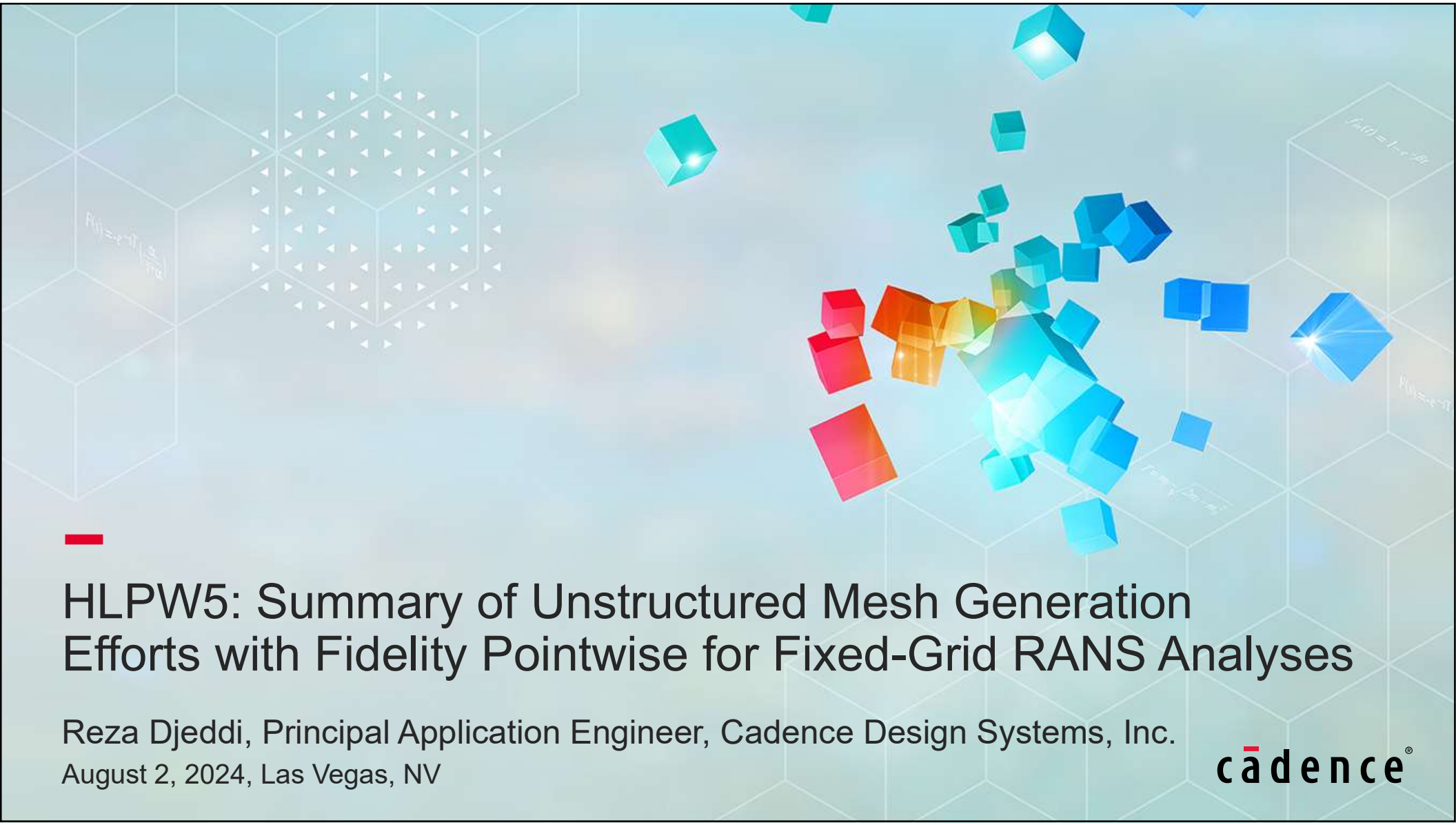


HLPW5: Summary of Unstructured Mesh Generation Efforts with Fidelity Pointwise for Fixed-Grid RANS Analyses

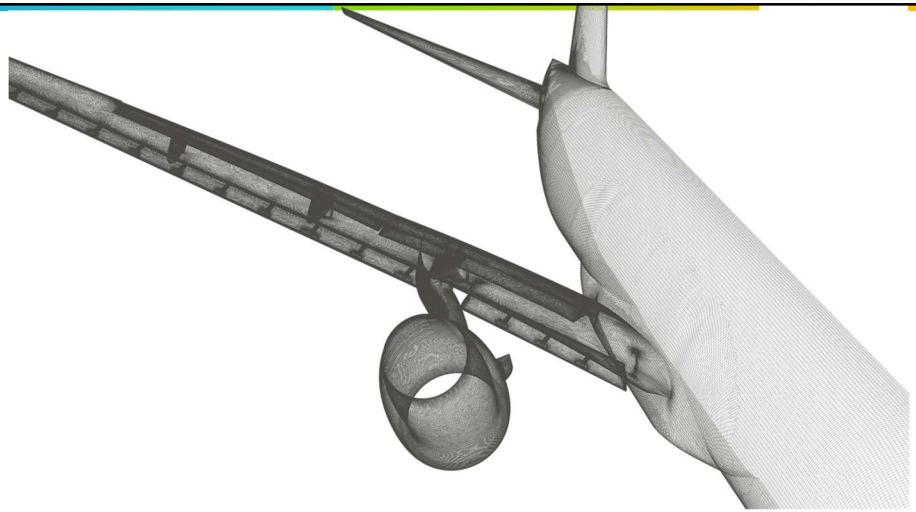
Reza Djeddi, Principal Application Engineer, Cadence Design Systems, Inc.

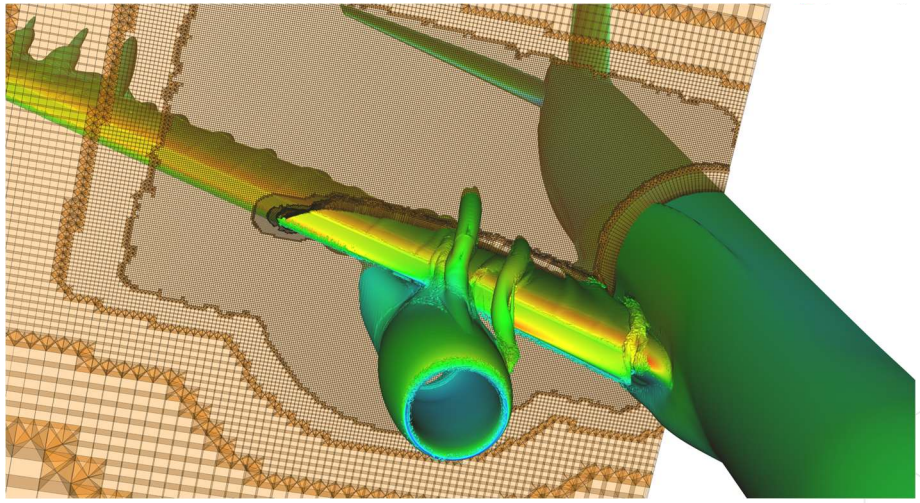
August 2, 2024, Las Vegas, NV

cadence®

Outline

- CAD Pre-Processing
  - CRM-HL Configurations
  - Automatic Feature Detection
  - Healing and Pinch-Point Remediation
- Automation
  - Assisted Quilt Assembly (AQA)
  - Automatic Surface Meshing (ASM)
  - Automatic Volume Meshing (AVM)
  - Automated Gridding Workflow
- Summary of Grid Families
- Conclusions



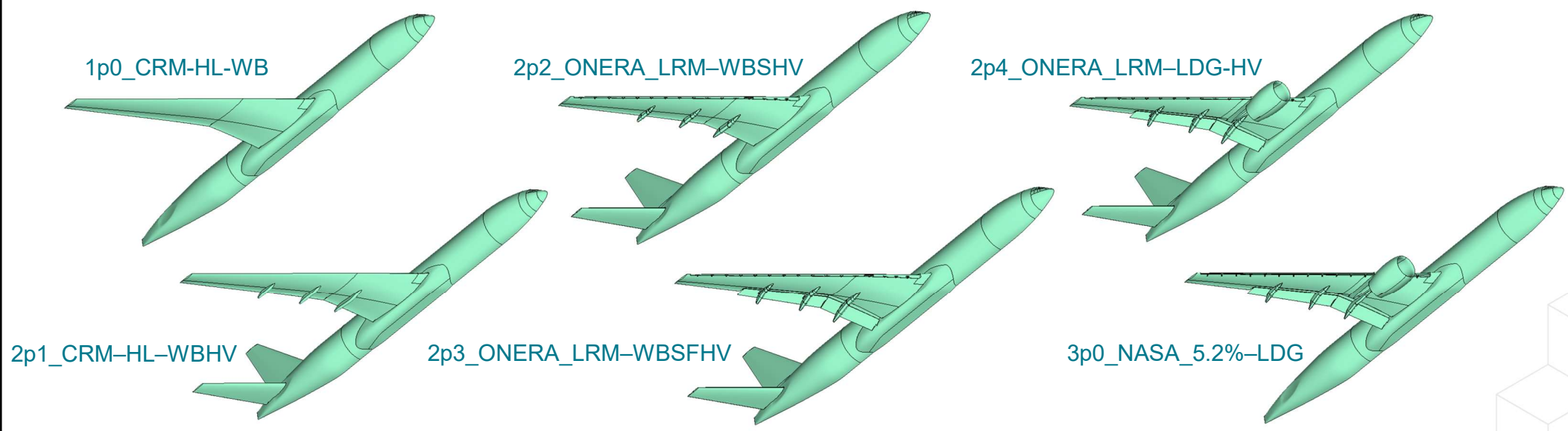


CAD Pre-Processing

Configurations, Feature Detection, Pinch Point Remediation

CAD Pre-Processing
CRM-HL configurations

- 6 different geometries were meshed for this workshop
- 40 meshes were generated and provided in various formats (+ PW project files)

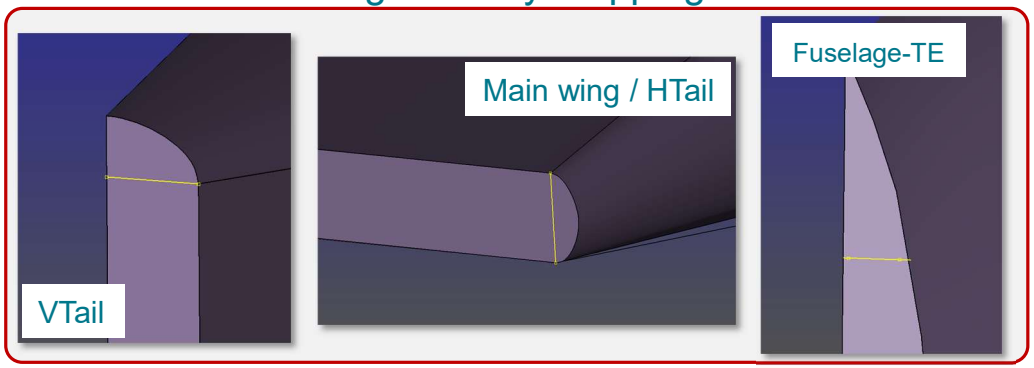


CAD Pre-Processing

Automatic feature detection

- **Feature edges** and m**apping**
  - Leading edge (Wing, Slat, WUSS)
  - Nacelle/Pylon (2p4 and 3p0 geometries)
  - Flap Track Fairing
  - Wing/HTail/VTail/Fuselage Trailing Edges

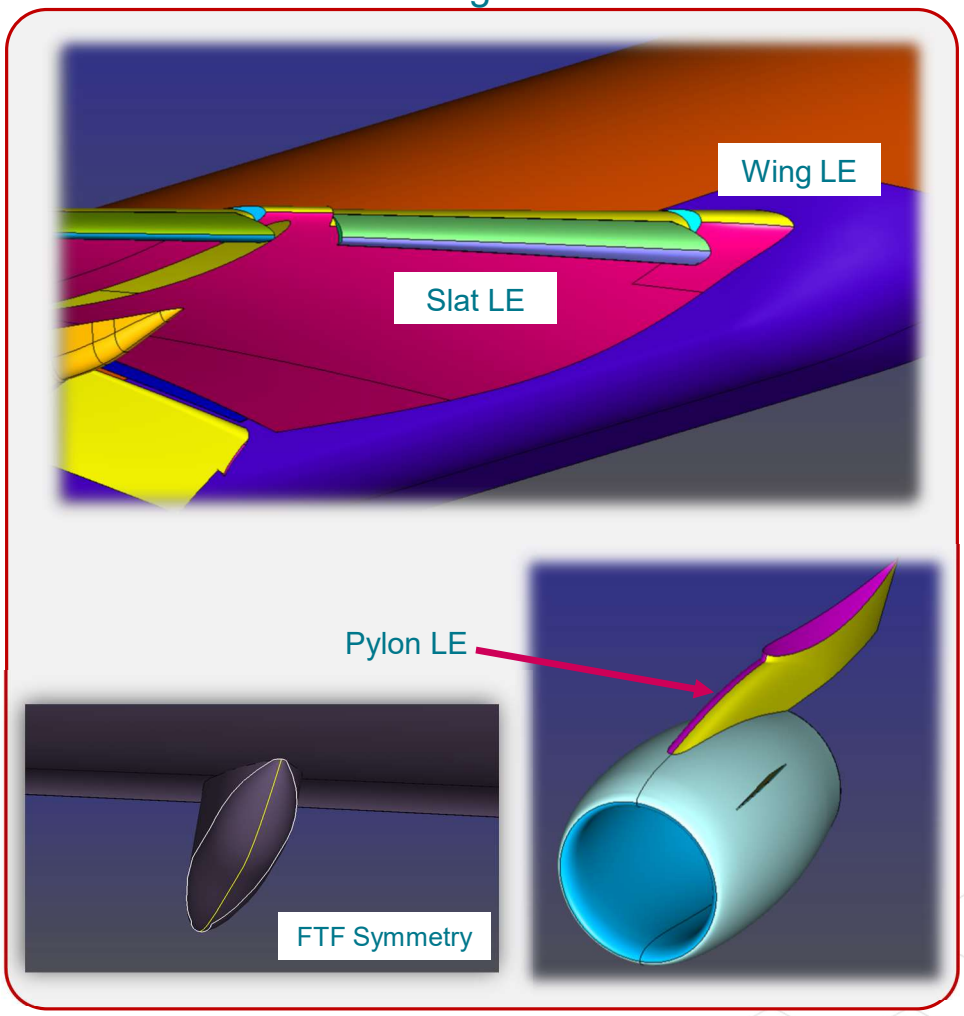
High Quality Mapping



Trim geometrically modes:

- Bisection
- 1-point
- 2-points
- n-points (star)

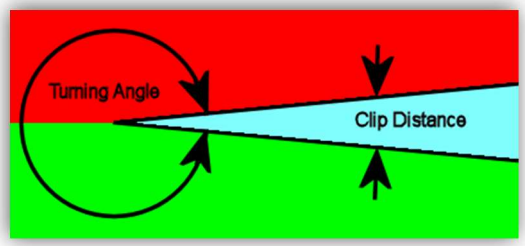
Feature Edge Definition

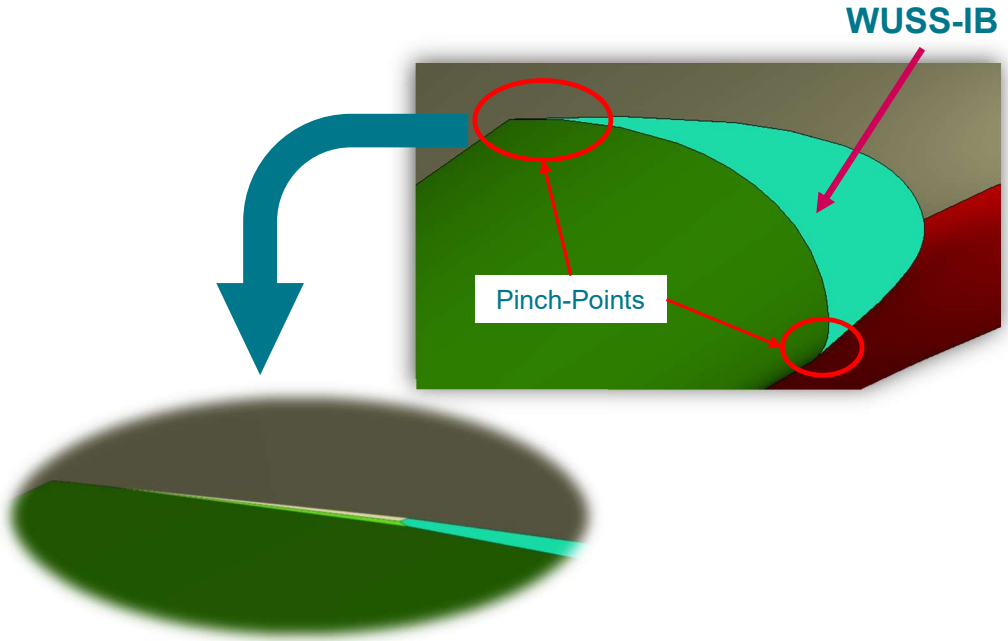


CAD Pre-Processing

Automatic pinch-point remediation

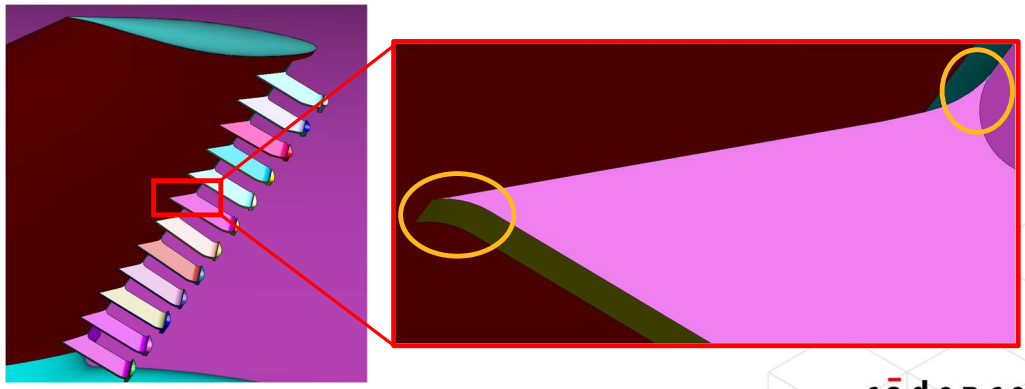
- Pinch points
  - Wing under slat surface (WUSS)
  - Slat brackets





Remediation

- Fully automated
- All pinch points that meet a certain turning angle threshold are detected
- Pinch points are remediated automatically using a clip distance of 0.02” (WUSS) and 0.04” (slat brackets)

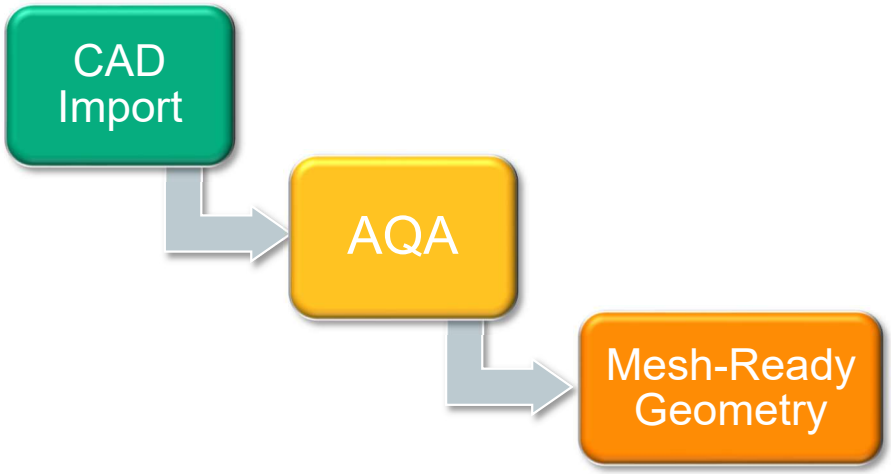


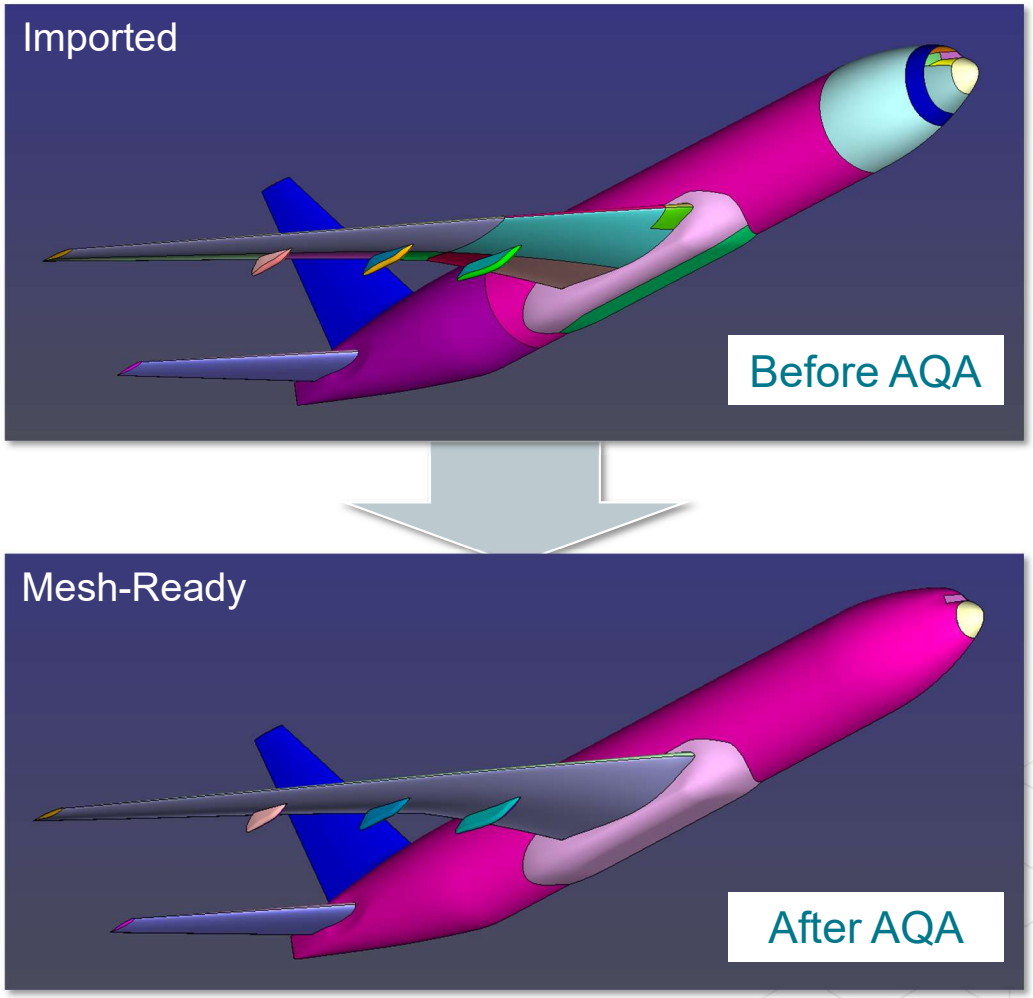
Automation

Flashpoint Tools (AQA, ASM, AVM), Automated Gridding Workflow

Automation
Geometry preparation

- Assisted Quilt Assembly (AQA)
  - Regions of engineering topology (quilts, in Pointwise terminology) are defined
  - These topological regions are created by assembling smaller surfaces into larger quilts
  - AQA automatically classifies/groups topological surfaces by identifying the “type of boundary” between them: **curvature, convex, concave**





Automation

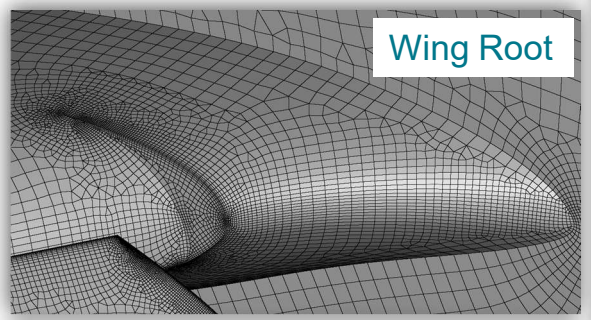
Automatic Surface Meshing (ASM)

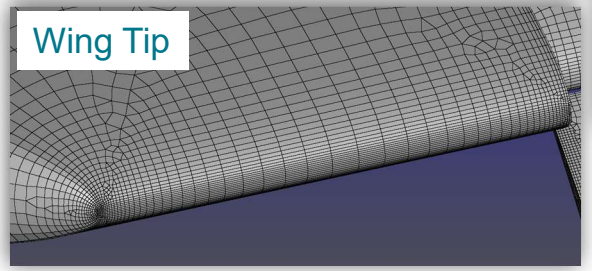
- Automatic Surface Meshing
  - A surface mesh recipe is defined for the most complex geometry (2p4: ONERA_LDG)
  - **Mapping filters** are used to enforce a certain number of subdivisions across the trailing edges (wing, flap, pylon, nacelle, and fuselage)
  - **Anisotropic stretching at surface boundaries**

GMGW-3 Gridding Guidelines

Level	Fuselage Cell Size	Cells (Points) on TE	Chordwise Spacing (Ang. resol.) *	Mesh Factor
A	≤ 2.25% C_{REF}	4 (5)	4.5 deg	
B	≤ 1.5% C_{REF}	6 (7)	3.0 deg	2/3
C	≤ 1.0% C_{REF}	9 (10)	2.0 deg	2/3
D	≤ 0.75% C_{REF}	12 (13)	1.5 deg	3/4
E	≤ 0.5% C_{REF}	18 (19)	1.0 deg	2/3
F	≤ 0.33% C_{REF}	27 (28)	0.66 deg	2/3

* Constant layers off LEs (delayed growth) and reduced growth rate are also incorporated





Automatically classified based on topology

- **Curvature**
- **Convex**
- **Concave**

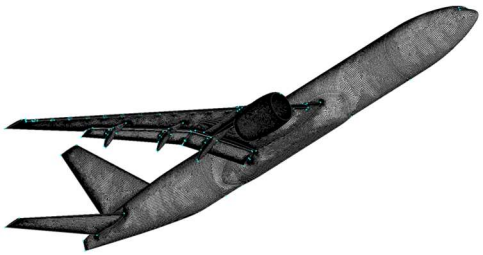
Set	#	Name	Type	Value
	93	Unspecified	Off	-
	40	Curvature	Angle	15
	143	Convex	Max. Aspect Ratio	20
	205	Concave	Off	20
	3	fuse tail	Max. Aspect Ratio	20
	66	slat brackets upper	Off	0
	1332	slat brackets	Off	0
	130	FTF brackets	Off	0
	36	slat endwall	Max. Aspect Ratio	8
	5	wing LE	Angle	3
	9	standard LE	Angle	5
	2	Nacelle lip	Angle	15
	7	Strake root	Off	0
	1	Pylon LE	Angle	5
	16	slat endwall concave	Off	0
	5	flap - fuse	Off	0
	61	pylon edge	Max. Aspect Ratio	8
	83	FTF curvature	Angle	15
	10	flap gap	Off	0
	14	flap - fuse gap	Max. Aspect Ratio	3
	59	FTF refinement	Max. Aspect Ratio	20

Automation
ASM – Refinement Factor

ASM and Grid Family Generation

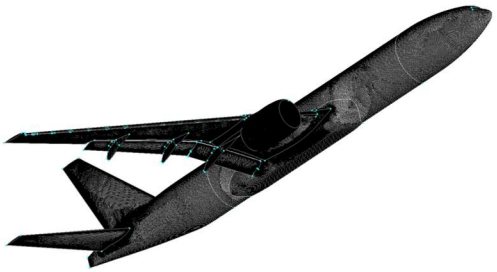
The “Refinement Factor” parameter is used to create additional grid levels in the family (Lvl-A, Lvl-C, Lvl-D, …)

Refinement Factor = 2/3
Coarse (Lvl-A)



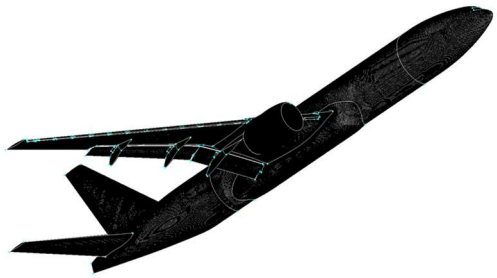
Surface Mesh Cell Count: **773,726**

Refinement Factor = 1.0
Baseline (Lvl-B)



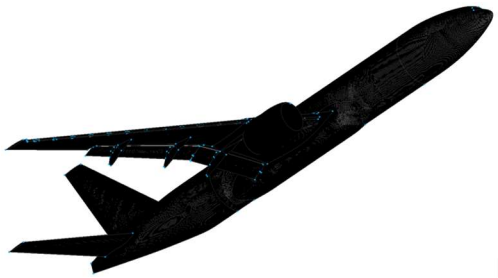
Surface Mesh Cell Count: **1,603,821**

Refinement Factor = 1.5
Fine (Lvl-C)



Surface Mesh Cell Count: **3,563,081**

Refinement Factor = 2.0
Extra Fine (Lvl-D)



Surface Mesh Cell Count: **6,879,990**

Configuration:
2p4_ONERA_LDG

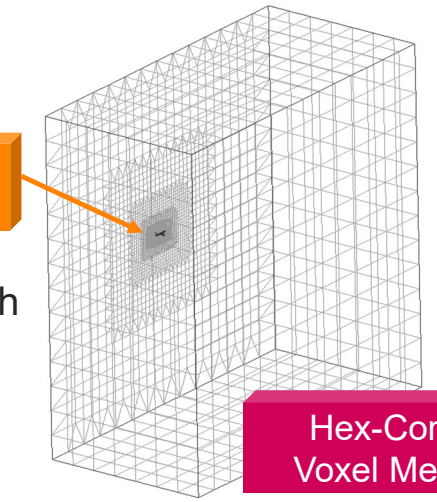
Automation

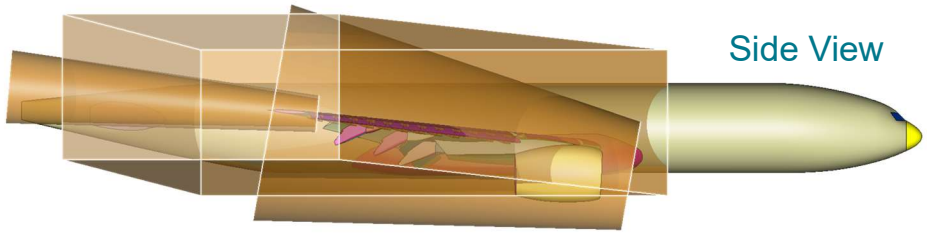
Automatic Volume Meshing (AVM)

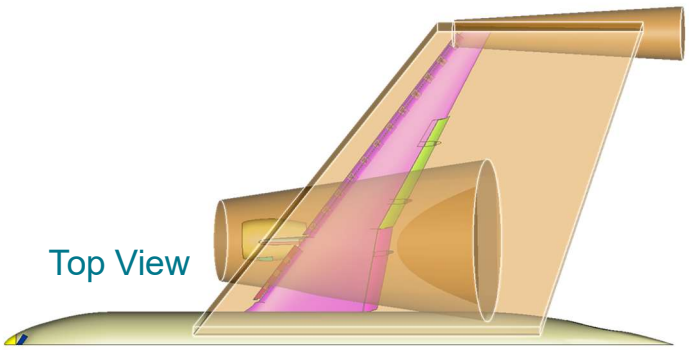
- Automatic Volume Meshing
  - A rectangular computational domain is defined with a **100*MAC** extent in each direction
- **Refinement sources**
  - Source shapes are introduced for additional wake refinement in important regions (best practices)

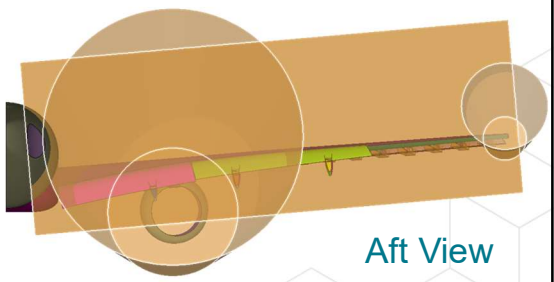
GMGW-3 Gridding Guidelines

Level	Estimated y+	BL Growth Rate	Mesh Factor
A	2.25	1.25	
B	1.5	1.16	2/3
C	1.0	1.10	2/3
D	3/4	1.07	3/4
E	1/2	1.05	2/3
F	1/3	1.03	2/3



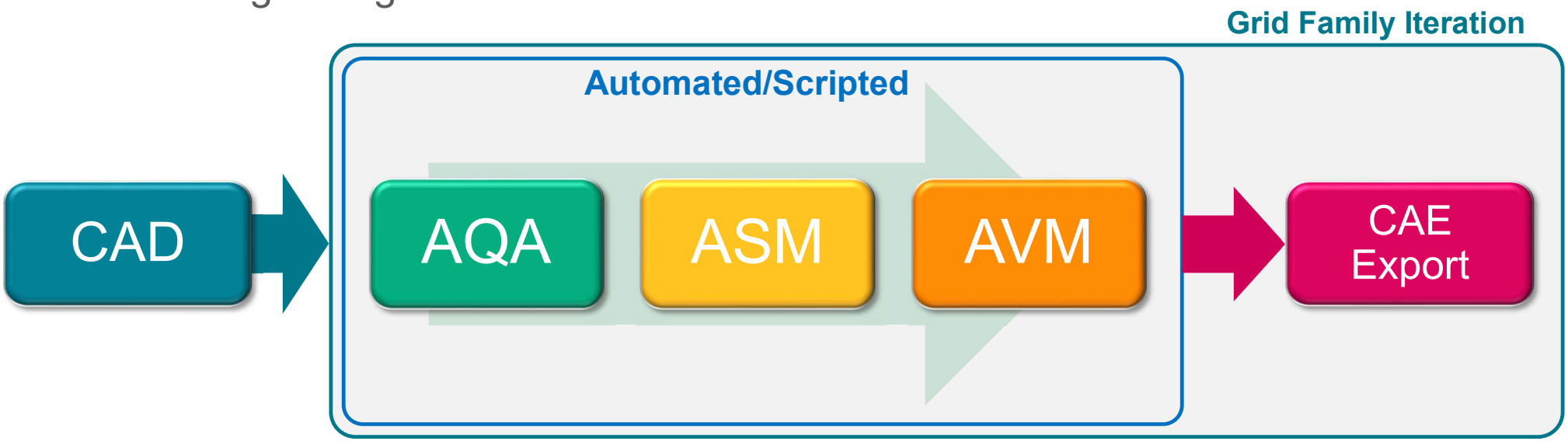


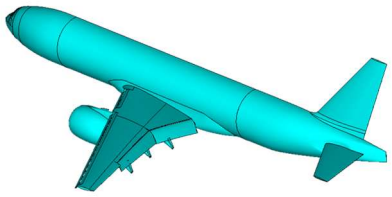




Automation

Automated gridding workflow





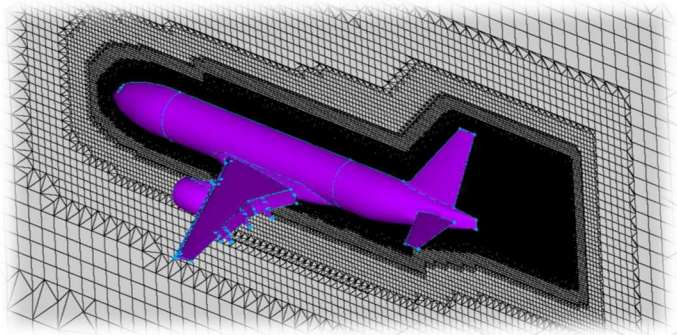
Glyph Script

```
set srcShapeList [pw::Source getAll]
set srcModifier [pw::Application begin Modify $srcShapeList]
  foreach src $srcShapeList {
    $src setBeginSpacing [expr ([$src getBeginSpacing])/$refinement_factor]
    $src setEndSpacing [expr ([$src getEndSpacing])/$refinement_factor]
  }
$srcModifier end

# Use ASM to regenerate surface mesh (w/ the Refinement Factor)
set model [pw::Database getAll -type pw::Model -visibleOnly]

# Start Automatic Surface Meshing (ASM)
set asmMode [pw::Application begin DatabaseMesher $model]
  $asmMode setRefinementFactor $refinement_factor

  # Regenerate surface mesh
  $asmMode createGridEntities Domain
$asmMode end
```



Summary of Grid Families

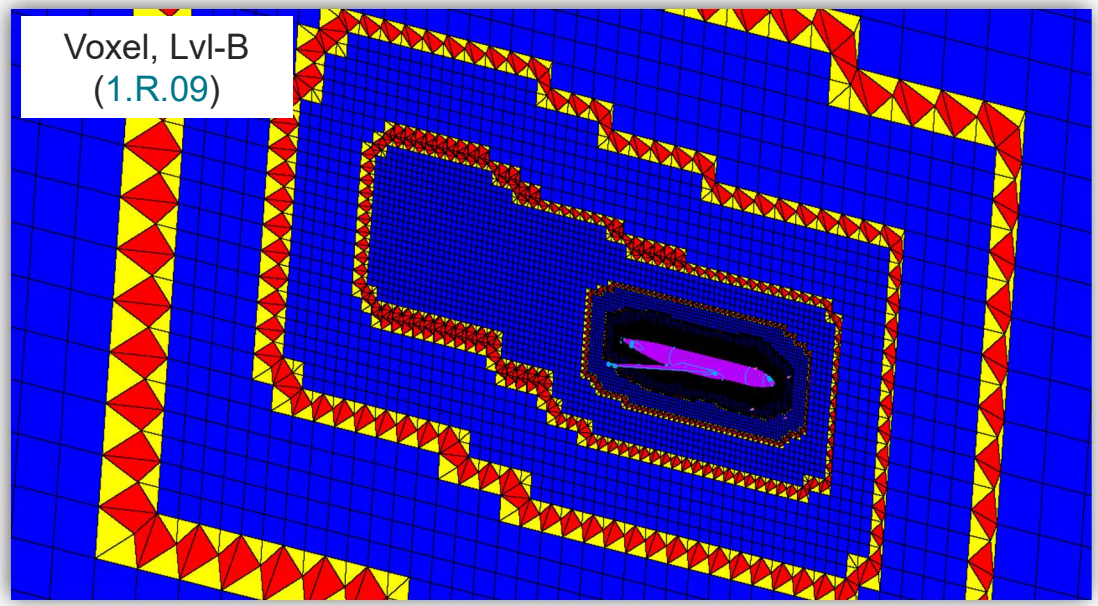
Fixed-Grid RANS: Test Cases 1, 2, and 3

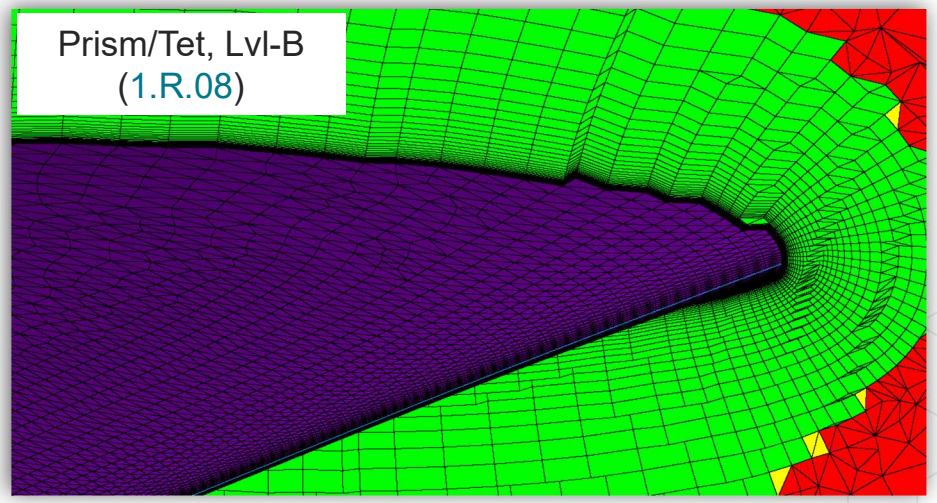
Summary of Grid Families

Test case 1

- Two grid families were generated (8 grids)
  - Family 1: Prism/Tet (1.R.08)
  - Family 2: Hex Dominant/Voxel (1.R.09)
  - Levels: B, C, D, E

	Level	Total Cells	Total Nodes	Hexahedra	Tetrahedra	Prisms	Pyramids
Family 1	**B**	11.6M	5M	0	2.5M	9M	0.048M
	C	34.2M	15.4M	0	5.5M	28.6M	0.123M
	D	68.2M	31.3M	0	8.9M	59M	0.209M
	E	199.8M	93.4M	0	20.7M	178.6M	0.474M
Family 2	**B**	14.2M	8.2M	6.6M	5.9M	0.16M	1.5M
	C	33.5	21.5M	18.2M	11.9M	0.38M	2.9M
	D	77.6M	54.6M	48.2M	22.6M	1.06M	5.66M
	E	246.5M	192.1M	176.6M	53.5M	2.98M	13.4M



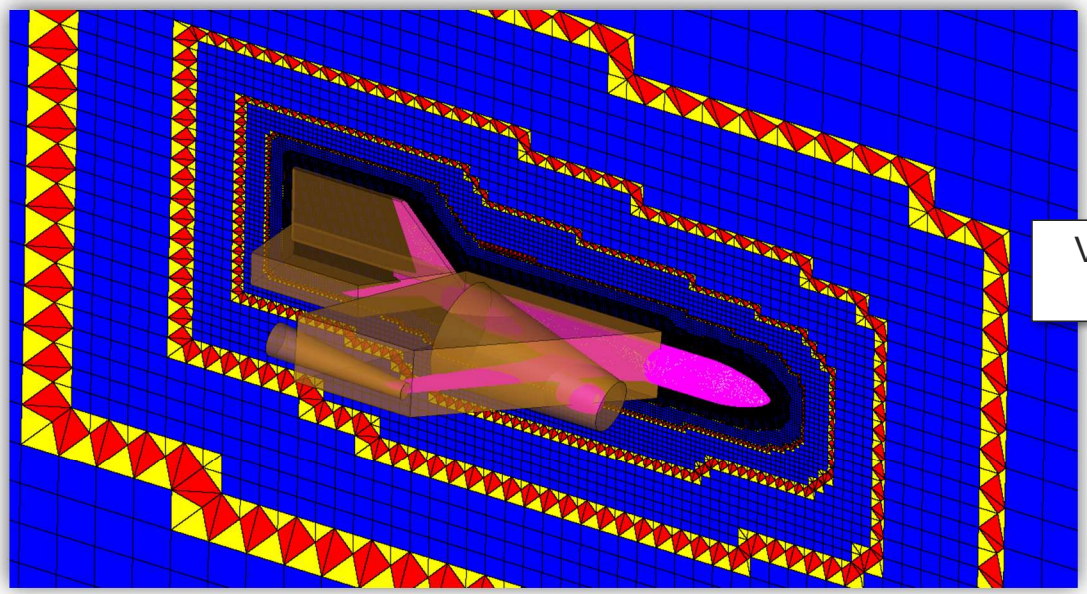


Summary of Grid Families

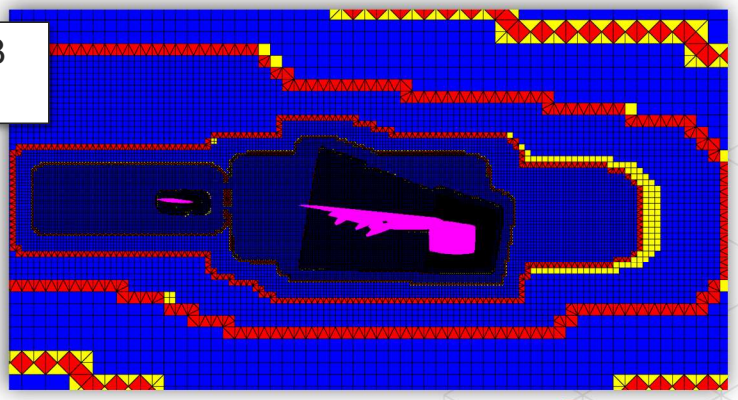
Test case 2

- One grid family was generated and supplied for each configuration (4 families, 16 grids)
  - Grid Family: 2.R.03
  - Hex Dominant/Voxel
  - Levels: A, B, C, D

Config.	Level	Total Cells	Total Nodes	Hexahedra	Tetrahedra	Prisms	Pyramids
Case 2.1	A	18.6M	10.4M	8.2M	8.2M	160K	1.9M
	B	72.5M	53.1M	48.1M	19.0M	327.9K	5.1M
	C	112.0M	76.4M	66.9M	35.8M	981.5K	8.3M
	D	449.0M	370.6M	349.5M	76.7M	2.2M	20.5M
Case 2.2	A	33M	18.7M	14.6M	14.1M	0.68M	3.5M
	B	118M	80.7M	70.3M	36.4M	1.5M	9.7M
	C	203M	142M	124.6M	60.6M	3.3M	15.1M
	D	663M	521.5M	481.5M	137.4M	7.8M	36.2M
Case 2.3	A	80M	40M	30M	40M	1.1M	9M
	B	148M	99M	85M	48M	2.3M	12.5M
	C	340M	229M	198M	110M	5.2M	27M
	D	720M	484M	421M	234M	10.7M	54M
Case 2.4	A	61.1M	36.4M	29.3M	24.5M	1.1M	6.1M
	B	198M	133M	114.8M	63.6M	2.9M	16.5M
	C	433.8M	316.8M	283M	114.9M	7.0M	28.9M
	D	1204M	936M	859.9M	261M	15.3M	68.4M



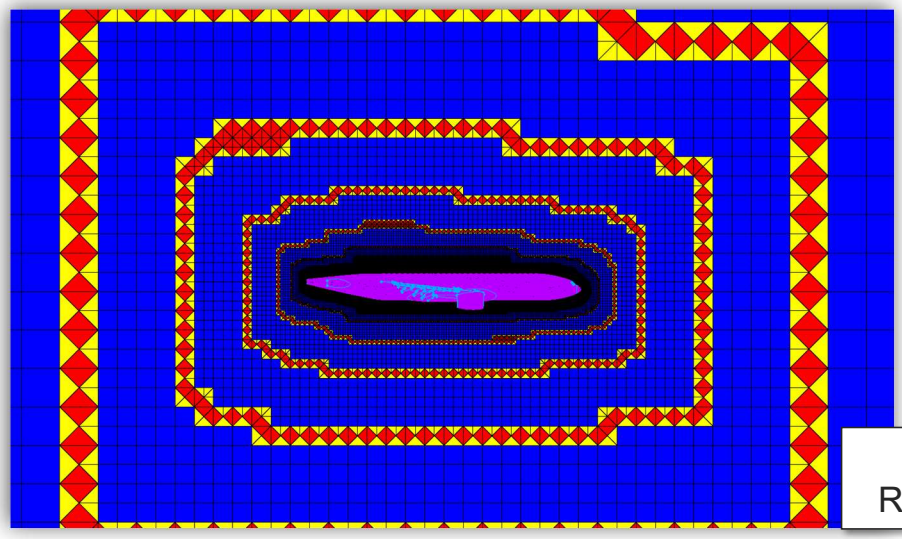
Voxel, 2.4-Lvl-B (2.R.03)



Summary of Grid Families

Test case 3

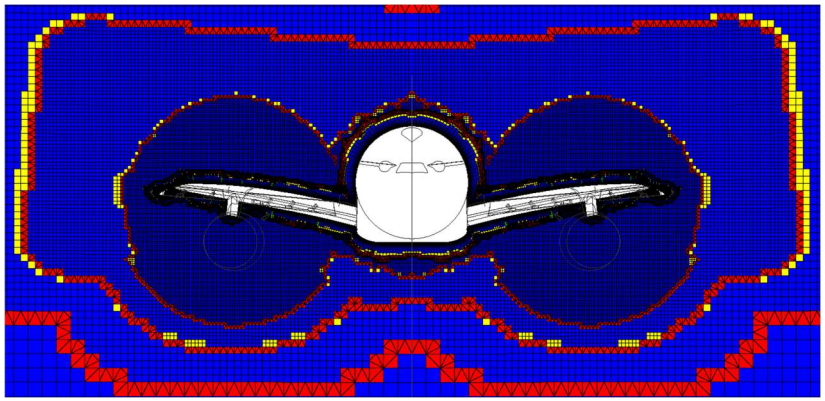
- One grid family was generated and supplied for each Reynolds number (4 families, 16 grids)
  - Grid Family: 3.R.01
  - Hex Dominant/Voxel
  - Levels: A, B, C, D



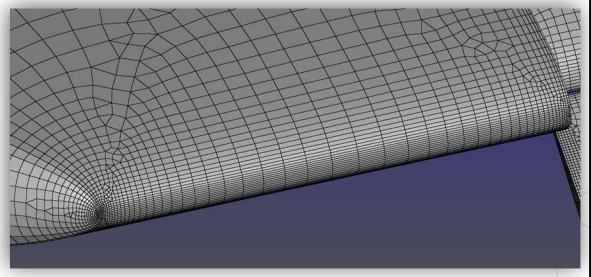
Voxel, 3.0-Lvl-B
Re = 5.49x10^6 (3.R.01)

Re # (x10^6)	Level	Total Cells	Total Nodes	Hexahedra	Tetrahedra	Pyramids	Prisms
1.05	**A**	52M	29M	23M	22M	6M	0.7M
5.49	**A**	58M	35M	28M	22M	6M	1M
16	**A**	62M	39M	32M	22M	6M	1.2M
30	**A**	64M	41M	34M	22M	6M	1.3M
1.05	**B**	162M	103M	88M	58M	15M	1.6M
5.49	**B**	179M	120M	103M	58M	15M	2.4M
16	**B**	189M	130M	114M	58M	15M	2.8M
30	**B**	196M	137M	120M	58M	15M	3.1M
1.05	**C**	352M	242M	211M	108M	27M	4.7M
5.49	**C**	407M	297M	265M	108M	27M	7M
16	**C**	444M	333M	300M	108M	27M	8.5M
30	**C**	465M	354M	321M	108M	27M	9.3M
1.05	**D**	956M	700M	631M	251M	62M	10M
5.49	**D**	1.07B	835M	762M	250M	62M	15M
16	**D**	1.18B	921M	848M	250M	62M	18M
30	**D**	1.23B	973M	898M	250M	62M	20M

Conclusions
Gridding for HLPW5



- Incorporated automated workflows for the construction of all mesh families
- Developed new best practices based on the experience from past HLPWs
  - Angular resolution off leading edges yields a “fixed” resolution of the geometry curvature
  - Constant layers combined with lower growth rate for anisotropic meshing across LEs
  - Automatically-mapped gridding techniques for TEs
  - Leveraged hex dominant volume meshing for flow-aligned wake capturing off high-lift elements



- Developed a “mesh recipe” based on best practices outlined
  - Consistent mesh characteristics and quality across the entire grid family
  - Order of magnitude reduction in turnaround time for mesh family generation