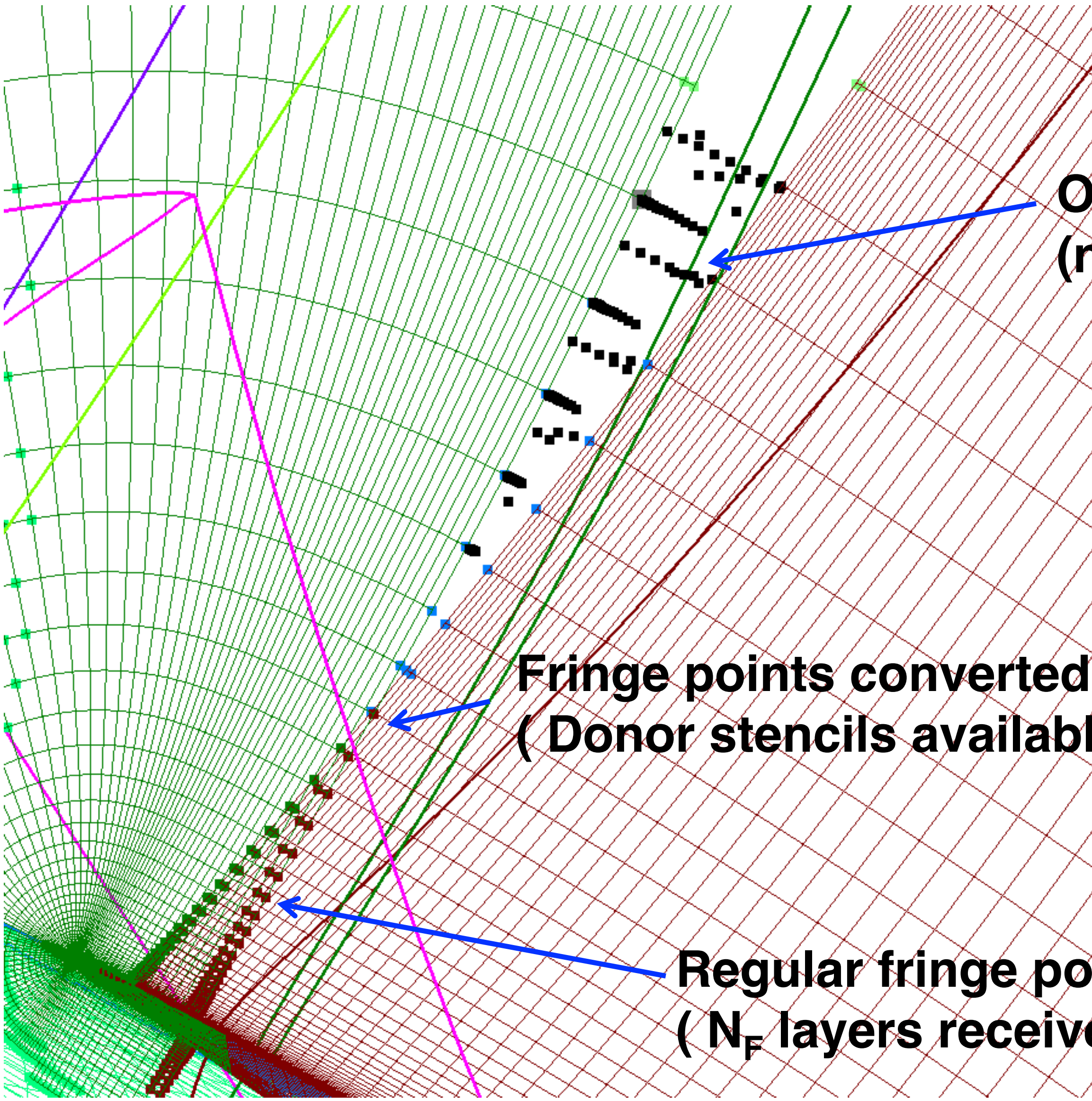


Fringe points: grid points at outer boundaries and hole boundaries that require interpolation data from another grid

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) 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)

FRINGE POINTS AND DONOR STENCILS SCENARIOS



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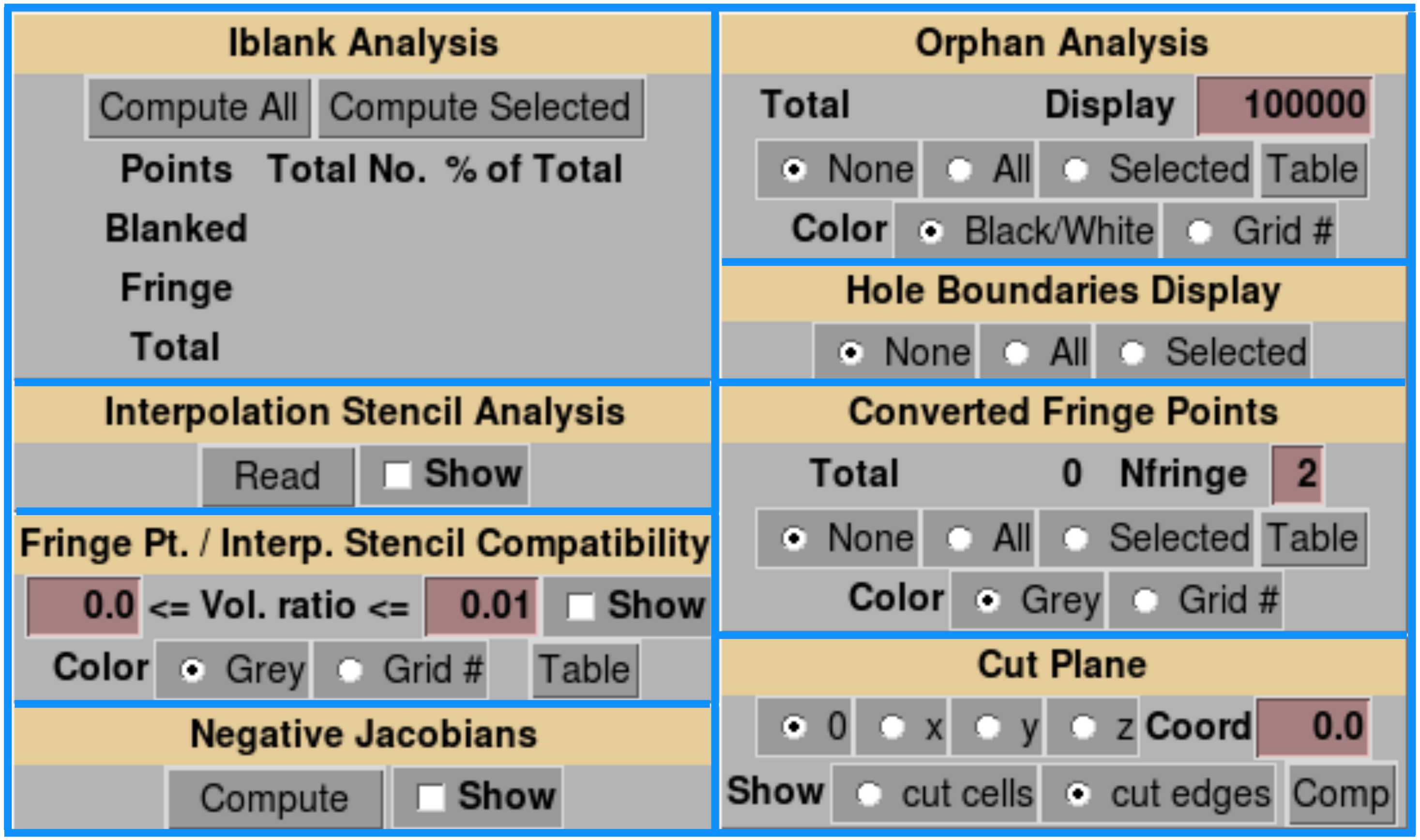
OVERGRID (2.3t) DIAGNOSTICS MODULE



- 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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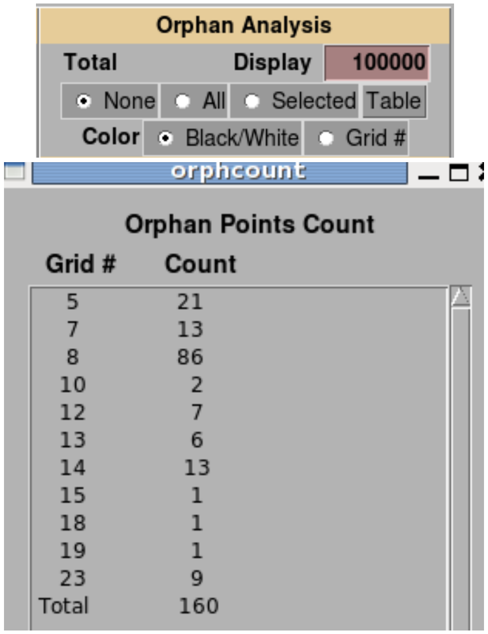
ORPHAN POINTS ANALYSIS

Orphan Points Display

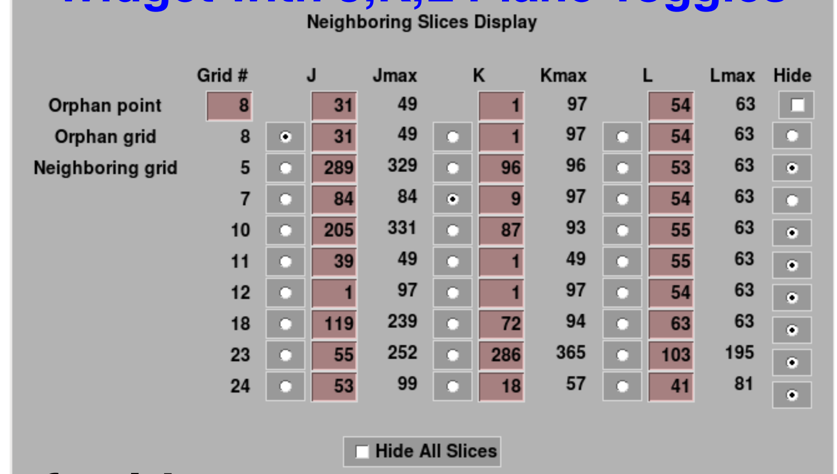


Grid #	Count
5	21
7	13
8	86
10	2
12	7
13	6
14	13
15	1
18	1
19	1
23	9
Total	160

Previous procedure: Manually select grid planes to display

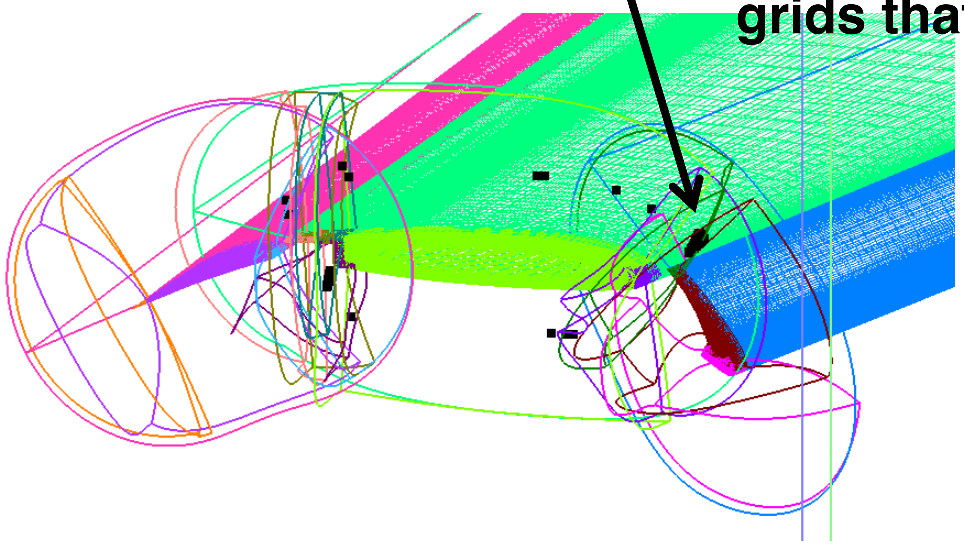
Current procedure: Mouse pick orphan point

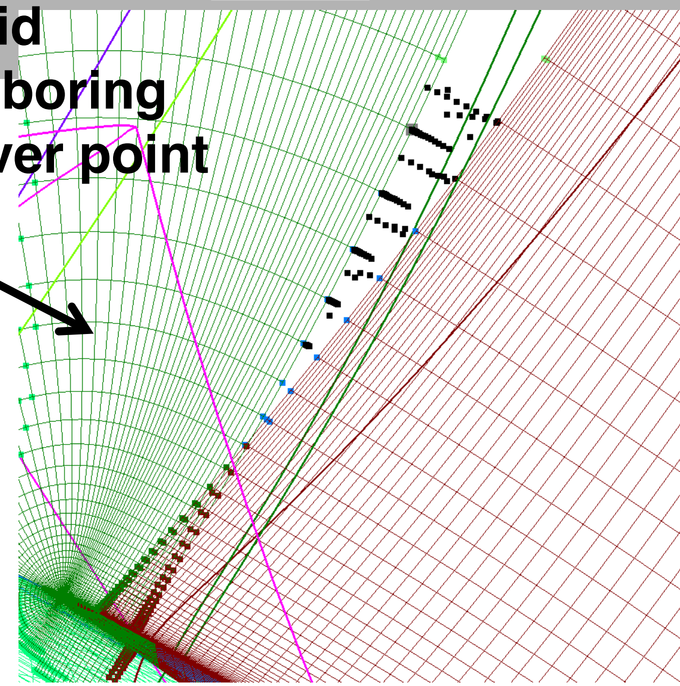
Neighboring Grid Slices Display Widget with J,K,L Plane Toggles



	Grid #	J	Jmax	K	Kmax	L	Lmax
Orphan point	8	31	49	1	97	54	63
Orphan grid	8	31	49	1	97	54	63
Neighboring grid	5	289	329	96	96	53	63
	7	84	84	9	97	54	63
	10	205	331	87	93	55	63
	11	39	49	1	49	55	63
	12	1	97	1	97	54	63
	18	119	239	72	94	63	63
	23	55	252	286	365	103	195
	24	53	99	18	57	41	81

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





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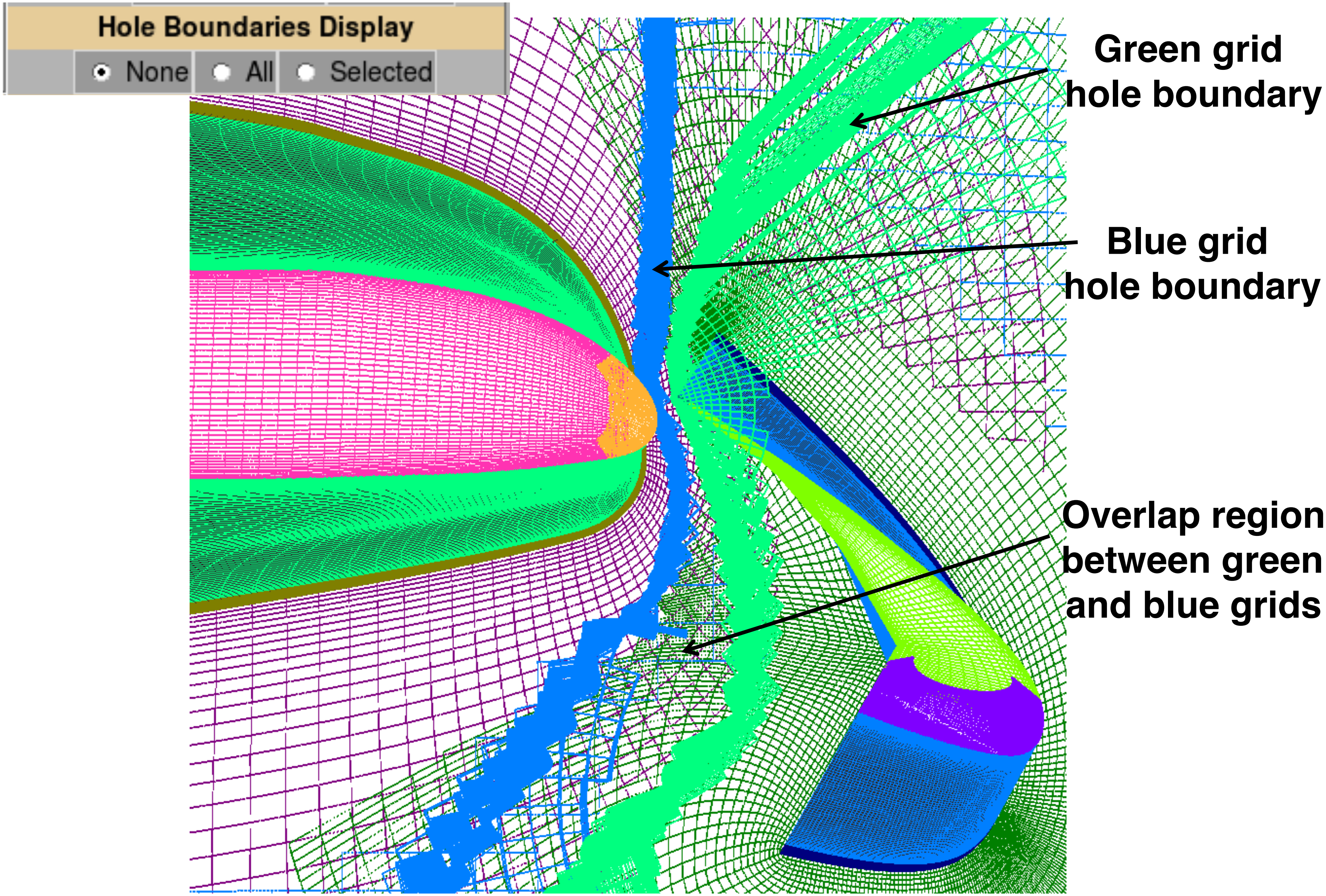
3-D HOLE BOUNDARIES



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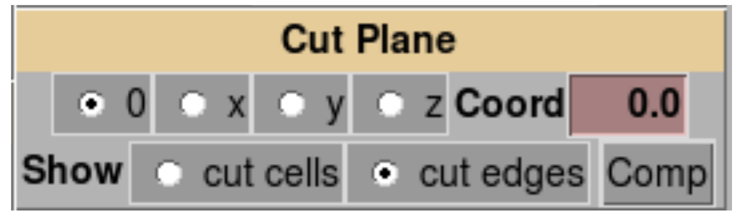
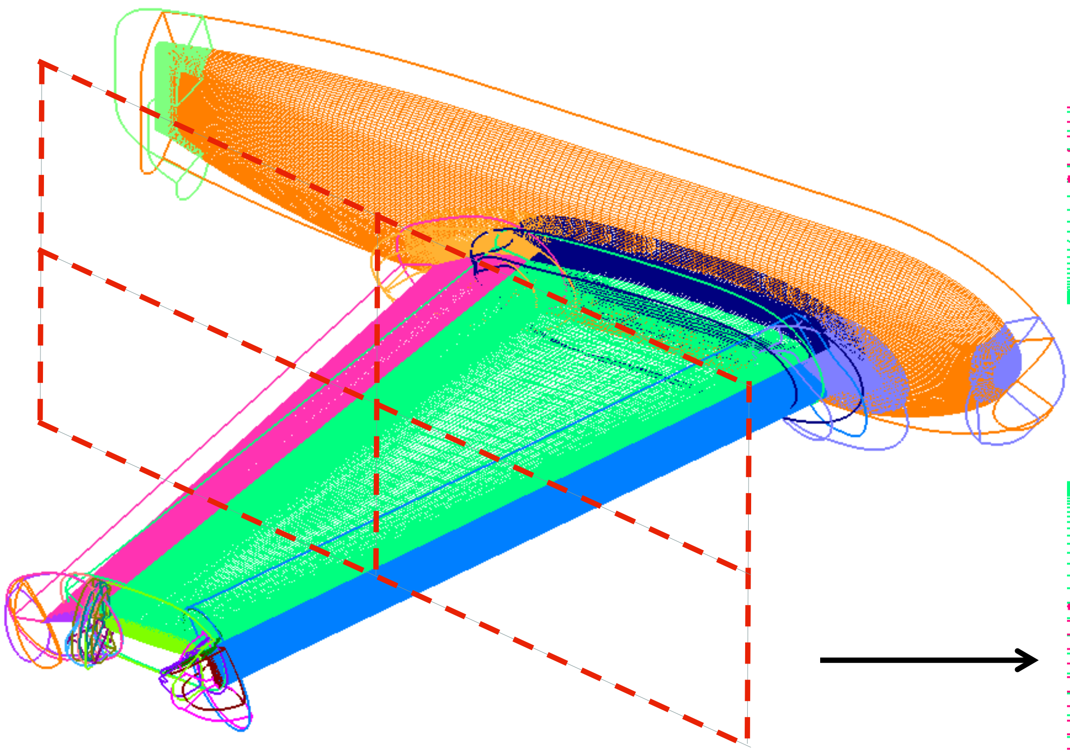
CONSTANT CARTESIAN CUTPLANE

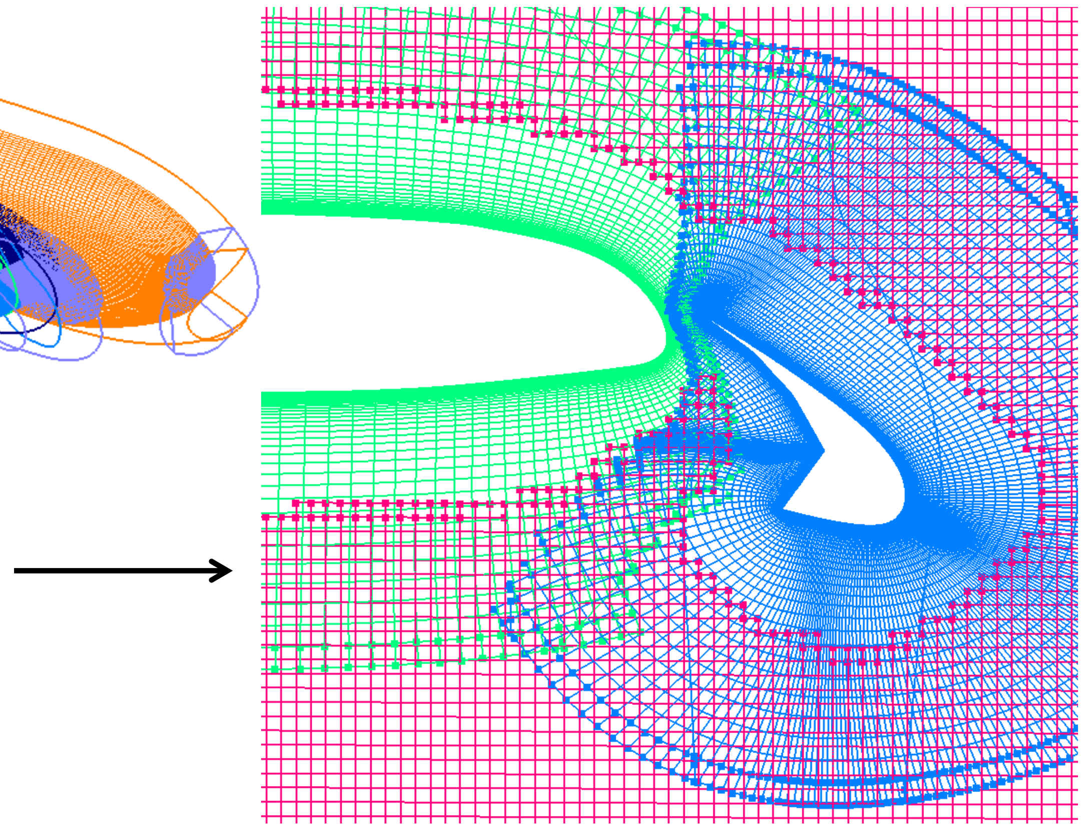
Display options:

- Edges formed by intersection of Cartesian plane and hex cells

- Complete cells cut by Cartesian plane

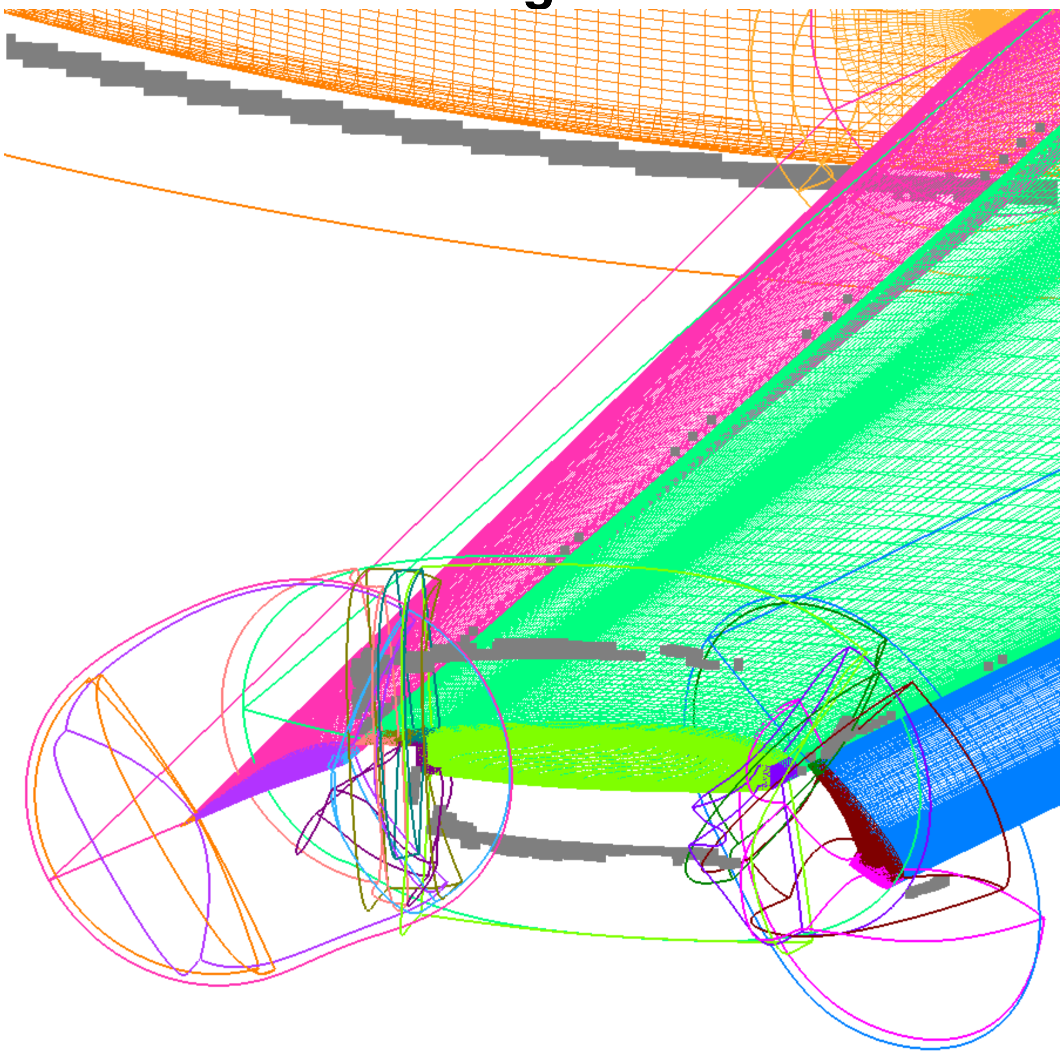


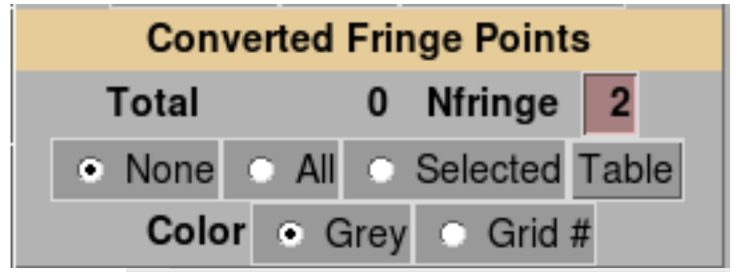




CONVERTED FRINGE POINTS

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





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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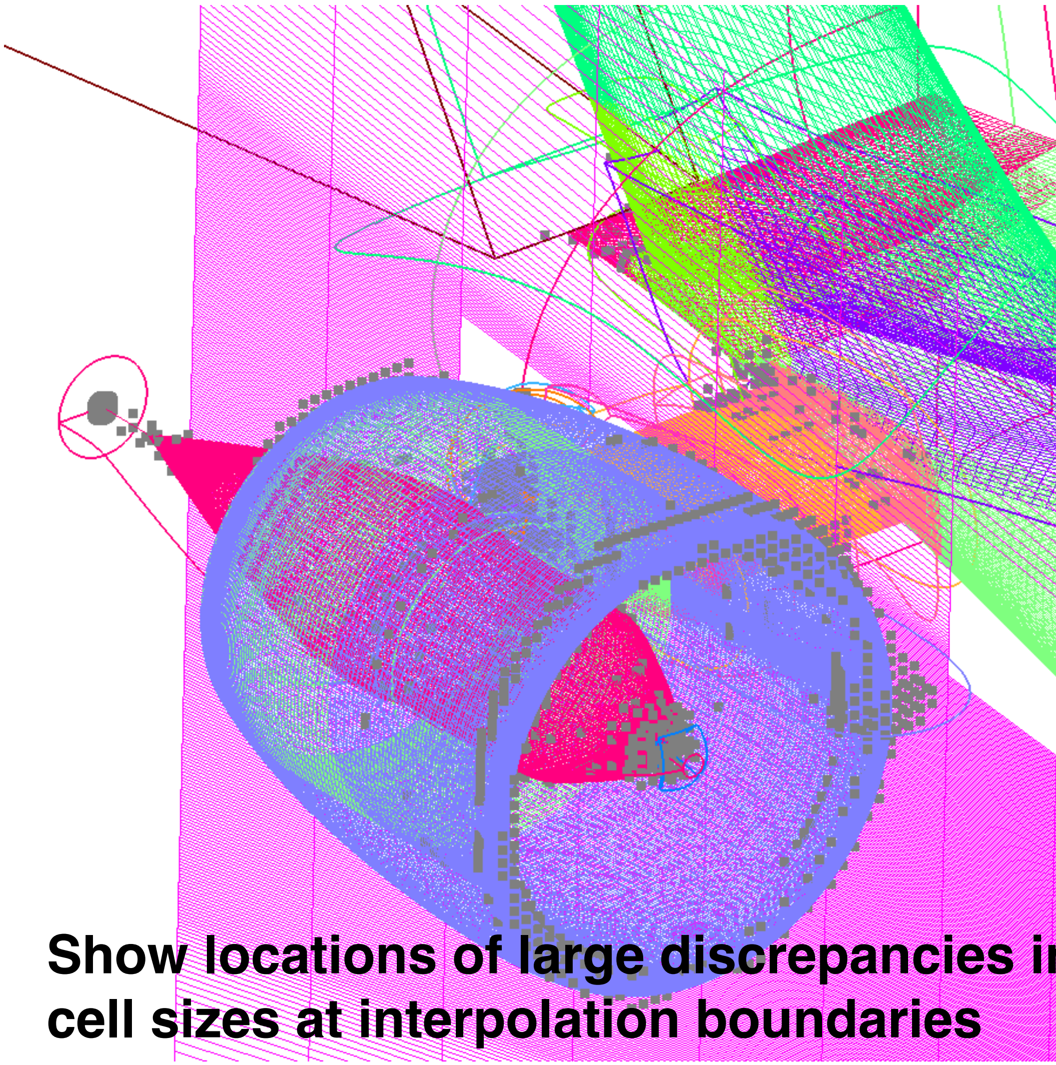
DONOR STENCIL COMPATIBILITY

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

Fringe Pt. / Interp. Stencil Compatibility

0.0 <= Vol. ratio <= 0.01 ☐ Show

Color ⦿ Grey ○ Grid # Table

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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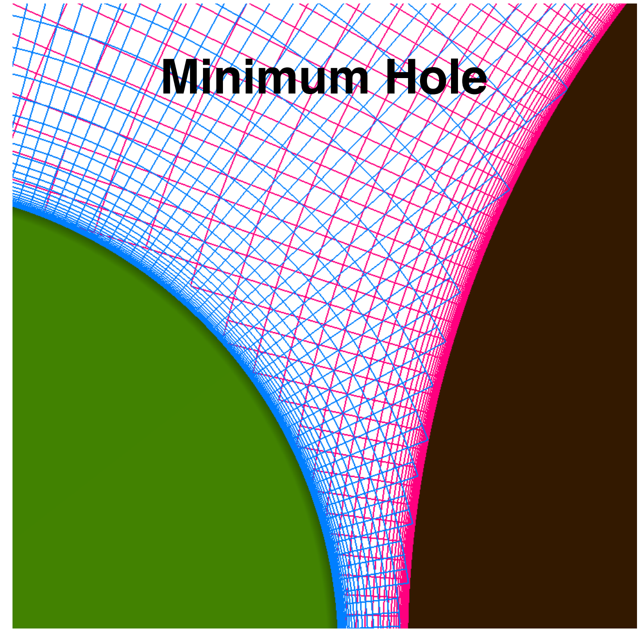
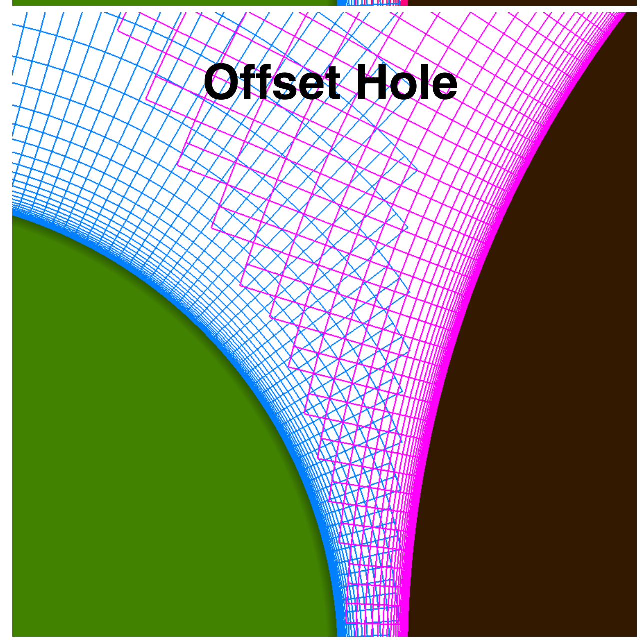
HOLE-CUTTING METHODS BEYOND MINIMUM HOLE

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**

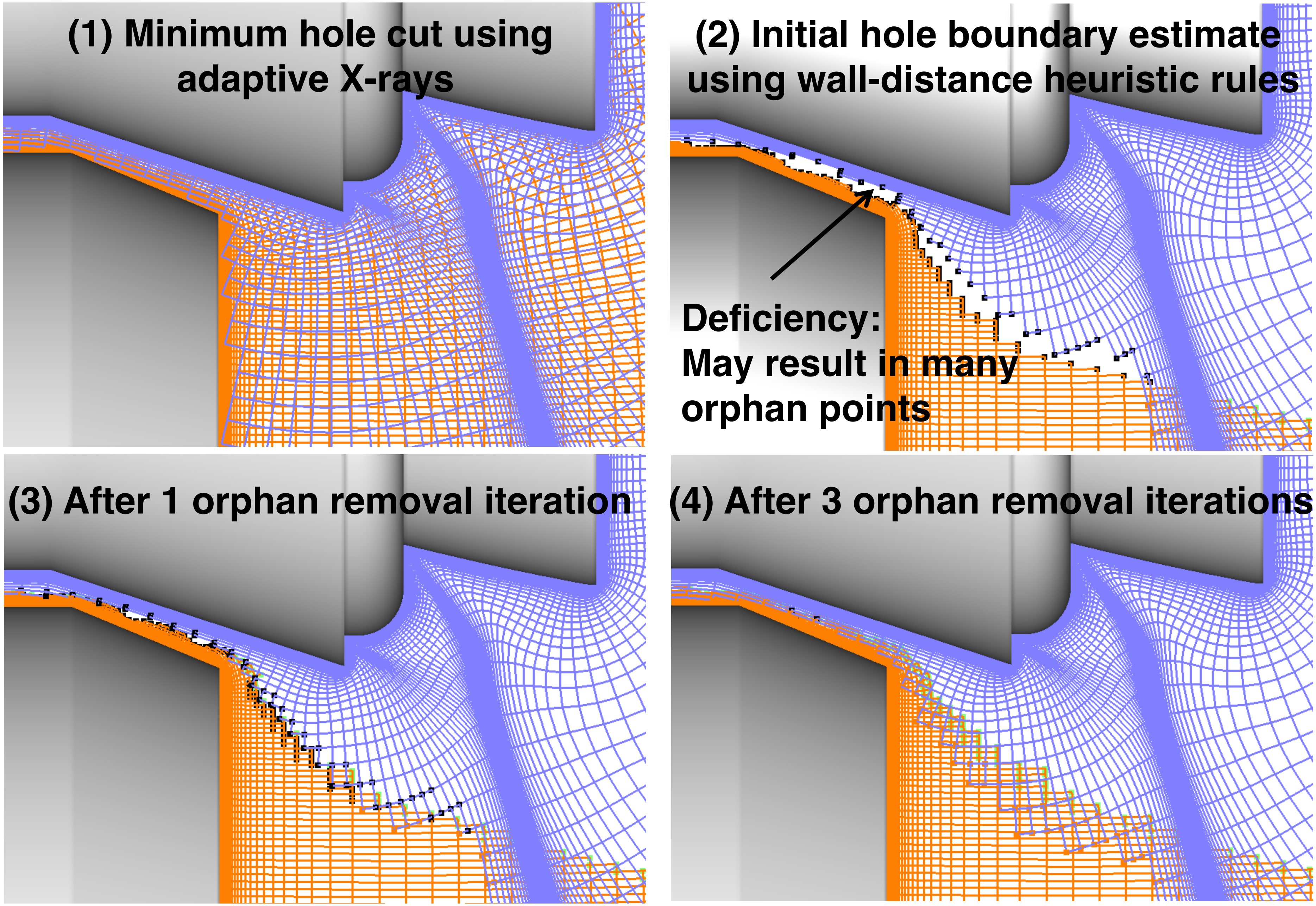
Publication

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**

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

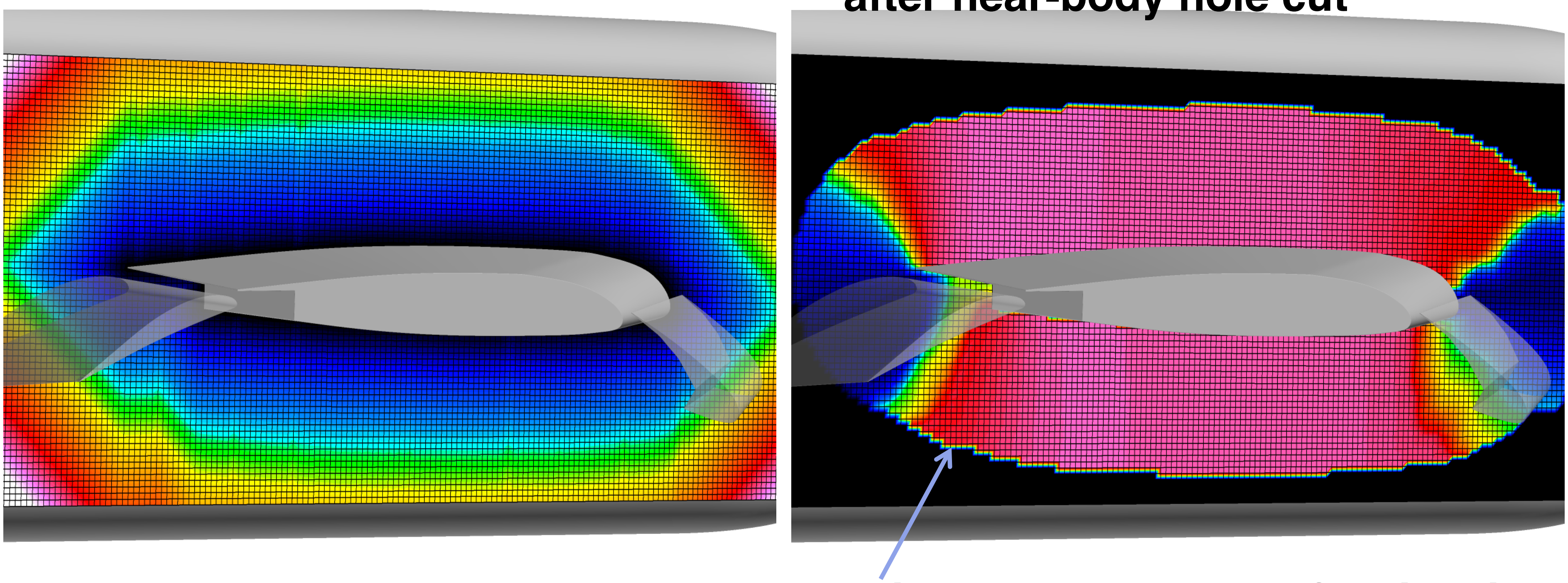
2. CPU time for auto offset needs to be no more expensive than orphan removal iterations

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**

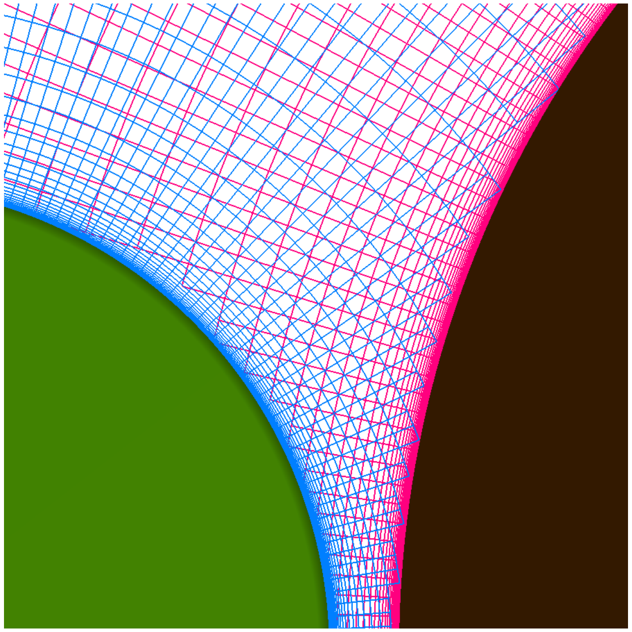
Distance to main-wing wall

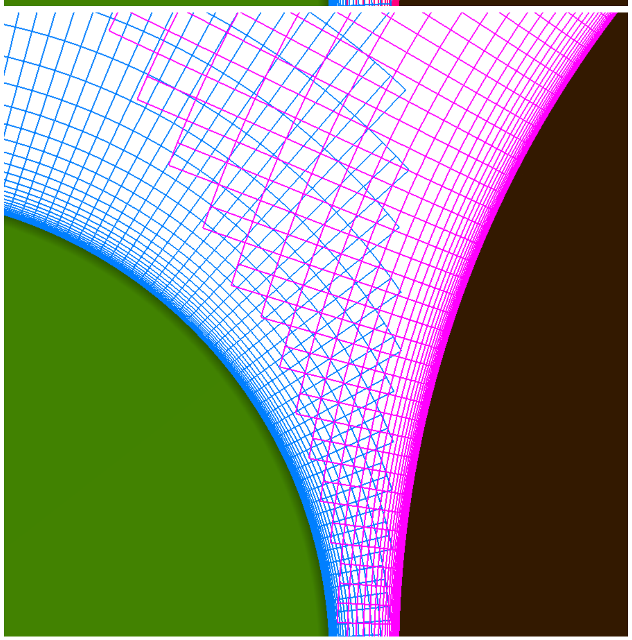
Local outer boundary extent of main-wing near-body grids after near-body hole cut



Volume grid outer boundary of main-wing

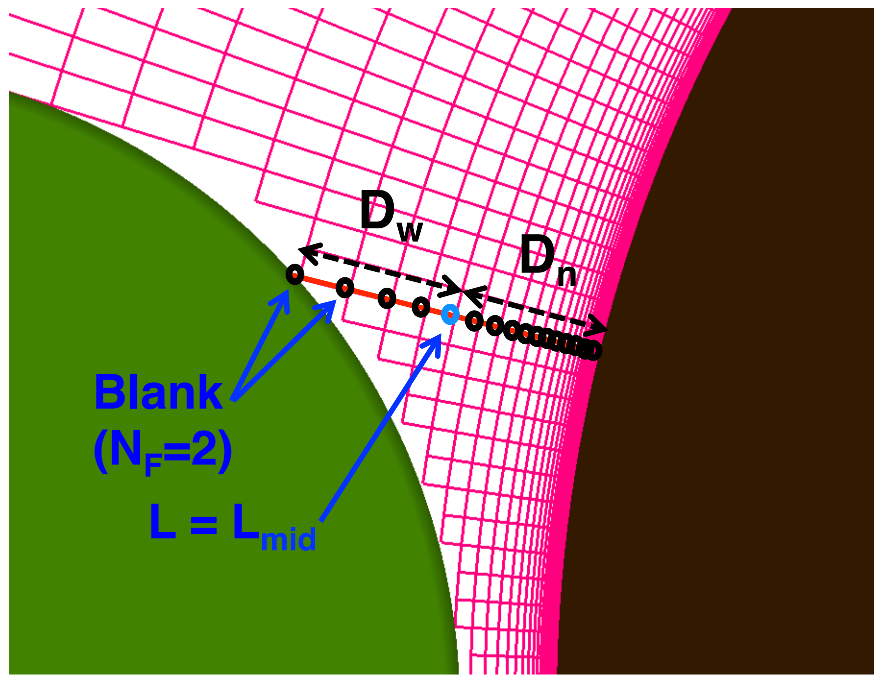
HOLE BOUNDARY ESTIMATE PROCEDURE (1)
(Near-Body Grids Blanking)





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 $L > L_{mid} + N_F$**



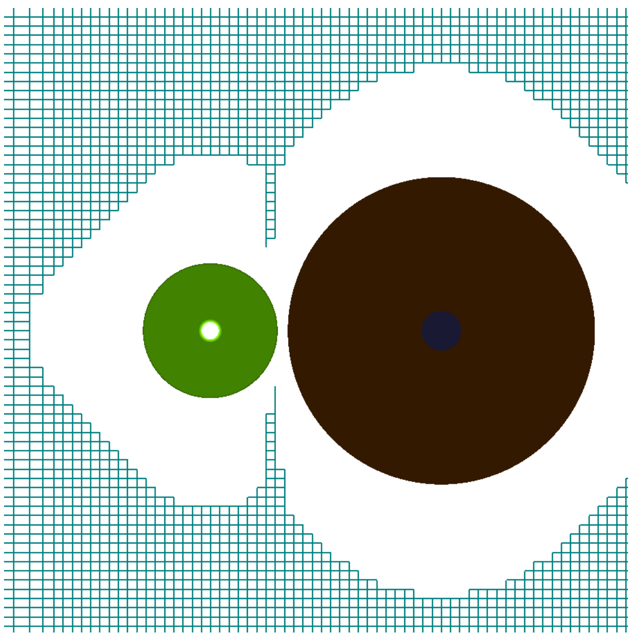
HOLE BOUNDARY ESTIMATE PROCEDURE (2)

(Off-Body Grids Treatment)

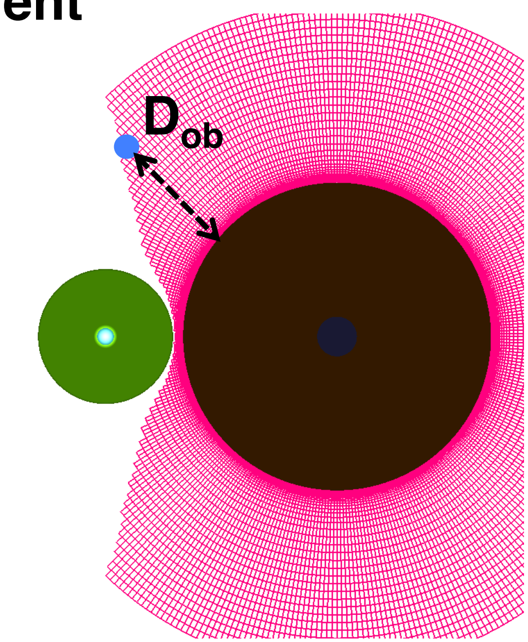
Starting point: minimum hole

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)

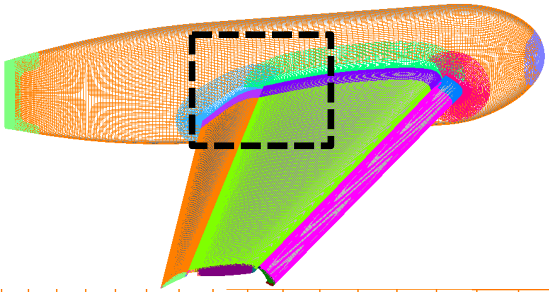
Closest wall component

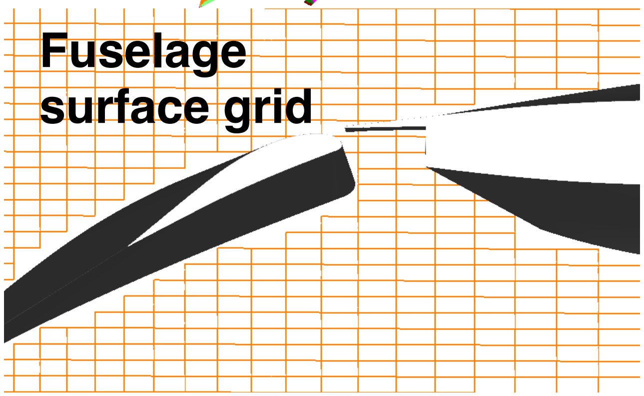


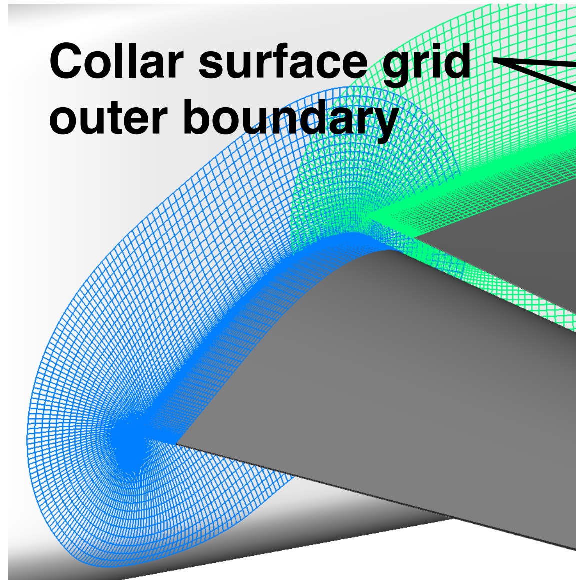
Outer boundary distance rule:
Blank point if
$D_w < \varepsilon D_{ob}$
where $\varepsilon \sim 0.5$

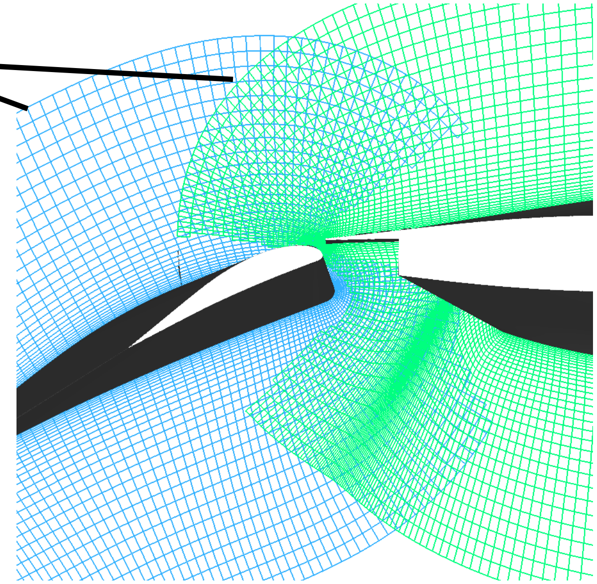


HOLE BOUNDARY ESTIMATE PROCEDURE (3)
(Treatment Near Collar Grids)



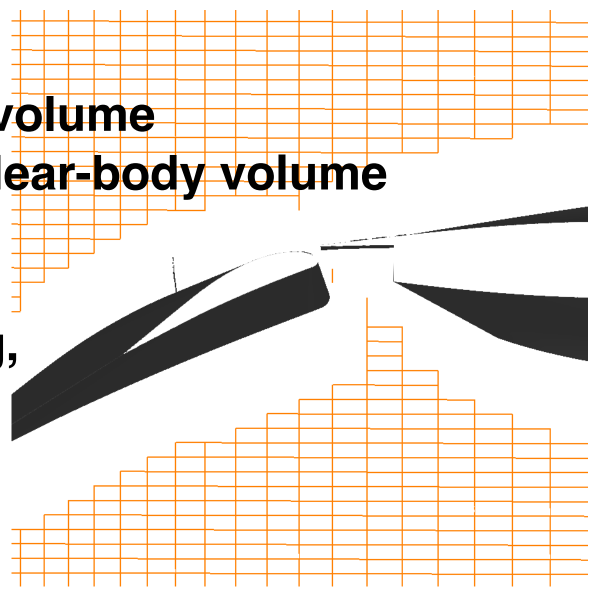


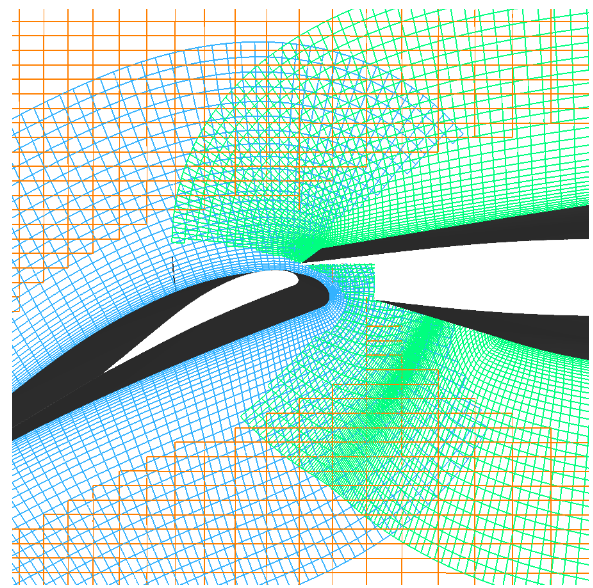




Analogy:
Fuselage surface : Off-body volume
Collar surface on fuselage: Near-body volume

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

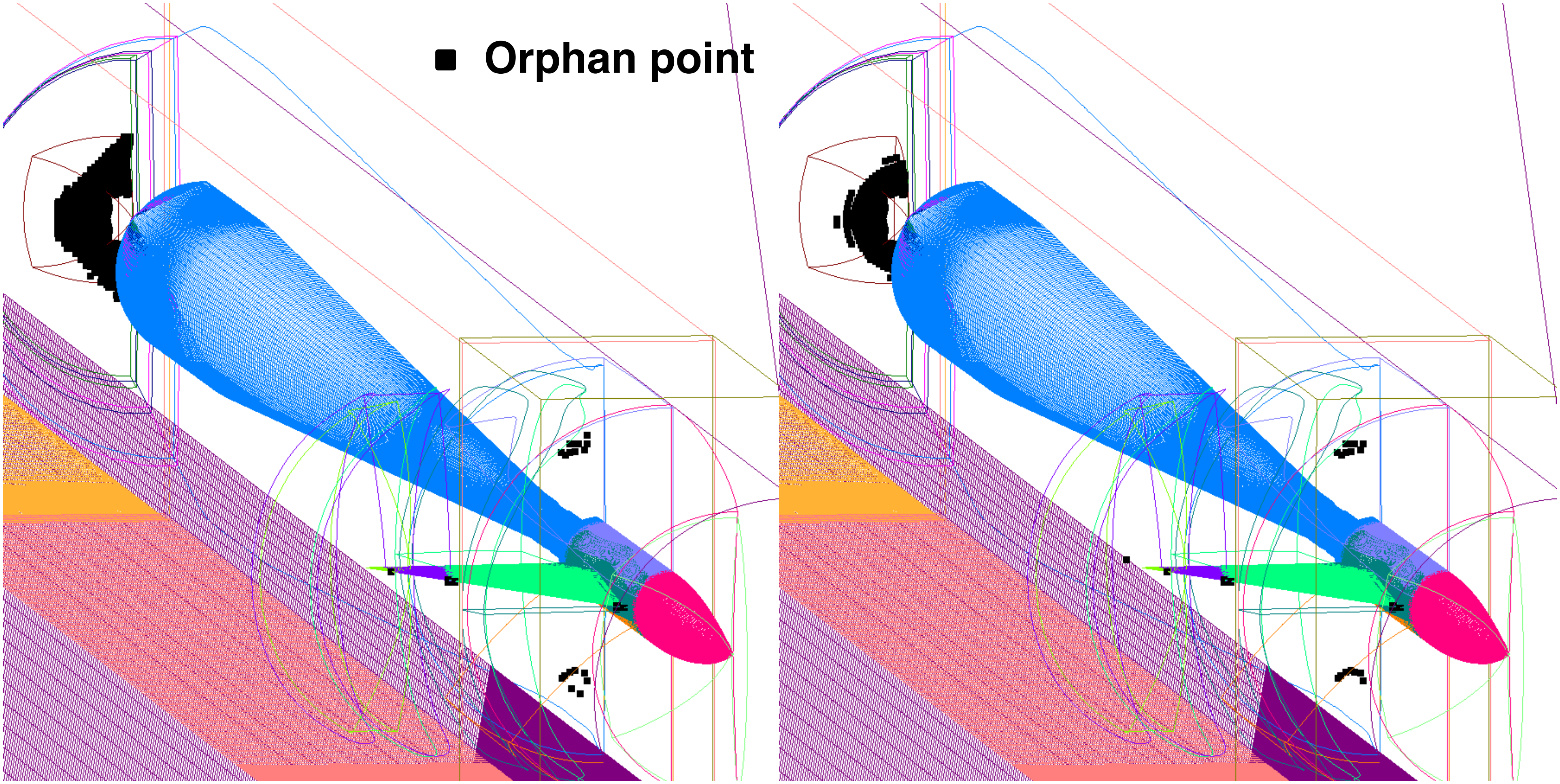




HOLE BOUNDARY ESTIMATE TEST CASE

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

32.6 million points, 17 grids



Previous: 1674 orphans | **New: 1042 orphans**

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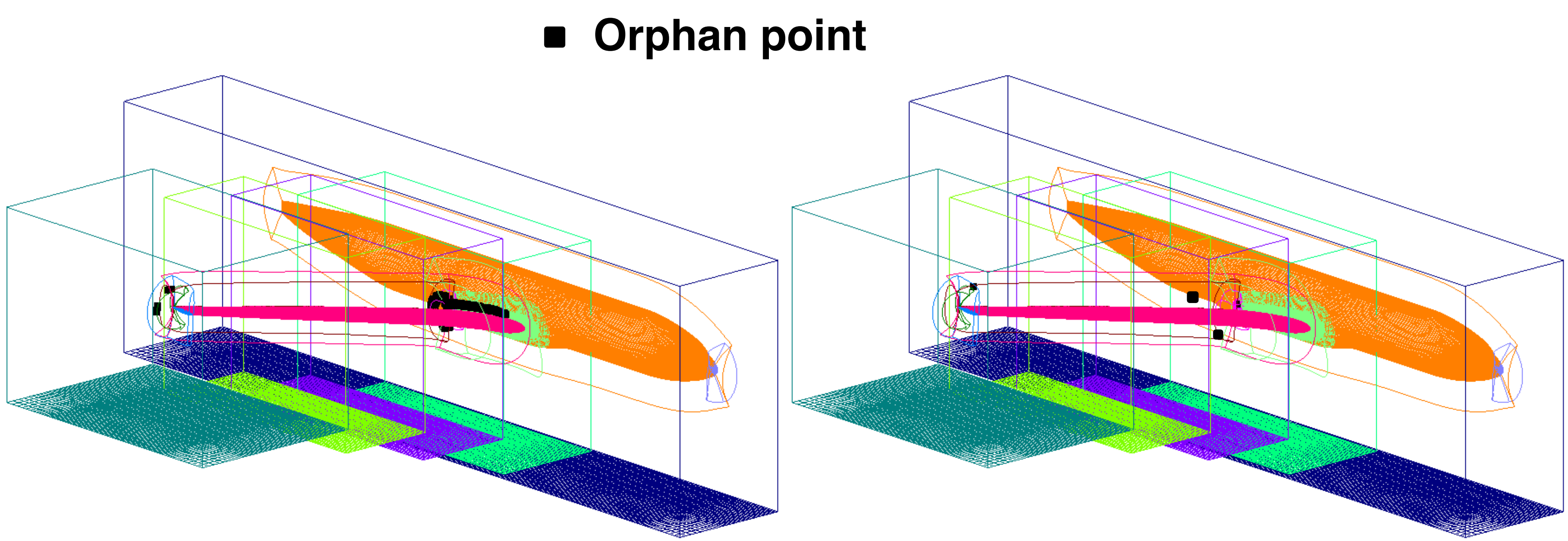
HOLE BOUNDARY ESTIMATE TEST CASE

Subsonic Wing/Body: Common Research Model (CRM)

17.8 million points, 14 grids



Previous: 513 orphans **New: 34 orphans**

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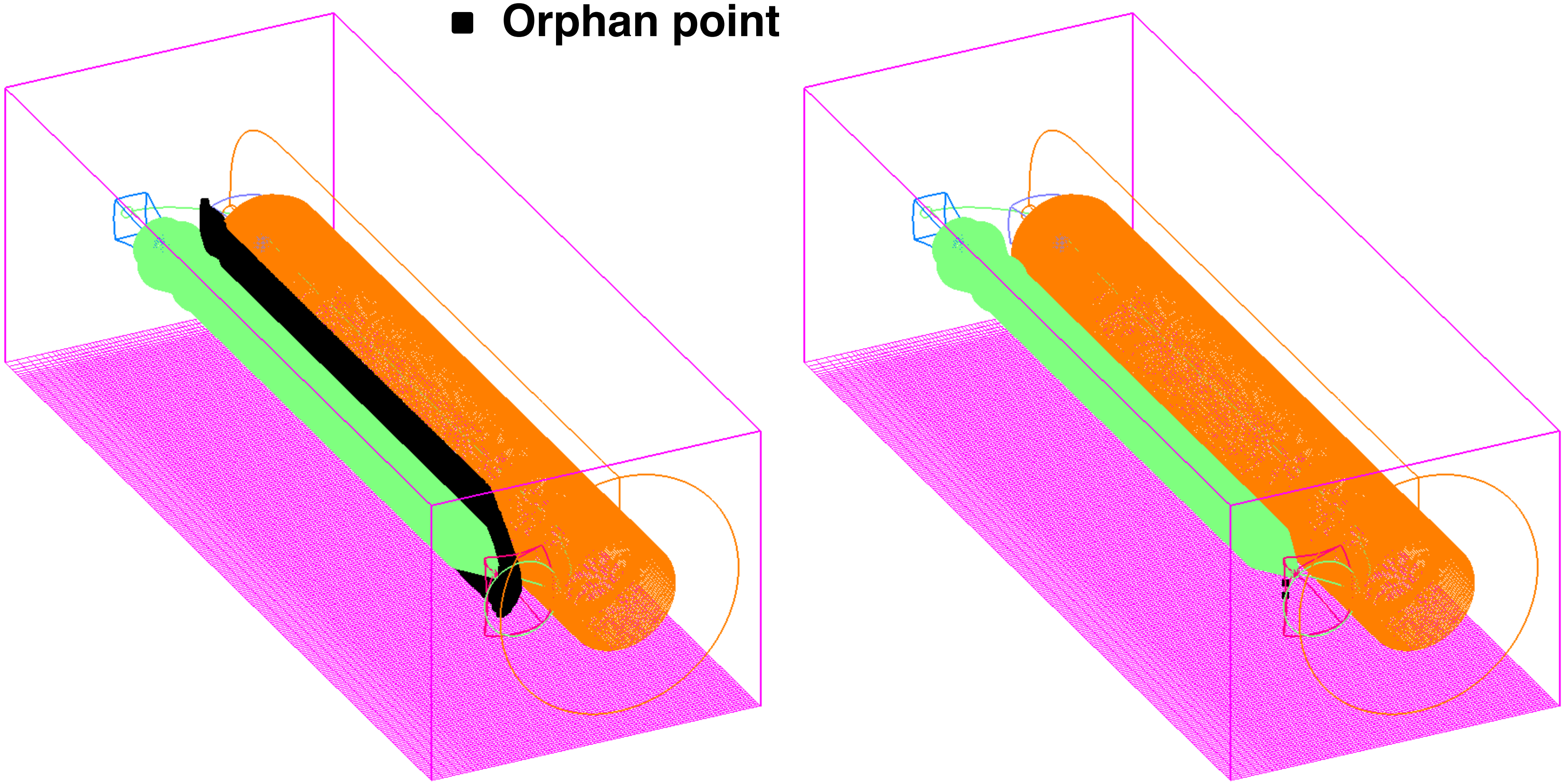
HOLE BOUNDARY ESTIMATE TEST CASE

Tank and Booster

28.5 million points, 6 grids



Previous: 112500 orphans

New: 2 orphans

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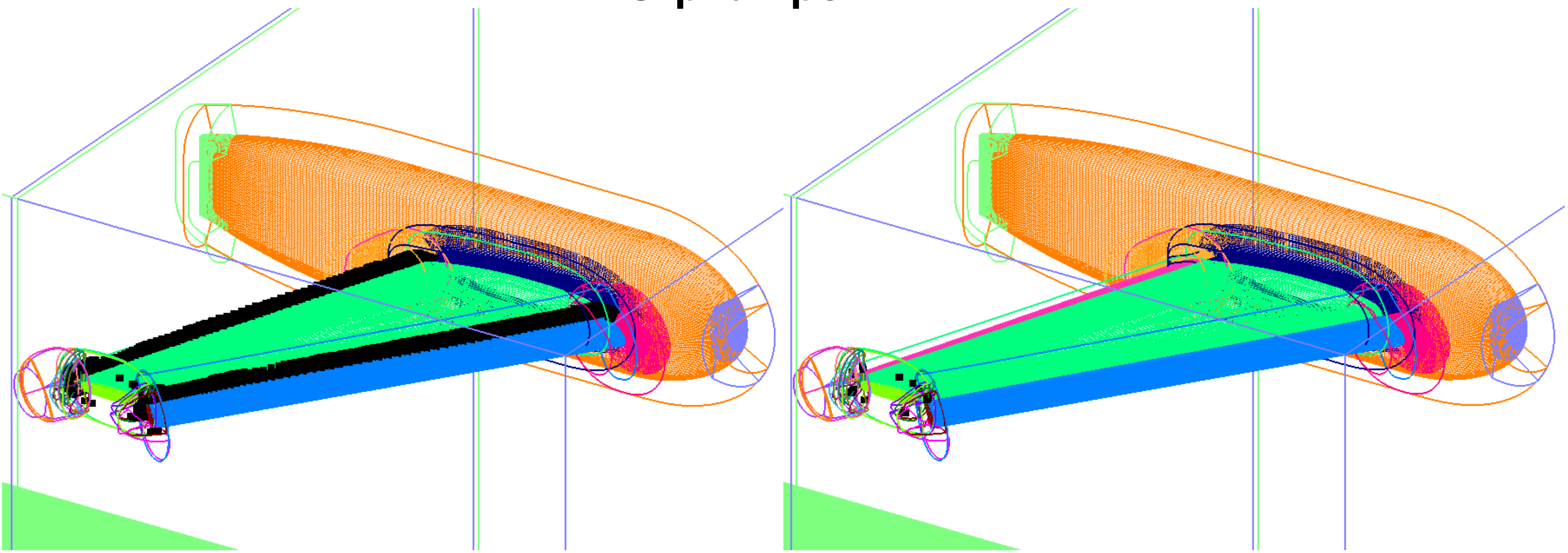
HOLE BOUNDARY ESTIMATE TEST CASE

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

50.6 million points, 24 grids

■ Orphan point

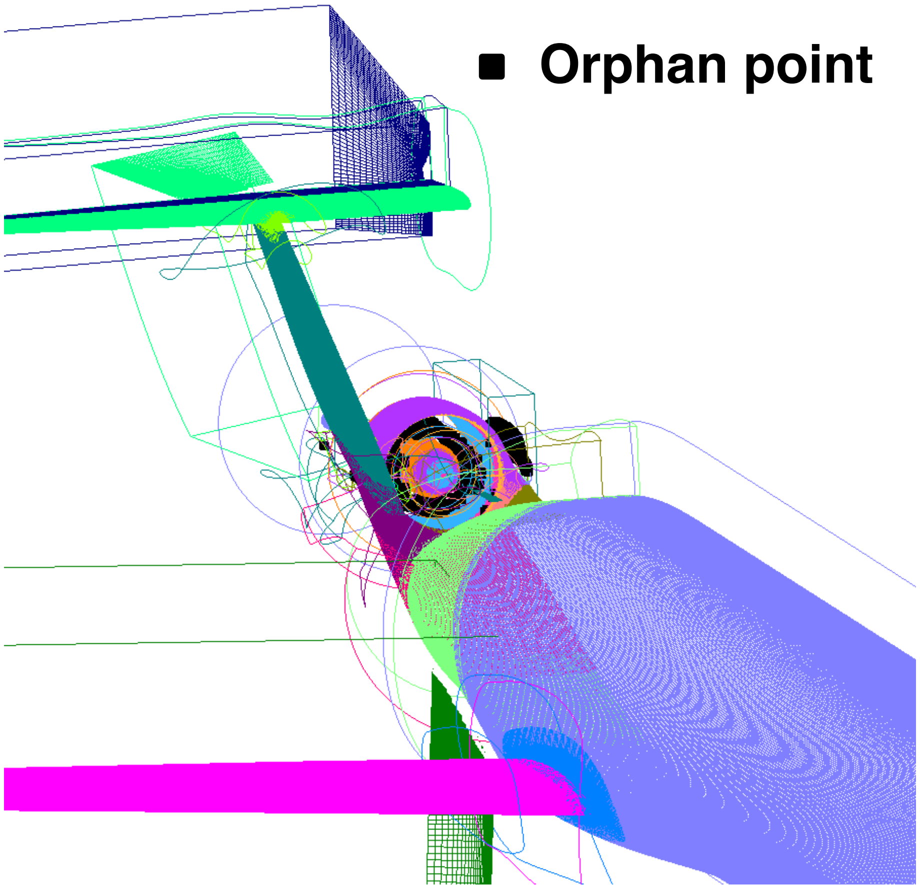


Previous: 85000 orphans

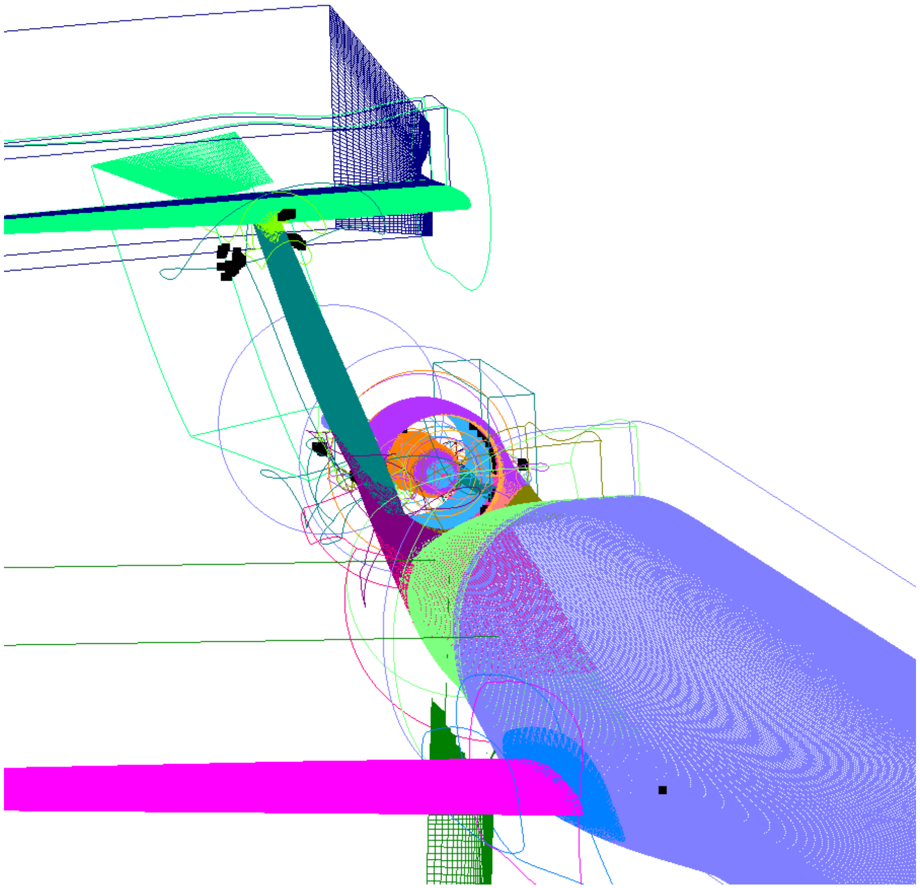
New: 32 orphans

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