DPW-VII
Opening Remarks

John Vassberg
Chairman, DPW-OC

Aviation 2022
Chicago, IL

June 25-26, 2022

DPW-VII: *"Expanding The Envelope"*

- **Introduction**
- **Organizing Committee**
- **Agenda**
- **DPW History**
- **Test Cases 1-6**
- **Participant Demographics**
- **CRM WB Geometry**
- **Measured Wing Deflections**
- **CRM Reference Quantities**
- **Gridding Guidelines & Family Plan**
- **Baseline Grid Families**
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DPW-VII: Organizing Committee

- Olaf Brodersen, DLR
- Ed Feltrop, Cessna
- David Hue, ONERA
- Stefan Keye, DLR
- Kelly Laflin, Cessna
- Dimitri Mavriplis, UWy
- Joe Morrison, NASA
- Mitsuhiro Murayama, JAXA
- Raj Nanjia, RAeS
- Ben Rider, Boeing
- Melissa Rivers, NASA
- Ed Tinoco, Retired
- Chris Toomer, UWE Bristol
- John Vassberg, JetZero
- Rich Wahls, NASA

15 Members
2 Charter Members
3 New Members
10 Institutions
5 Countries
3 Continents

DPW-VII Agenda – Day 1

Day 1 - Saturday June 25, 2022					
8:00 AM	**9:00 AM**	**Arrive and Registration**			
Session 1 - Opening Remarks Agenda, Purpose, CRM Geometry/Design, & Test Cases				**Rich Wahls**	**NASA**
9:00 AM	**9:15 AM**	**Opening Remarks Agenda, Purpose, CRM Geometry/Design, Test Cases**		**John Vassberg**	Jet Zero
9:15 AM	**9:35 AM**	**CRM Baseline Grids:**		**John Vassberg Stefan Keye (remote) Mitsuhiro Murayama**	Jet Zero DLR JAXA
9:35 AM	**9:50 AM**	**CRM Experimantal Data (NTF, 11'TWT, ETW)**		**Melissa Rivers Rich Wahls**	NASA
9:50 AM	**10:00 AM**	**Aeroelastic Deflections Overview**		**Stefan Keye (remote)**	DLR
10:00 AM	**10:20 AM**	Break			
Session 2 - Participant Presentations I				**David Hue**	**ONERA**
10:40 AM	**11:00 AM**	**TAU**	unstructured	**Stefan Keye, Olaf Brodersen**	DLR (Aerodynamics)
10:20 AM	**10:40 AM**	**USM3D**	structured/unstructured	**Brent Pomeroy**	NASA
11:00 AM	**11:15 AM**	**M-Edge**	structured/unstructured	**Peter Eliasson**	SAAB/VZLU/FOI
11:15 AM	**11:30 AM**	**ENSOLV**	structured	**Michel van Rooij**	NLR
11:30 AM	**1:00 PM**	LUNCH (on your own)			
Session 3 - Participant Presentations II				**Dimitri Mavriplis**	**U of Wyoming**
1:00 PM	**1:25 PM**	**OVERFLOW 2.3e + GGNS**	structured/unstructured	**Ben Rider**	Boeing
1:25 PM	**1:40 PM**	**CHAMPS**	structured	**Frédéric Plante**	Polytechnique Montreal
1:40 PM	**1:55 PM**	**OVERFLOW**	structured	**Lawton Shoemaker**	Univ. Tennessee (Knoxville)
1:55 PM	**2:10 PM**	**ASOP**	structured	**Yalu Zhu**	Nanjing Xfluids Aerospace Tech. Ltd
2:10 PM	**2:30 PM**	Break			
Session 4 - Participant Presentations III				**Mitsuhiro Murayama**	**JAXA**
2:30 PM	**2:45 PM**	**TAS**	unstructured	**Mitsuhiro Murayama**	JAXA
2:45 PM	**3:10 PM**	**FaSTAR**	unstructured	**Sansica/Abe**	JAXA
3:10 PM	**3:25 PM**	**FLOW360**	unstructured	**Thomas Fitzgibbon**	FlexCompute
3:25 PM	**3:45 PM**	**CFD++20.1**	unstructured	**Amarnatha Potturi**	Metacomp
3:45 PM	**4:00 PM**	**Closing of Day 1, Review Day 2 Agenda**		**Mitsuhiro Murayama**	

DPW-VII Agenda – Day 2

Day 2 - Sunday June 26, 2022					
8:30 AM	**9:00 AM**	**Arrive**			
Session 5 - Participant Presentations IV				**Ben Rider**	**Boeing**
9:00 AM	**9:05 AM**	**Welcome to Day 2, Agenda Review, etc**		**Ben Rider**	Boeing
9:05 AM	**9:20 AM**	**Ansys Fluent**	unstructured	**Krishna Zore, Cristhian Aliaga**	Ansys
9:20 AM	**9:35 AM**	**zCFD**	unstructured	**Oliver Darbyshire**	ZenoTech
9:35 AM	**9:50 AM**	**TAU**	unstructured	**Diliana Friedewald**	DLR (Aeroelasticity)
9:50 AM	**10:05 AM**			**Yannick Hoarau**	Univ. Strasbourg
10:05 AM	**10:25 AM**	Break			
Session 6 - Participant Presentations V				**Kelly Laflin**	**Textron**
10:25 AM	**10:50 AM**	**elsA**	structured	**David Hue**	ONERA
10:50 AM	**11:15 AM**	**Kestrel 12.1**	structured/unstructured	**Brent Pomeroy**	NASA
11:15 AM	**12:45 PM**	LUNCH (on your own)			
Session 7 - Summary Presentations				**Ed Tinoco**	**Retired**
12:45 PM	**1:30 PM**	**DPW-VII Summary of Participant Data - Force/Moment/CP**		**Ed Tinoco**	Retired
1:30 PM	**2:15 PM**	**DPW-VI Summary of Participant Data - CRM Case 6** **SOB Separation** **TE Separation**		**Stefan Keye (remote)** **Kelly Laflin** **Ben Rider/Olaf Brodersen**	DLR Textron Boeing/DLR
2:15 PM	**2:30 PM**	Break			
Session 8 - Summary/Closing				**John Vassberg**	**Boeing**
2:30 PM	**3:15 PM**	**Open Discussion**		**All Attendees**	
3:15 PM	**3:25 PM**	**Next Steps**		**All Attendees**	
3:25 PM	**3:30 PM**	**Closing Remarks/Thanks!**		**John Vassberg**	

DPW Series – Brief History

- **DPW Charter Formalized** **Jan 2000**
  - State of the Art/Practice CFD Drag Prediction
- **DPW-I, Anaheim, CA** **Jun 2001**
  - DLR-F4 WB, Fixed CL & Drag Polar Studies
  - Scatter > 100 Counts → SOP Worse Than Expected
- **DPW-II, Orlando, FL** **Jun 2003**
  - DLR-F6 WB & WBNP, Fixed-CL Grid Convergence
  - Scatter > 50 Counts, Drag Deltas, Juncture Flow Issues
- **DPW-III, San Francisco, CA** **Jun 2006**
  - DLR-F6 WB & WBF, DPW-W1/W2 Wing-Only Fixed AoA
- **DPW-IV, San Antonio, TX** **Jun 2009**
  - CRM WBT, Trim-Drag Study, Blind CFD Predictions
- **DPW-V, New Orleans, LA** **Jun 2012**
  - CRM WB, Common Grid Study, TMR Verification Case
- **DPW-VI, Washington, DC** **Jun 2016**
  - CRM WB & WBNP, Aero-Elastic Deflection Study
- **DPW-VII, Chicago, IL** **Jun 2022**
  - CRM WB, “Expanding the Envelope Beyond RANS”

CFD DRAG PREDICTION WORKSHOP SERIES

DPW

ESTABLISHED 2000

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DPW-VII: Case 1 "Halfway to Buffet"

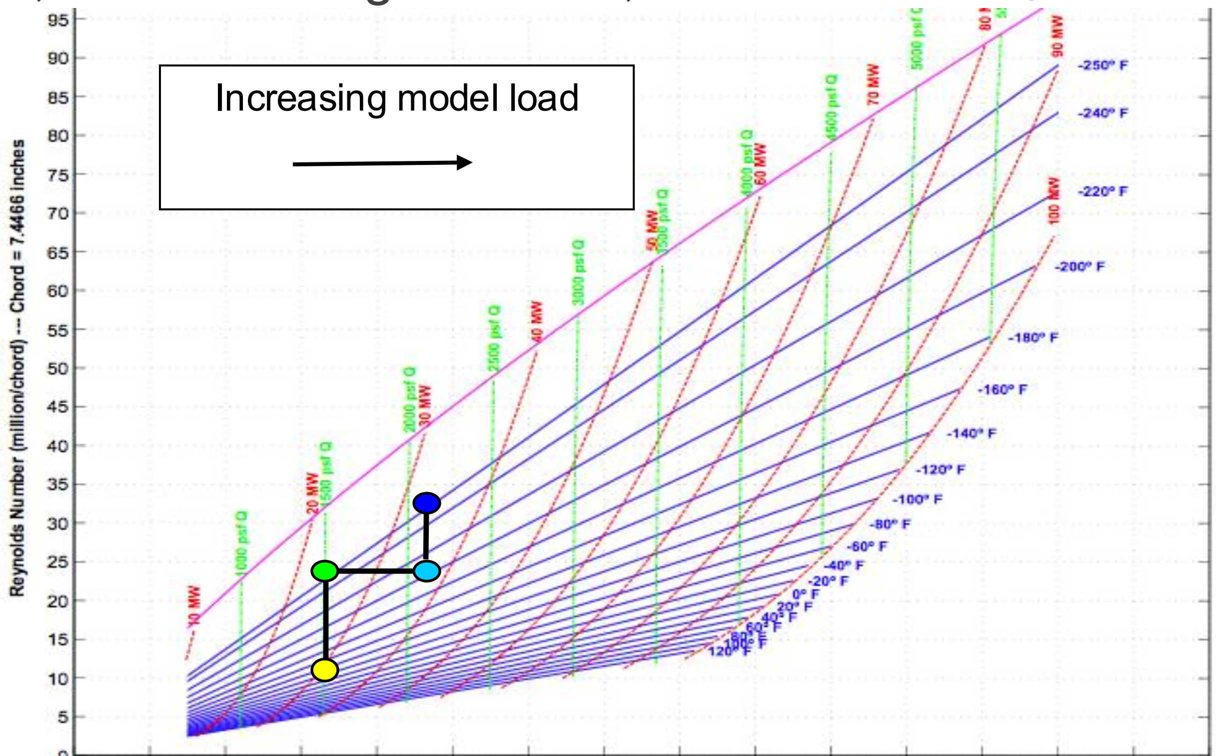
- **Case 1: CRM Wing-Body Grid Convergence Study**
  - Use 3.00-deg LoQ AE CRM Geometry/Grids
  - Use at least 4 Grids in Family
  - Plot [CD, CM, AoA] .vs. $N^{-(2/3)}$
  - Case 1a (Requested)
    - M = 0.85, Re = 20 million, Fixed CL = 0.58, T = -250°F
  - Case 1b (Optional)
    - M = 0.85, Re = 05 million, Fixed CL = 0.58, T = 100°F

DPW-VII: Case 2 “Polar with AE Effects”

- **Case 2: CRM Wing-Body Static LoQ Aero-Elastic Effect**
  - AoA Sweep with ETW Deflections
  - CL = 0.50 on 2.50-deg LoQ Geometry
  - AoA = [2.50, 2.75, 3.00, 3.25, 3.50, 3.75, 4.00, 4.25] degrees
  - Medium Baseline Grids: [9 Solutions on 8 Grids/Geometries]
  - Case 2a (Requsted)
    - Mach=0.85, Re=20 million, T=-250ºF
  - Case 2b (Optional)
    - Mach=0.85, Re=05 million, T=100ºF

DPW-VII: Case 3 "Ren & AE Effects"

- **Case 3: CRM WB Ren-Sweep at Fixed CL**
  - M = 0.85, CL = 0.50, Medium Grids
  - Re=05M, LoQ 2.50-deg R05 Grid, T= 100°F
  - Re=20M, LoQ 2.50-deg R30 Grid, T= -250°F
  - Re=20M, HiQ 2.50-deg R30 Grid, T = -182°F
  - Re=30M, HiQ 2.50-deg R30 Grid, T = -250°F



DPW-VII: Case 4 “Grid Adaptation”

- **Case 4: CRM WB Grid Adaptation – Alpha Sweep**
  - Optional Test Case
  - M = 0.85, Re = 20 million, T = -250°F
  - CL = 0.50 on 2.50-deg LoQ Geometry
  - AoA = [2.50, 2.75, 3.00, 3.25, 3.50, 3.75, 4.00, 4.25] degrees
  - Start Adaptation from Appropriate Baseline LoQ Mesh or AE Geometry
  - Participants to Document Adaptation Process
  - Additional cases: M = 0.85; Re = 5 million; T = 100°F

DPW-VII: Case 5 “Beyond RANS”

- **Case 5: Beyond RANS**
  - Optional Test Case
  - URANS, DDES, WMLES, Lattice Boltzmann, etc.
  - M = 0.85, Re = 20 million, T = -250°F
  - CL ~ 0.58 on 3.00-deg LoQ Geometry
  - AoA = [2.50, 2.75, 3.00, 3.25, 3.50, 3.75, 4.00, 4.25] degrees
  - Use Appropriate LoQ AE Geometry

DPW-VII: Case 6 “Couple AE Simulation”

- **Case 6: CRM WB Coupled Aero-Elastic Simulation**
  - Optional Test Case
  - M = 0.85, Re = 20 million, T = -250°F
  - CL = 0.58
  - AoA = [2.50, 2.75, 3.00, 3.25, 3.50, 3.75, 4.00, 4.25] degrees
  - Start AE Process with NoQ AE Geometry or NoQ R30 Medium Grid

DPW-VII: Participant Demographics

- **18 Teams/Organizations**
  - 7 N. America, 7 Europe, 4 Asia
  - 7 Government, 3 Industry, 3 Academia, 5 Commercial
- **30 Total Data Submittals**
- **Grid Types:**
  - 16 Unstructured
  - 3 Overset
  - 3 Structured Multi-Block
  - 1 Custom Cartesian
- **Turbulence Models:**
  - 14 SA (w/ & w/o QCR), 4 SST,
    2 EARSM, 1 SSG/LRR, 1 AMM-QCR, 1 RSW-ln(w)

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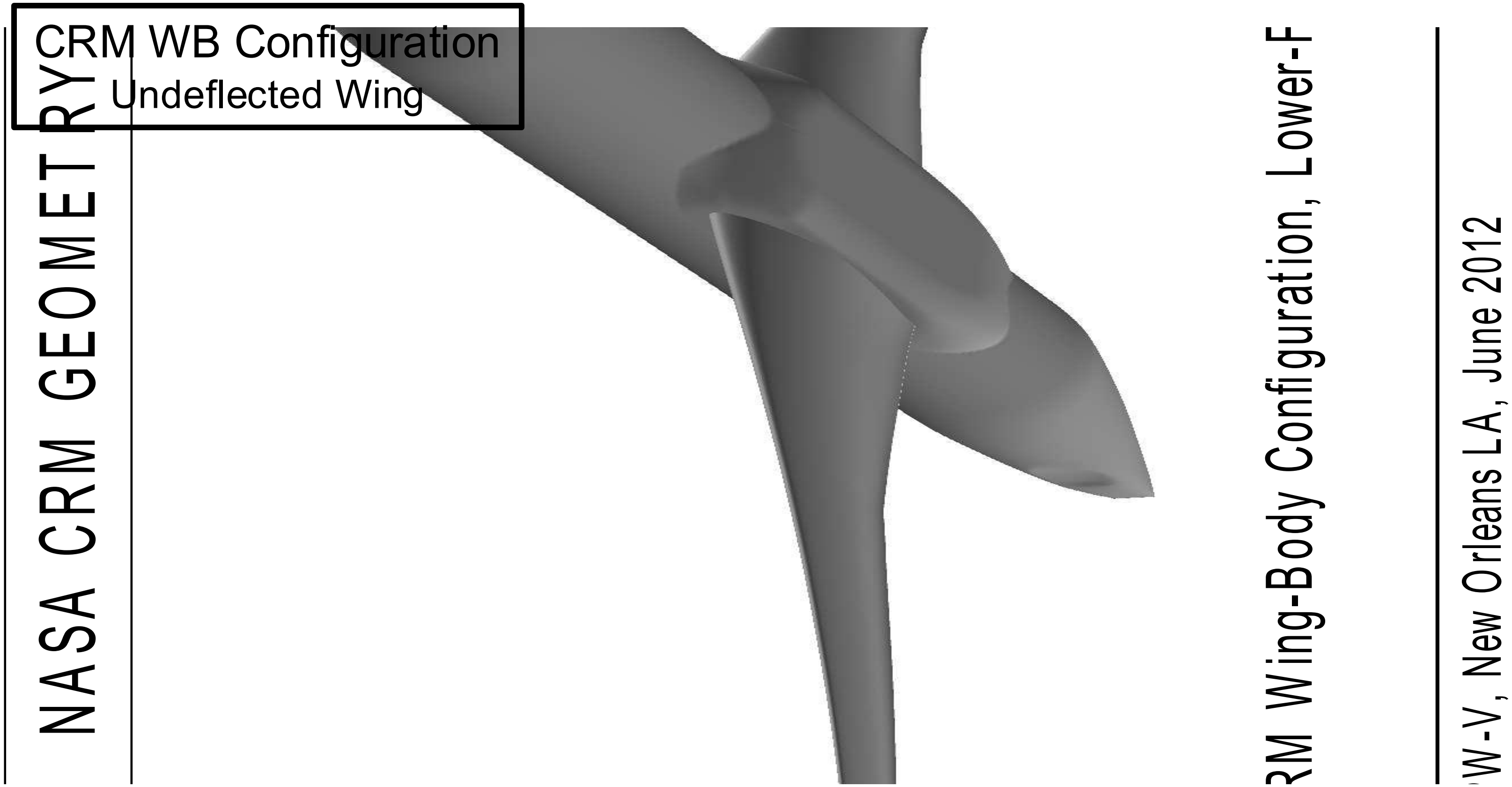
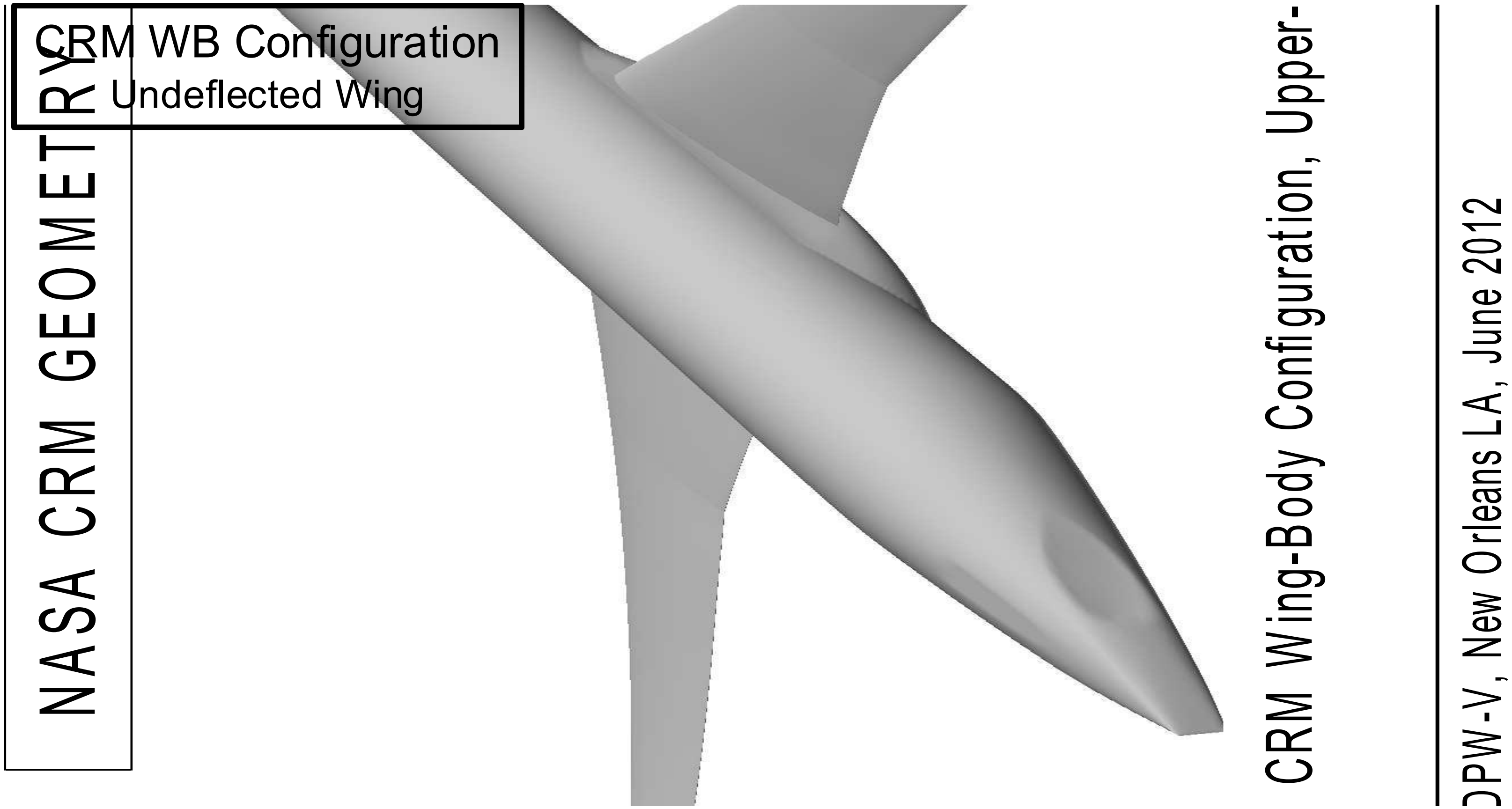
Common Research Model (CRM)



Vassberg AIAA 2008-6919

Common Research Model (CRM)

CRM WB Configuration
Undeflected Wing



Vassberg AIAA 2008-6919

Common Research Model (CRM)

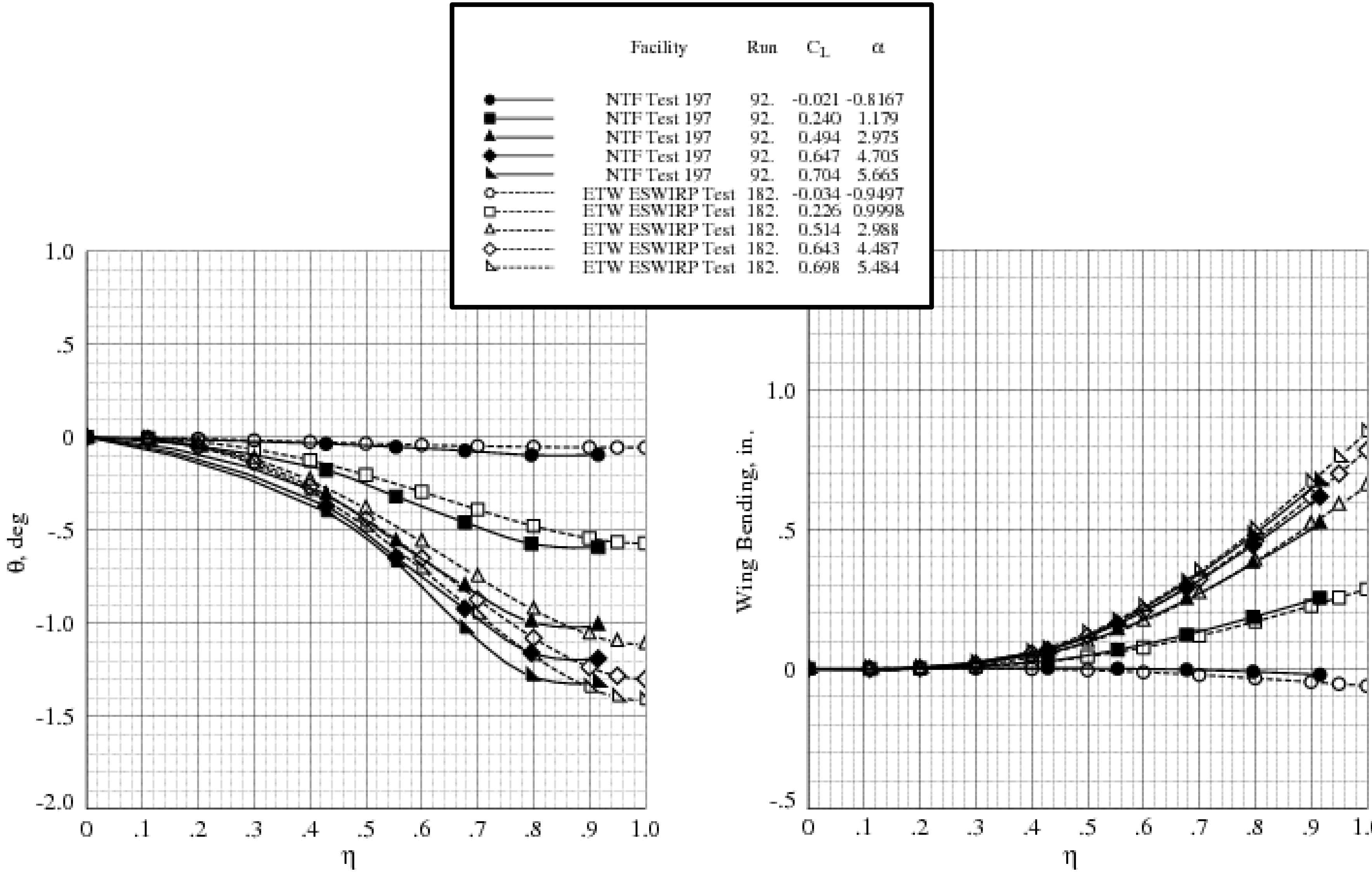
http://commonresearchmodel.larc.nasa.gov/

Common Research Model (CRM)

Table 1: Reference Quantities for the CRM.

Sref	594,720.0 in^2	4,130.0 ft^2
Trap-Wing Area	576,000.0 in^2	4,000.0 ft^2
Cref	275.80 in	
Span	2,313.50 in	192.8 ft
Xref	1,325.90 in	
Yref	468.75 in	
Zref	177.95 in	
λ	0.275	
$\Lambda_{C/4}$	35°	
AR	9.0	

CRM Wing Deflections in NTF, ETW



DPW-7 Utilizes ETW Deflections

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DPW-VII: Gridding Guidelines (1/2)

- **Tiny Grid (L1)**
  - Viscous Wall Spacing: $Y^+ \sim 1.0 \rightarrow \Delta y_1 = 0.0002332''$
    - Based on local C_f @ 10% Cref for Re_c = 30 million
    - $C_f \sim 0.455 / \ln^2(0.06*Re_x) = 0.003107$, where $Re_x = 0.1*Re_c$ = 3 million
    - Δy_1 = Cref / $[Re_c*\text{sqrt}(C_f/2)] = 0.0002332''$
  - At Least 2 Constantly-Spaced Cells at Viscous Walls, $\Delta y_2 = \Delta y_1$
  - Growth Rates < 1.2X Normal to Viscous Walls
  - Wing Spanwise Spacing < 0.1%*Semispan at Root & Tip
  - Wing Chordwise Spacing < 0.1%*C (Local Chord) at LE & TE
  - Wing TE Base >> 8 Cells
  - Spacing Near Fuselage Nose & End-of-Body < 1%*Cref
- **Grow Next-Finer Grid in Family by ~ $[(L+2)/(L+1)]^3$ in Size**
  - Scale Dimensions in All Three Directions by ~ [(L+2)/(L+1)]
  - Grid Spacings Should Reduce as follows, (0.1% in Tiny Grid)
    - [T,C,M,F,X,U] = [0.100, 0.067, 0.050, 0.040, 0.033, 0.029]%

DPW-VII: Gridding Guidelines (2/2)

- **Farfield Boundary > 100*Semispans**
- **Miscellaneous Notes:**
  - Try to be Multigrid Friendly on Structured Meshes
  - Store Grid Coordinates in 64-bit Precision
  - If Storing Grids in Plot3D Format, Keep Zones < 38M Nodes
  - Itemize Surface Elements by Components [W, B, Sym, Far]
  - Itemize Element Count for Unstructured Meshes
    - Volume: Tetrahedra, Prisms, Pyramids, Hexahedra
    - Surface: Triangles, Quads
  - Total of 15 Grids Needed per Grid Type
    - Subtotal of 8 AE Medium Grids @ Low-Q for Alpha Sweep
    - Subtotal of 1 AE Medium Grid @ High-Q for Q Effect
    - Subtotal of 1 Medium Grid on Undeflected Geometry for Case 6
    - Subtotal of 6 Grids in Grid Family for Grid Convergence
      - AE3.00degLoQ Geometry, CL = 0.58, Re = 20M, (Re = 5M Optional)

DPW-VII: Baseline RANS Grid Family Plan

Name	L	WB	Δy_1	Y^+	$^{\#}\Delta y_1 s$
Tiny (T)	1	~5	0.0002332”	~1.00	2
Coarse (C)	2	~17	0.0001555”	~0.67	3
Medium (M)	3	~40	0.0001166”	~0.50	4
Fine (F)	4	~78	0.0000933”	~0.40	5
Extra Fine (X)	5	~135	0.0000777”	~0.33	6
Ultra Fine (U)	6	~215	0.0000666”	~0.29	7

Rough Nominal Size of Grid System in M-DOF

At Least 4 Sequential Mesh Levels & Bias Towards Finest

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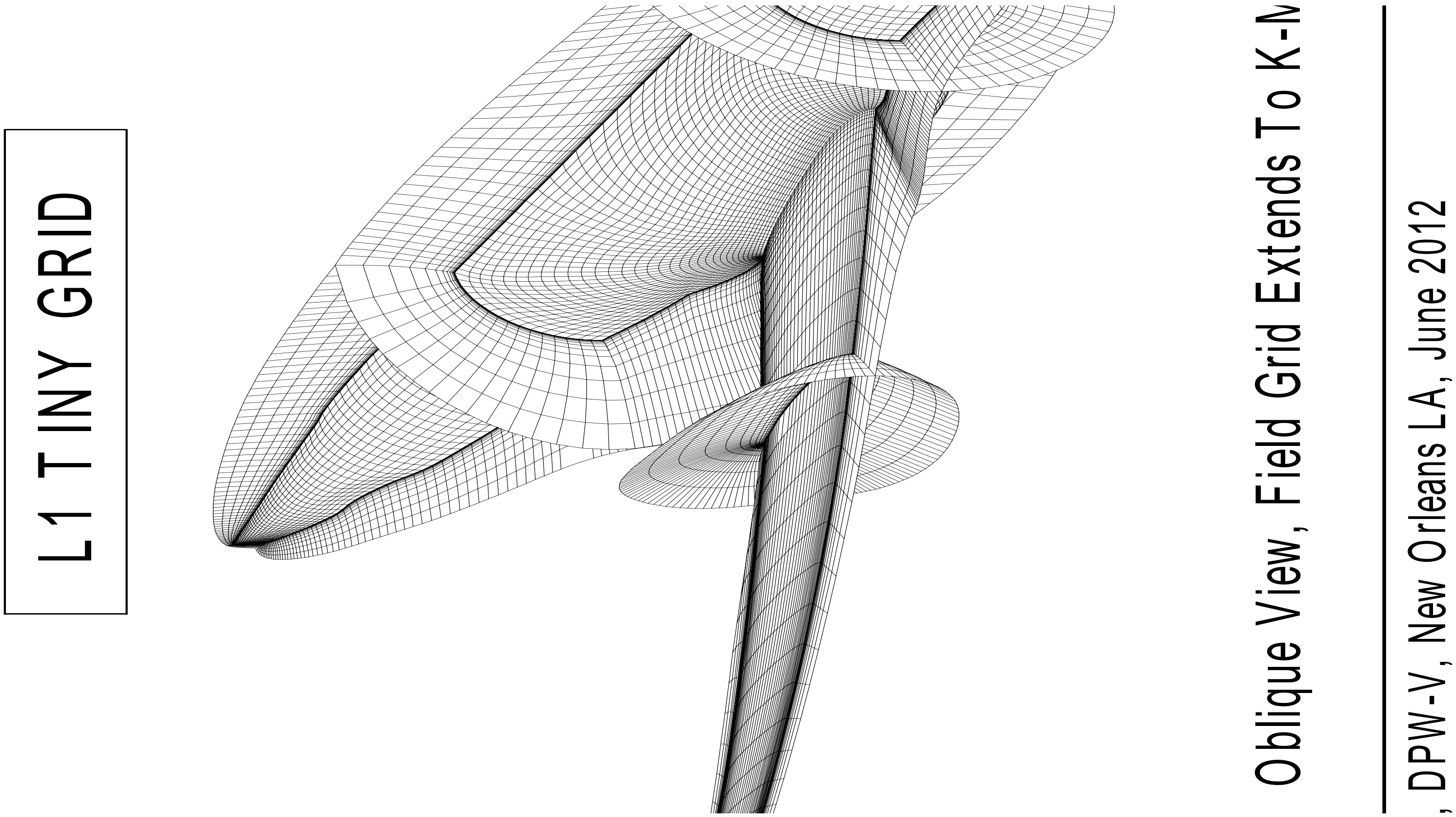
DPW-VII: Vassberg Grid Family Data

Name	L	WB	Δy_1	Y^+	$\#\Delta y_1 s$
Tiny (T)	1	5,286,597	0.0002332”	~1.00	2
Coarse (C)	2	17,644,325	0.0001555”	~0.67	3
Medium (M)	3	41,590,149	0.0001166”	~0.50	4
Fine (F)	4	80,957,925	0.0000933”	~0.40	5
Extra Fine (X)	5	139,581,509	0.0000777”	~0.33	6
Ultra Fine (U)	6	221,294,757	0.0000666”	~0.29	7

DPW-VII: Vassberg Grid Topology



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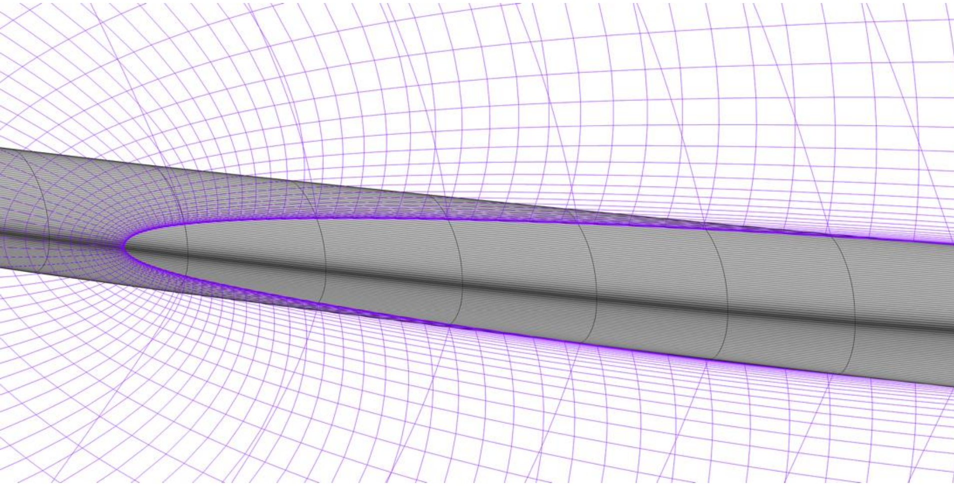
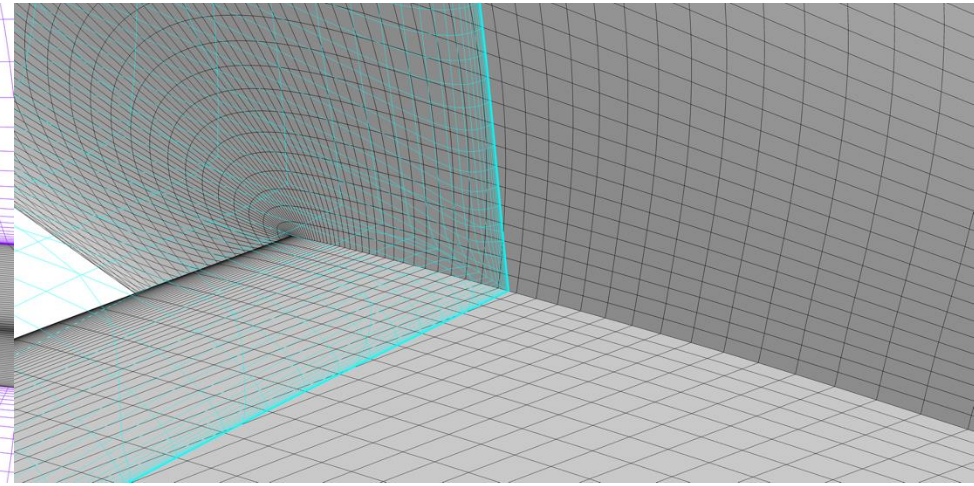
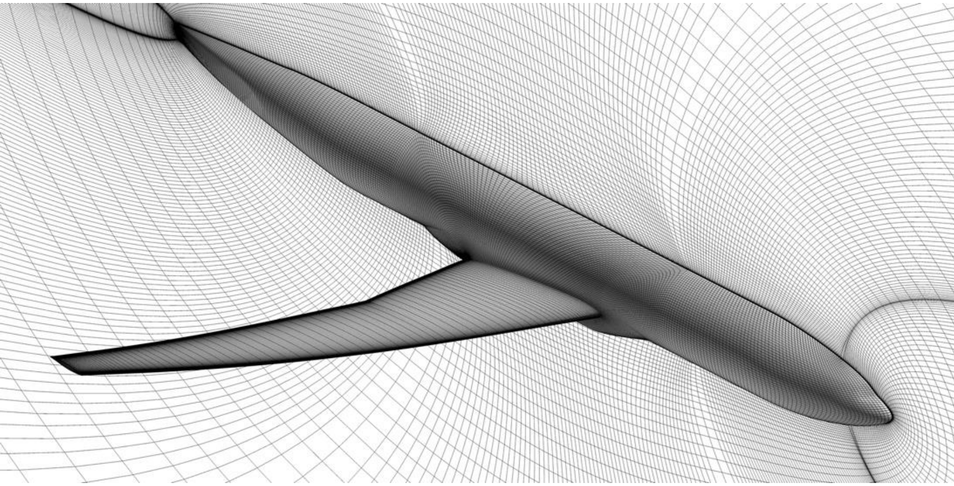
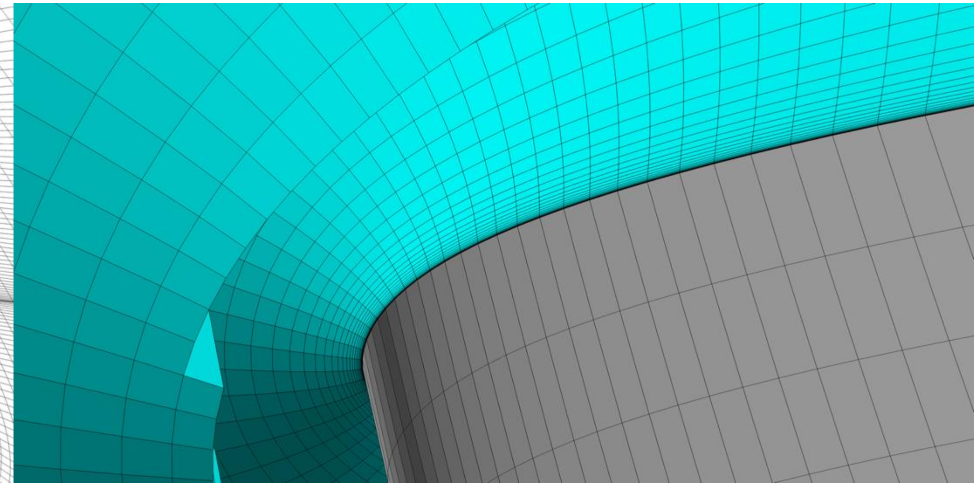
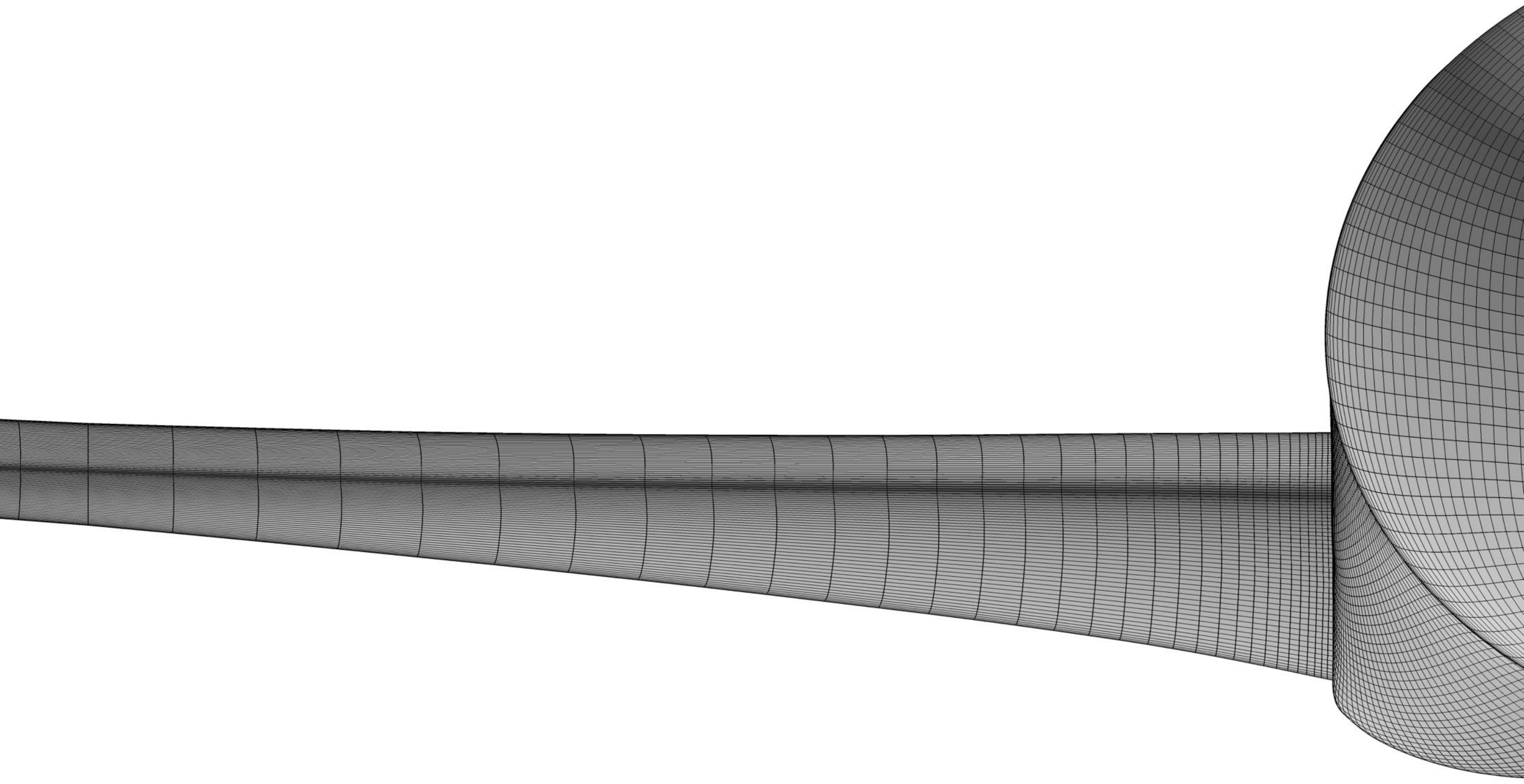




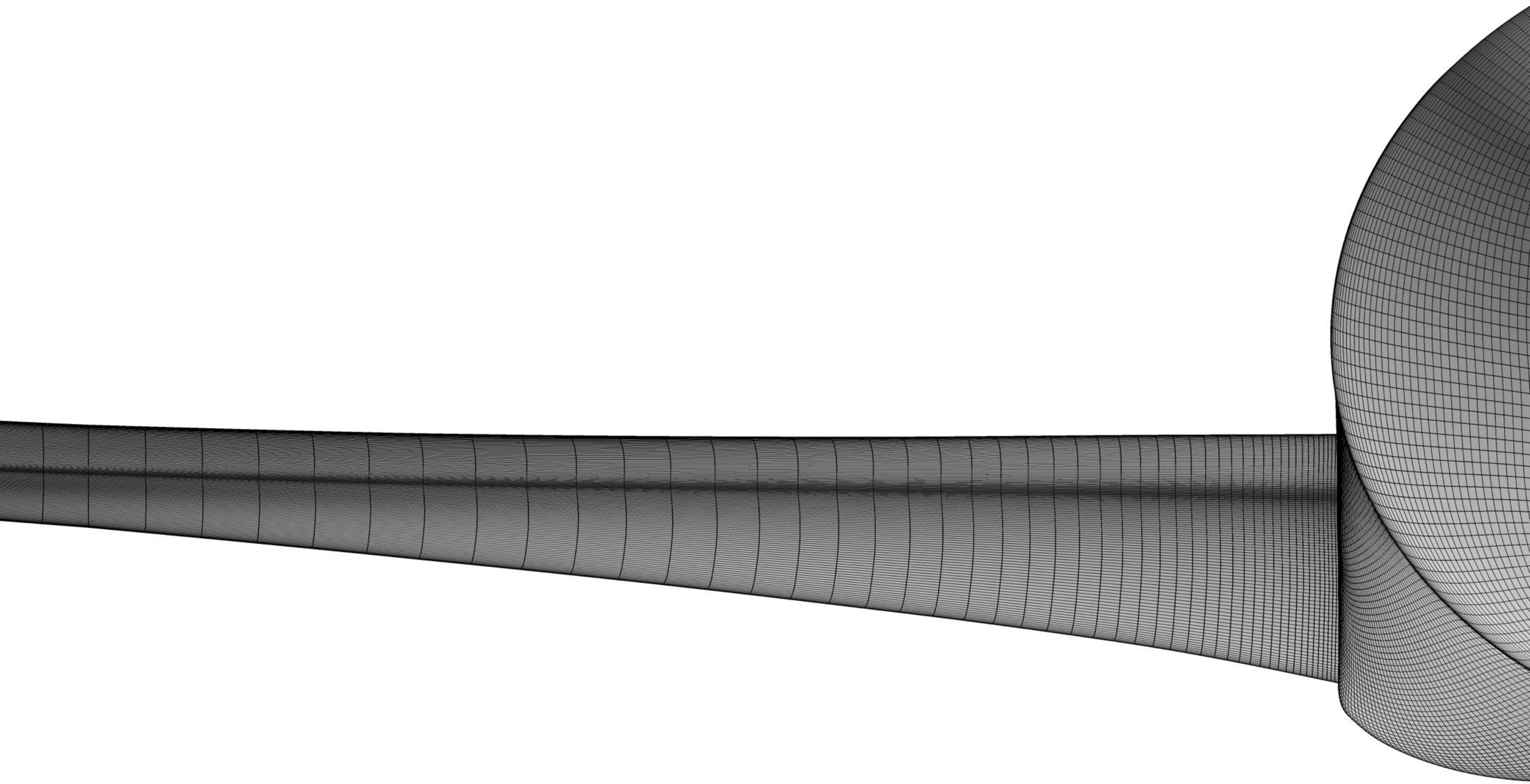




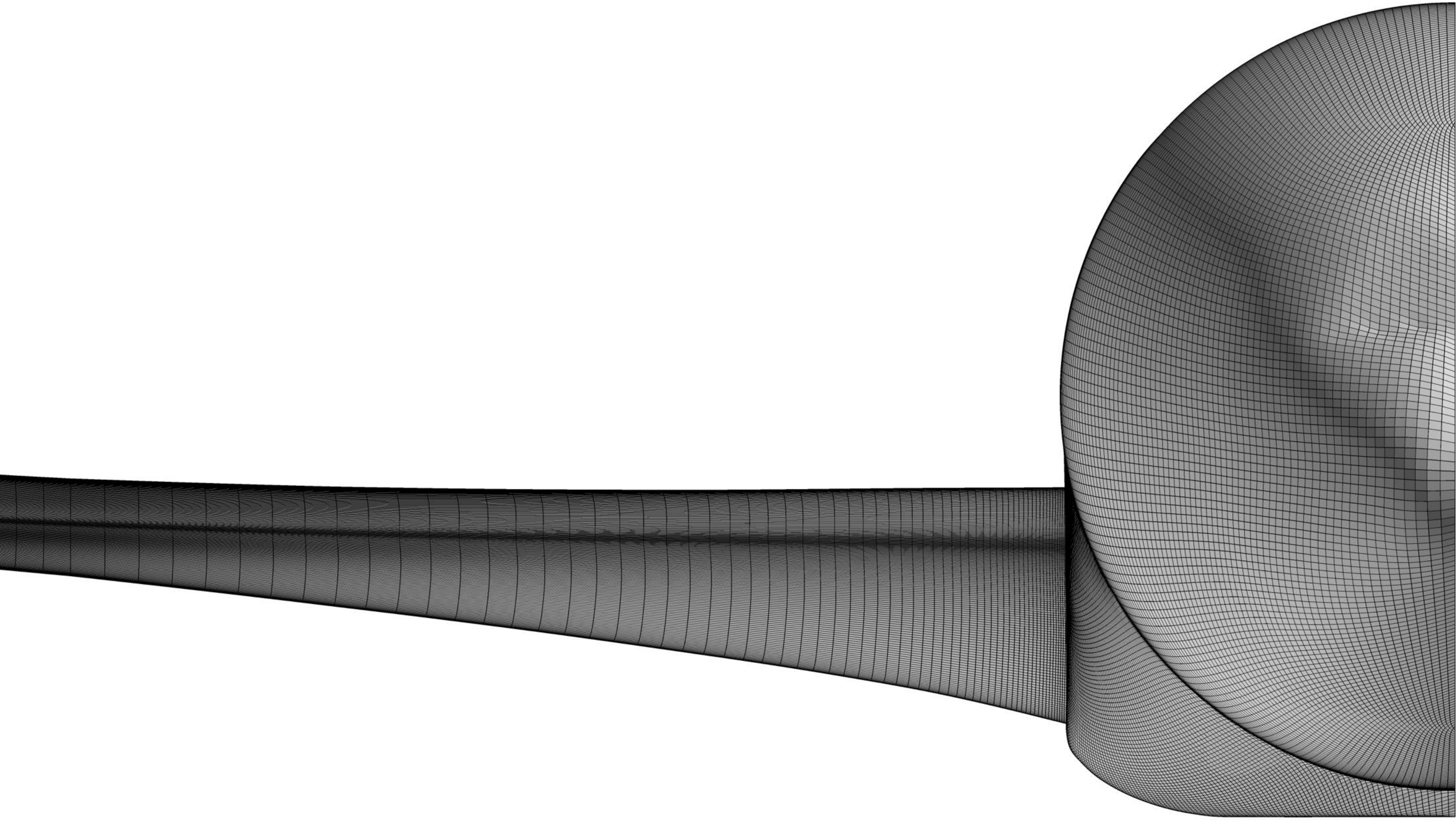
DPW-VII: Vassberg L1 Tiny Grid



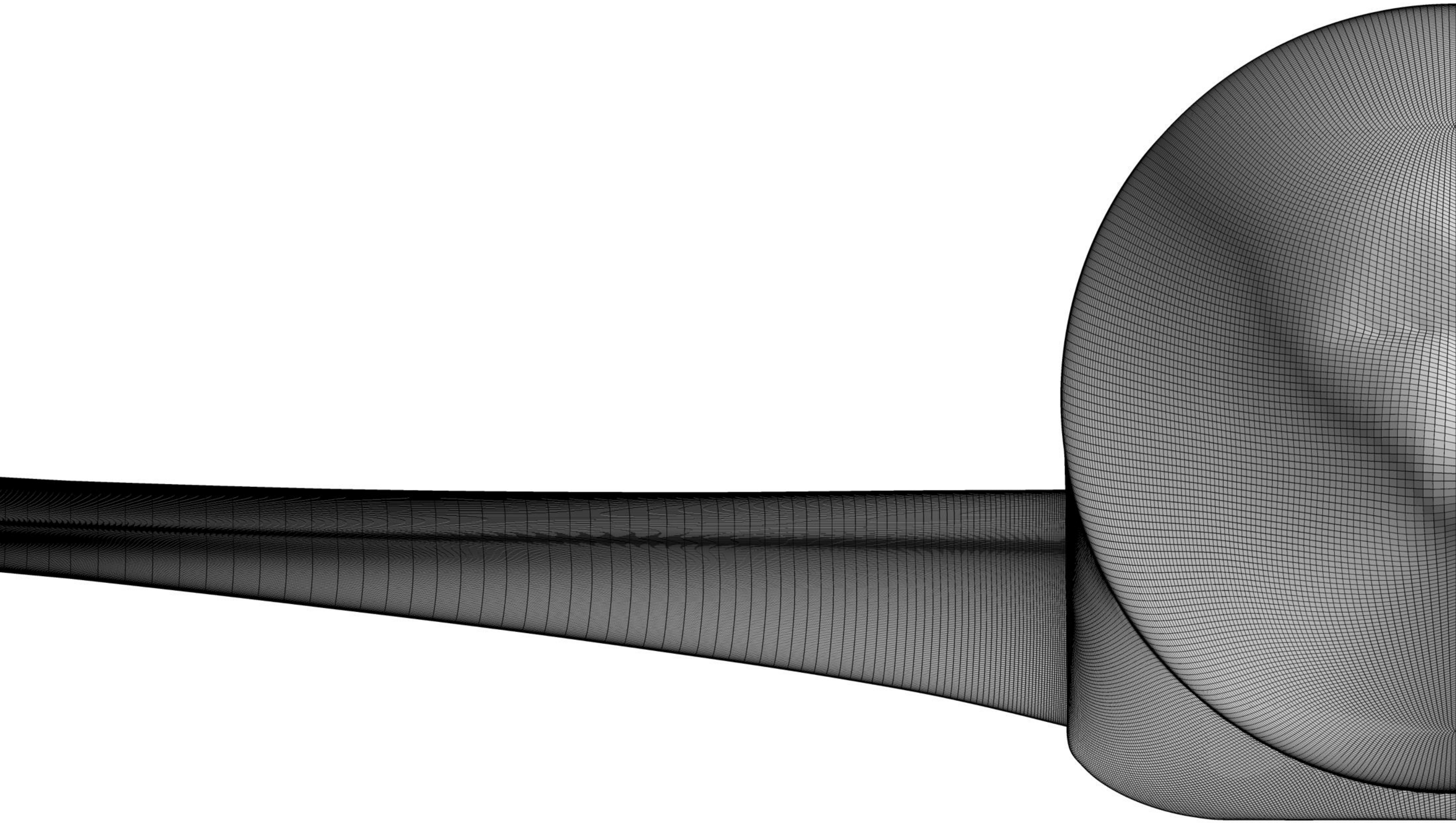
DPW-VII: Vassberg L2 Coarse Grid



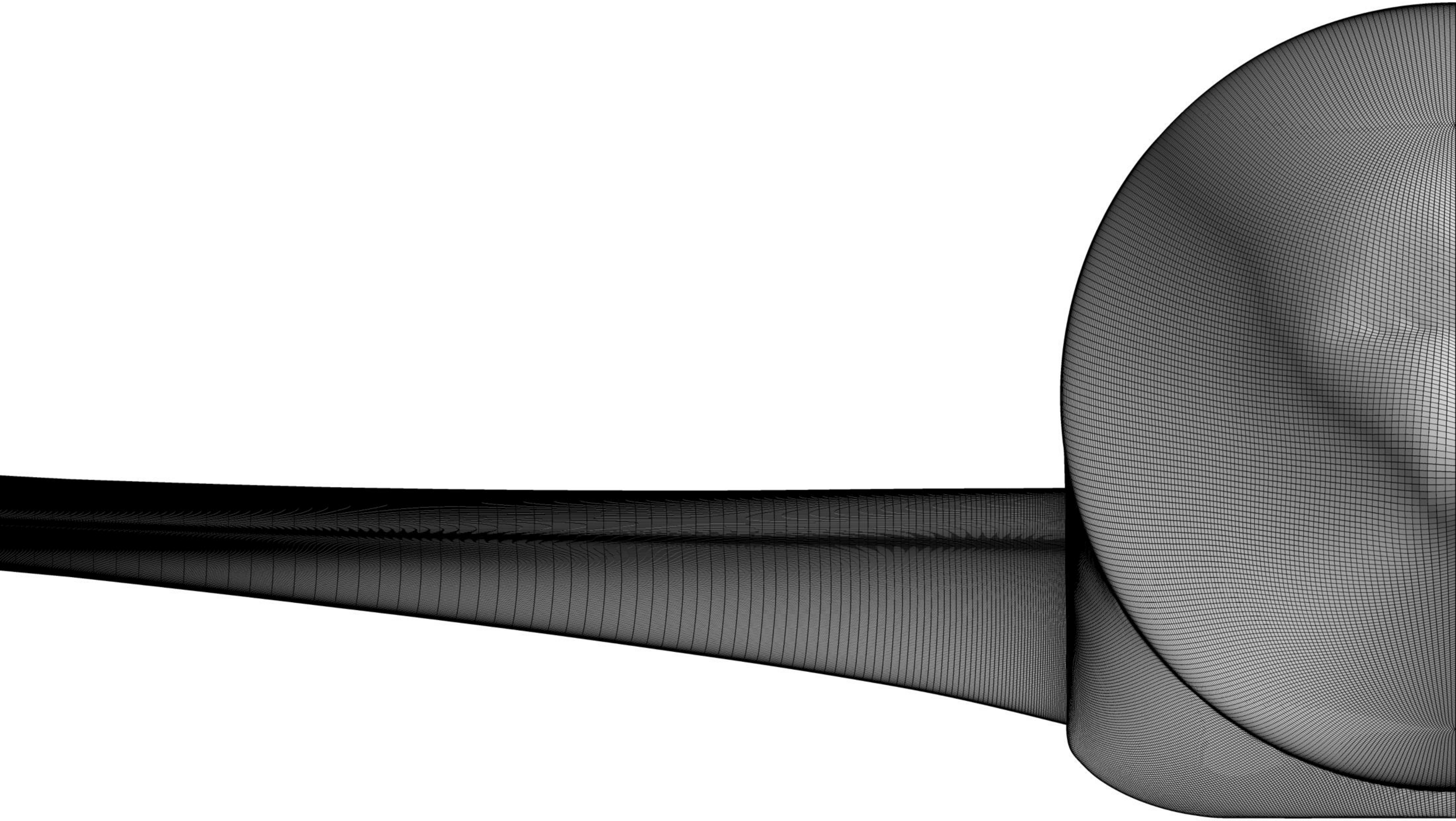
DPW-VII: Vassberg L3 Medium Grid



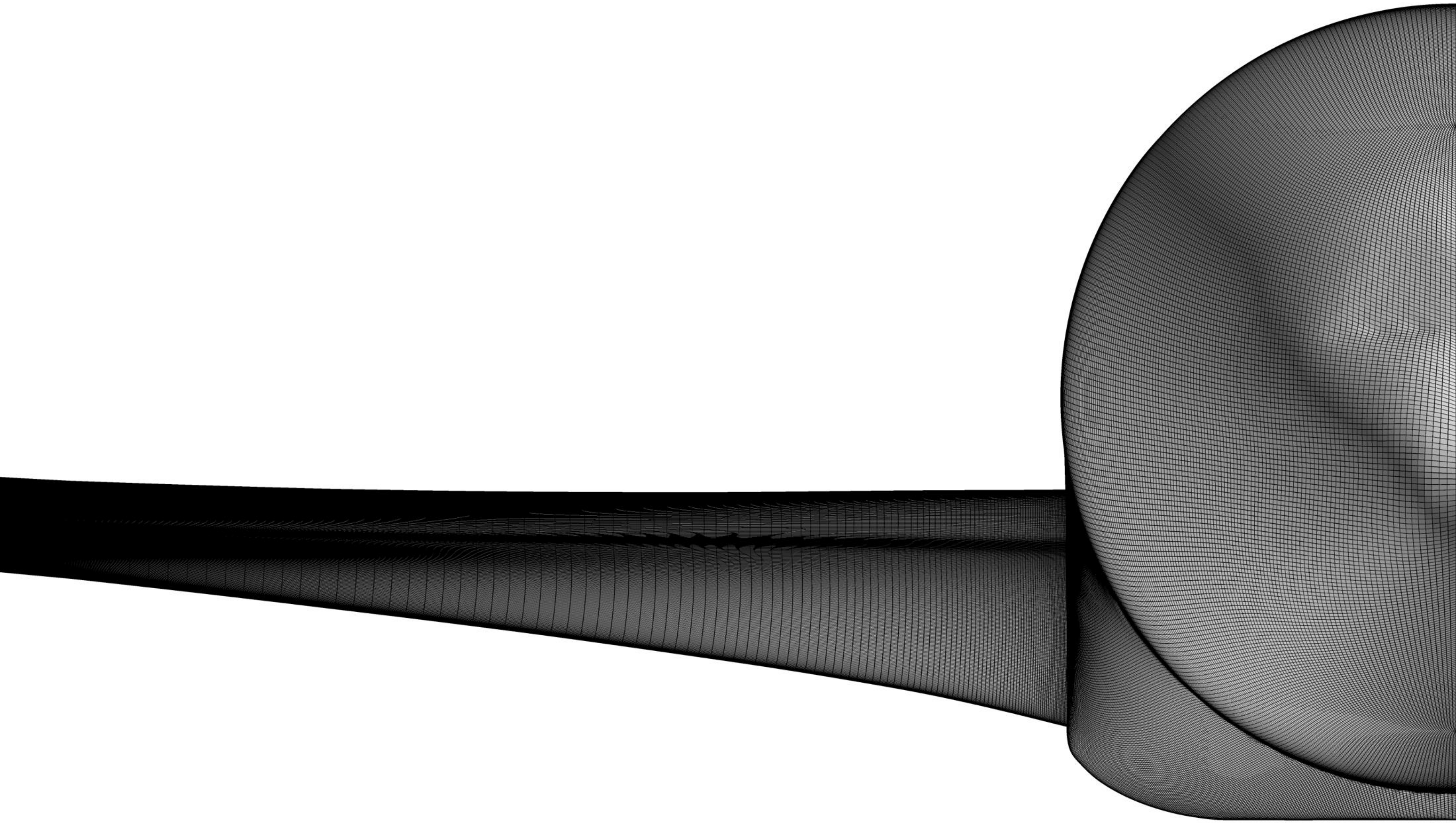
DPW-VII: Vassberg L4 Fine Grid



DPW-VII: Vassberg L5 Extra-Fine Grid



DPW-VII: Vassberg L6 Ultra-Fine Grid



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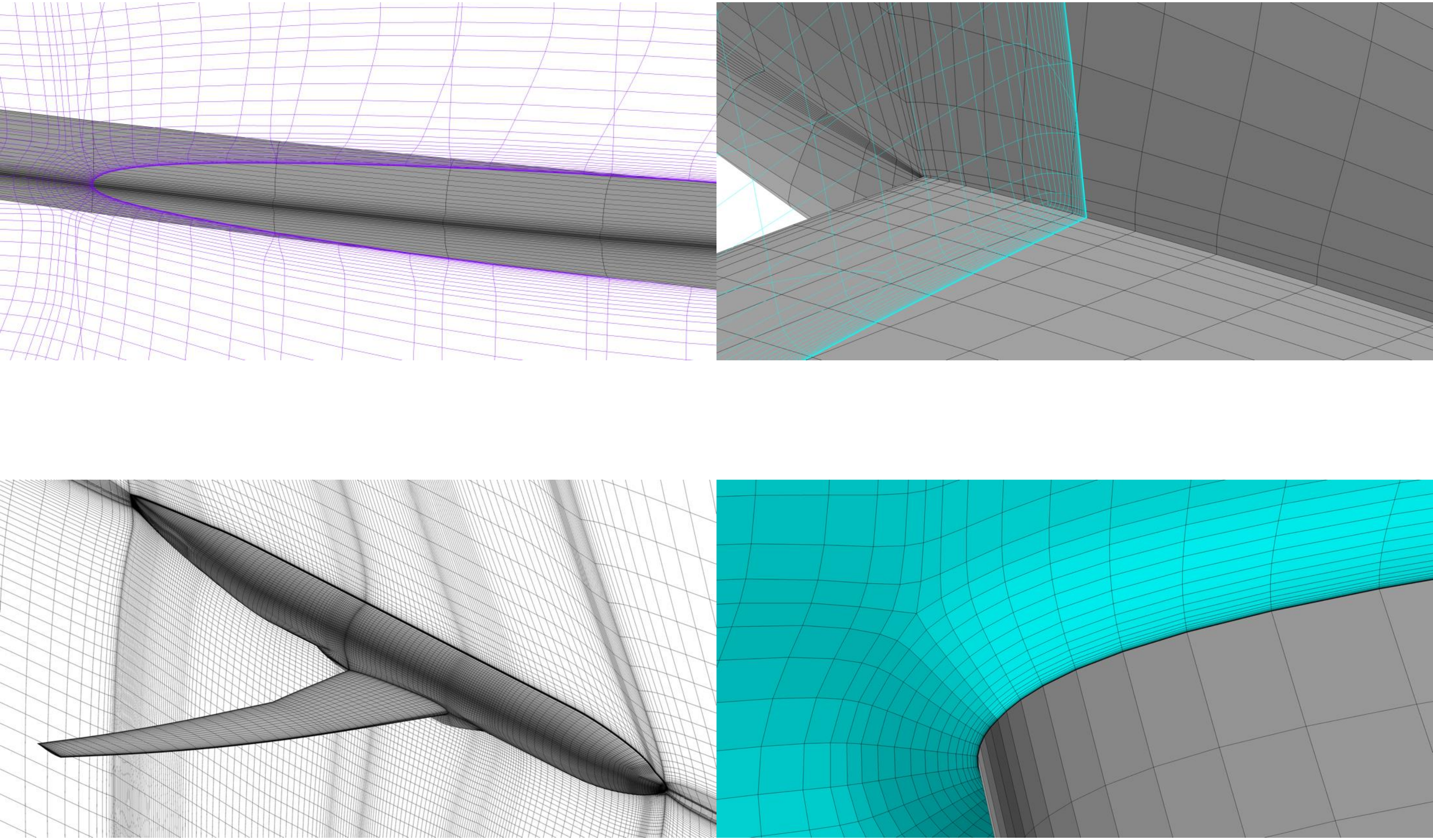
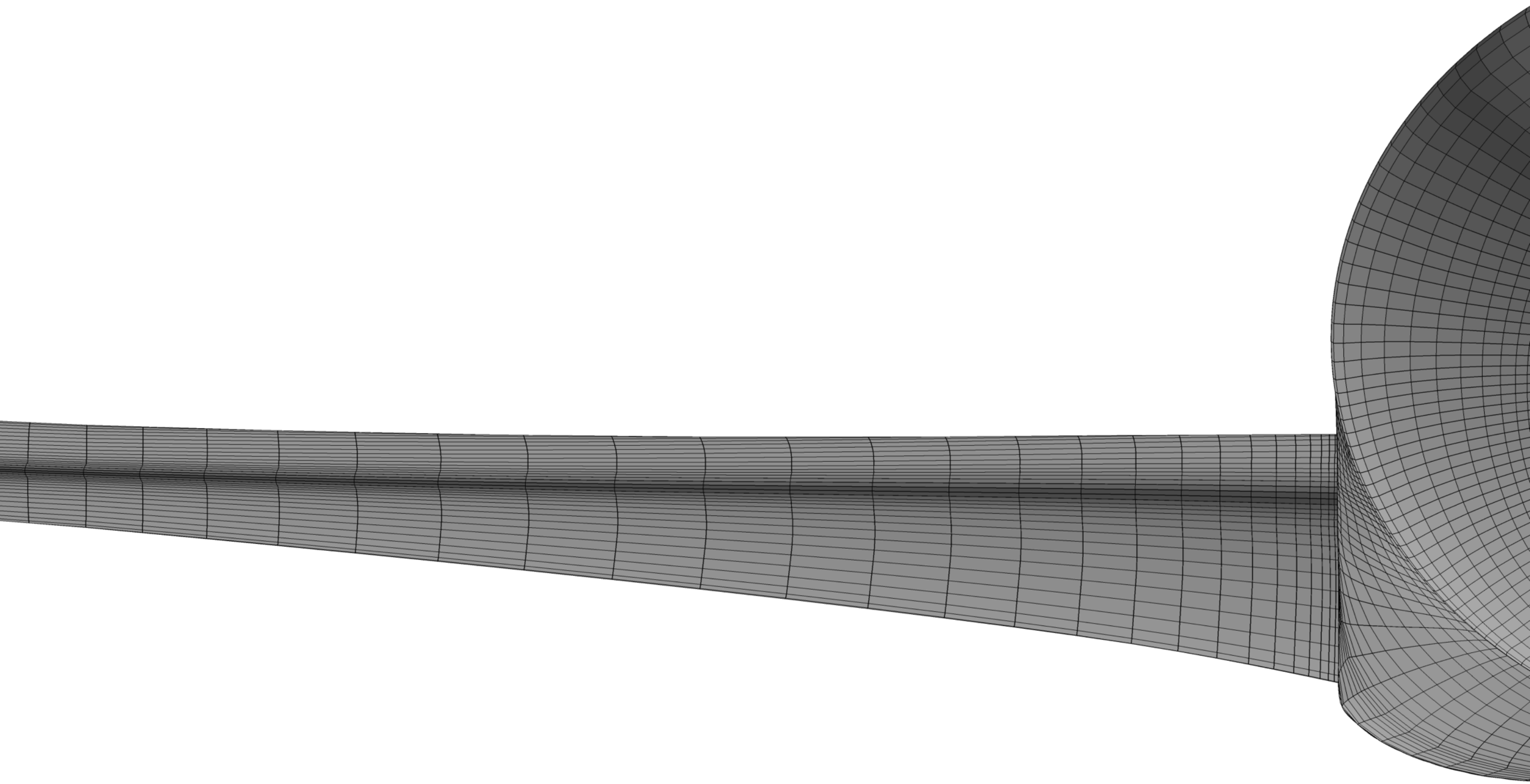
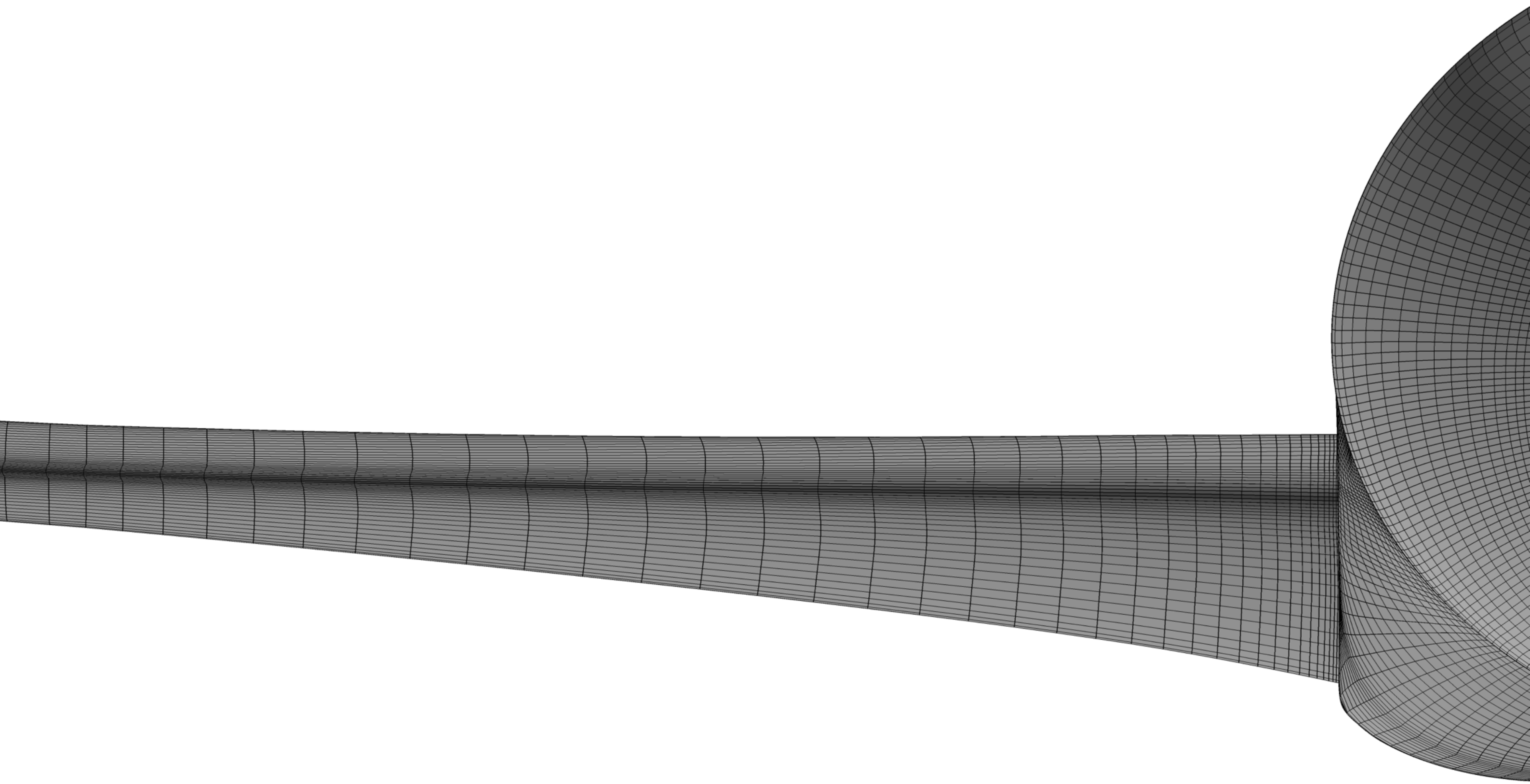
DPW-VII: NLR Grid Topology



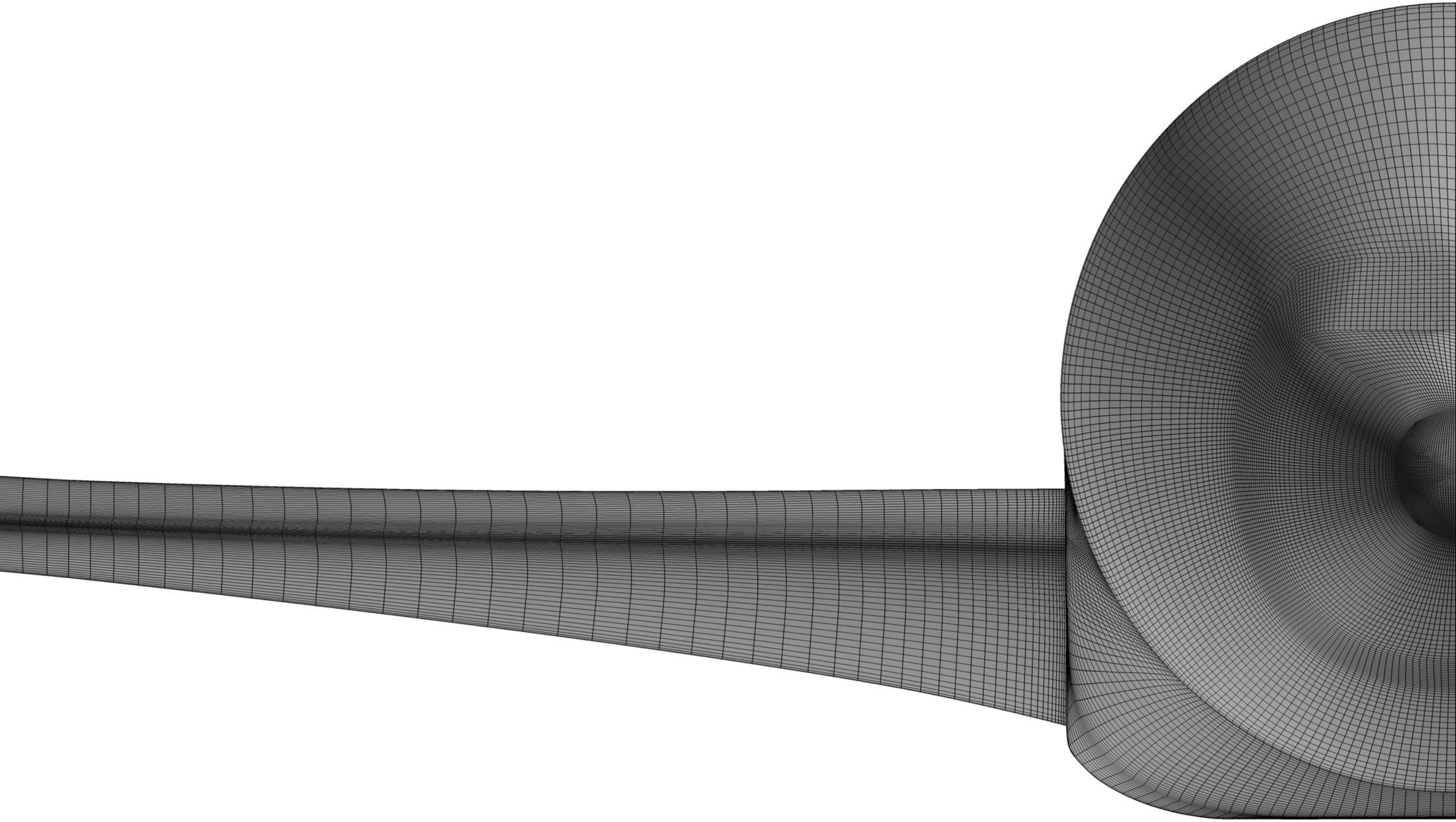
DPW-VII: NLR L1 Tiny Grid



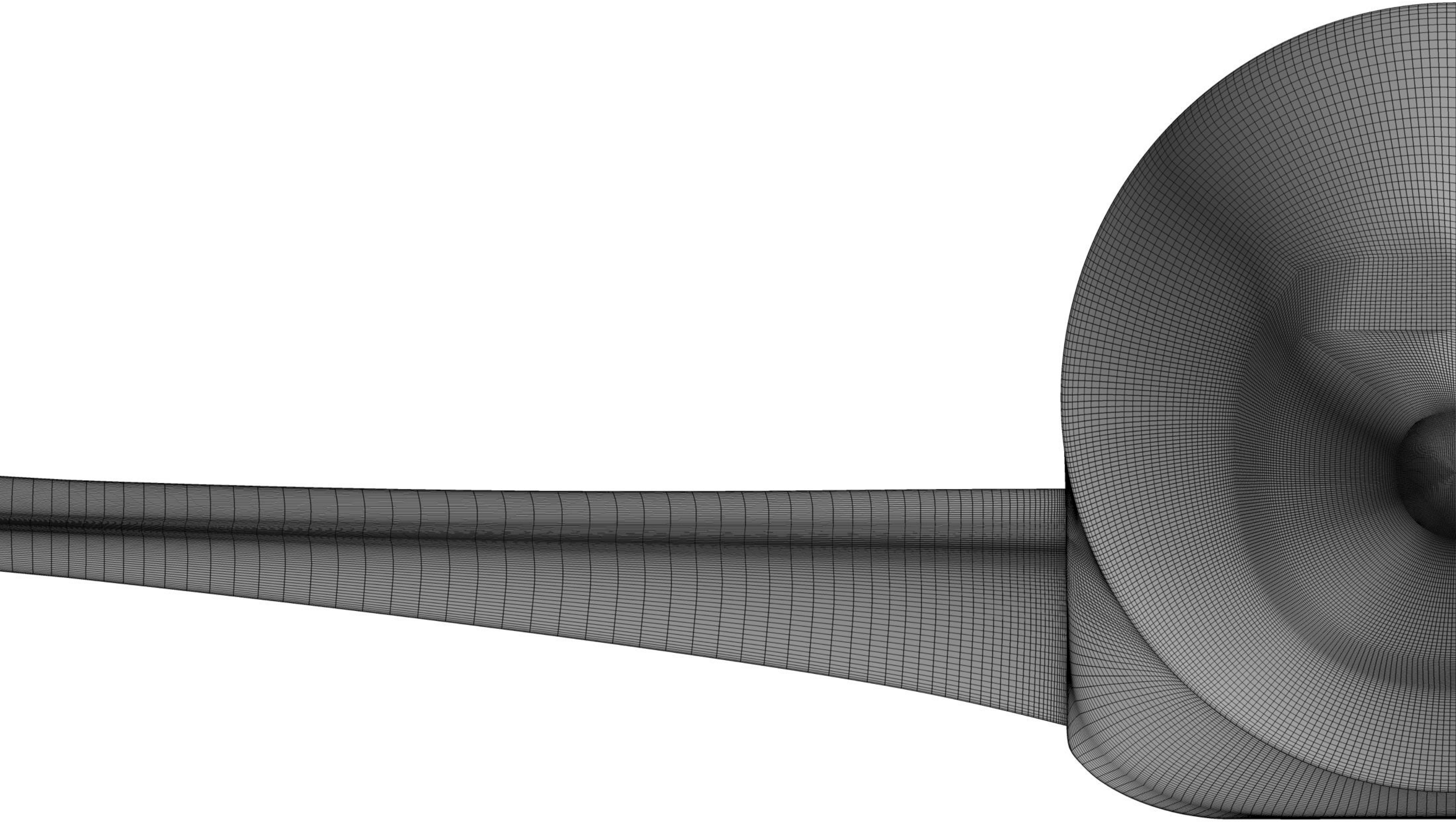
DPW-VII: NLR L2 Coarse Grid



DPW-VII: NLR L3 Medium Grid



DPW-VII: NLR L4 Fine Grid



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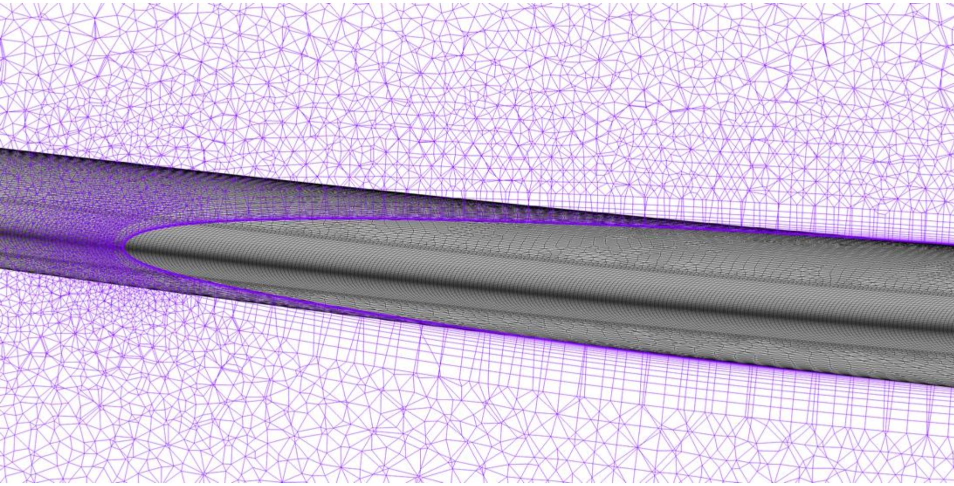
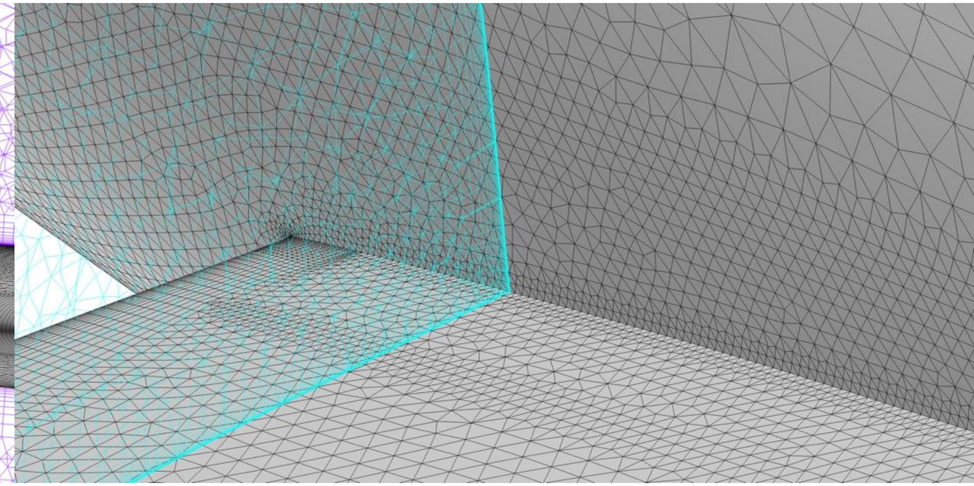
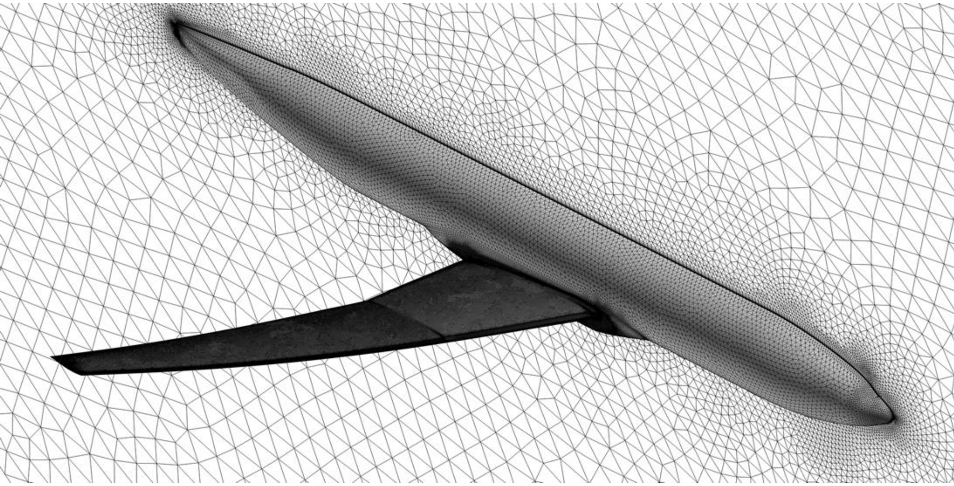
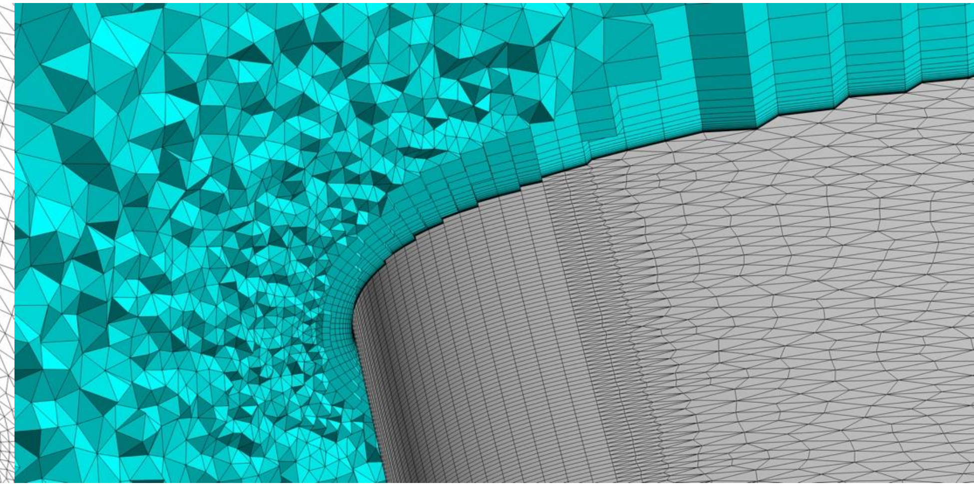


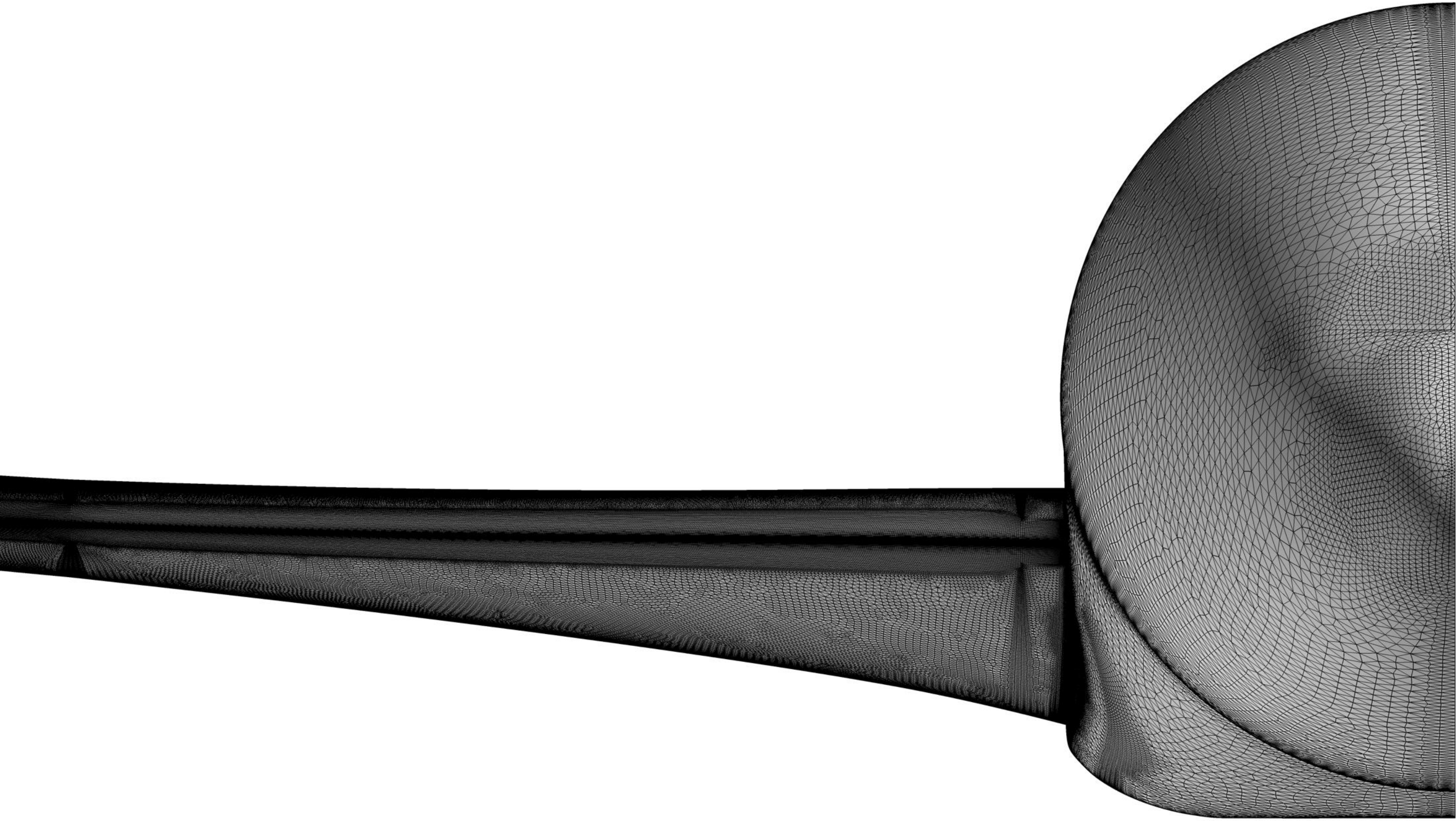






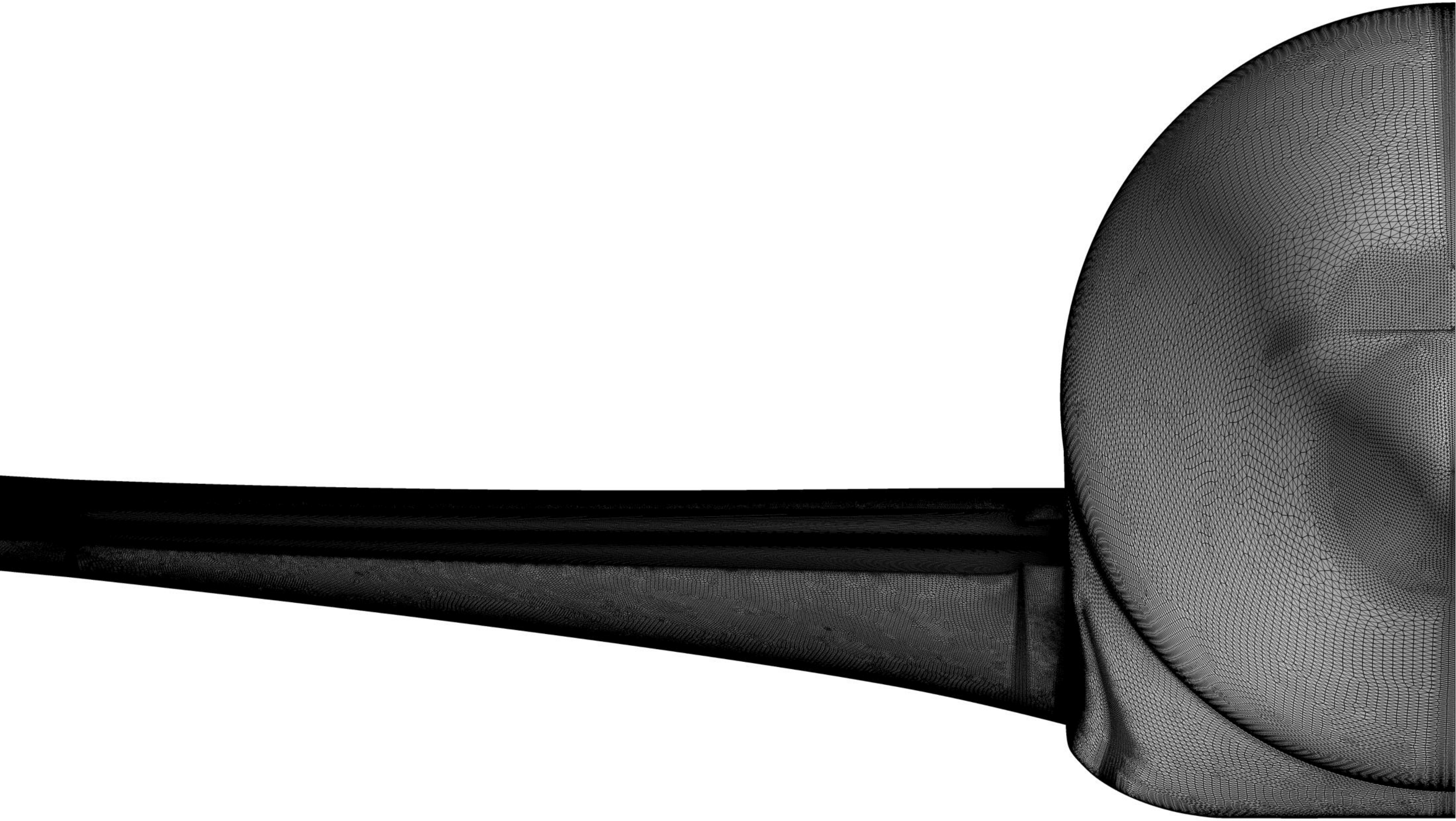
DPW-VII: JAXA L1 Tiny Grid

DPW-VII: JAXA L3 Medium Grid



DPW-VII: JAXA L5 Extra-Fine Grid

DPW-VII: JAXA L6 Ultra-Fine Grid



DPW-VII: *“Expanding The Envelope”*

- Introduction
- Organizing Committee
- Agenda
- DPW History
- Test Cases 1-6
- Participant Demographics
- CRM WB Geometry
- Measured Wing Deflections
- CRM Reference Quantities
- Gridding Guidelines & Family Plan
- **Baseline Grid Families**
  - Vassberg Multi-Block & Overset
  - NLR Multi-Block
  - JAXA Unstructured
  - DLR Unstructured

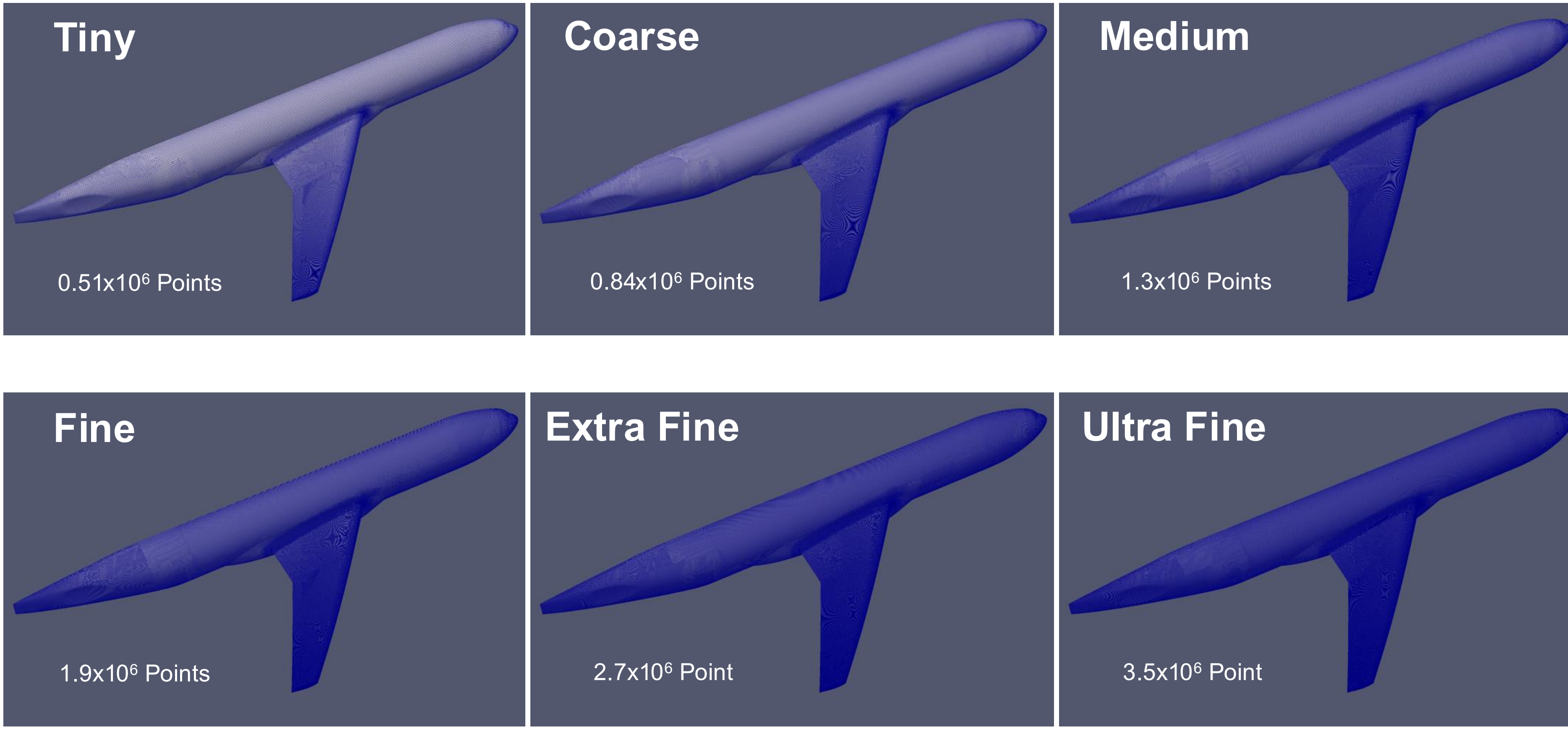
DPW-VII: DLR Grid Family Statistics

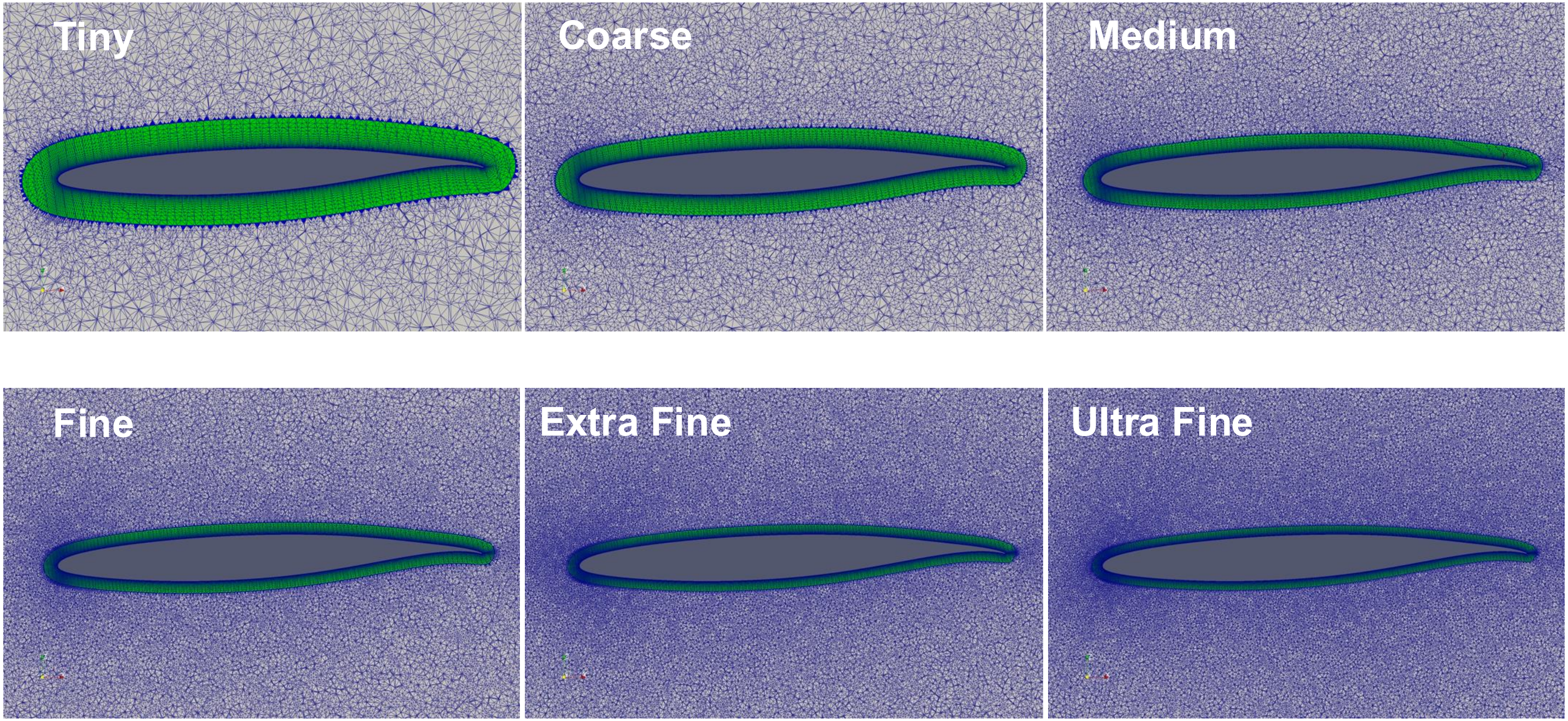
Grid	Points /[10^6]	Elements /[10^6]	Surface Points /[10^6]	y_1/[µm]	# Layers	# constant Cells @ Wall	Stretching Ratio in BL
T	11.70	31.59	0.506	6.560	53	2	1.2
C	25.01	64.33	0.837	4.374	53	3	1.2
M	47.06	130.7	1.317	3.280	52	4	1.2
F	76.51	224.1	1.931	2.624	52	5	1.2
X	118.8	367.9	2.726	2.187	52	6	1.2
U	164.5	534.2	3.485	1.874	53	7	1.2

Additional Grid Family built using Hybrid Meshing Approach:

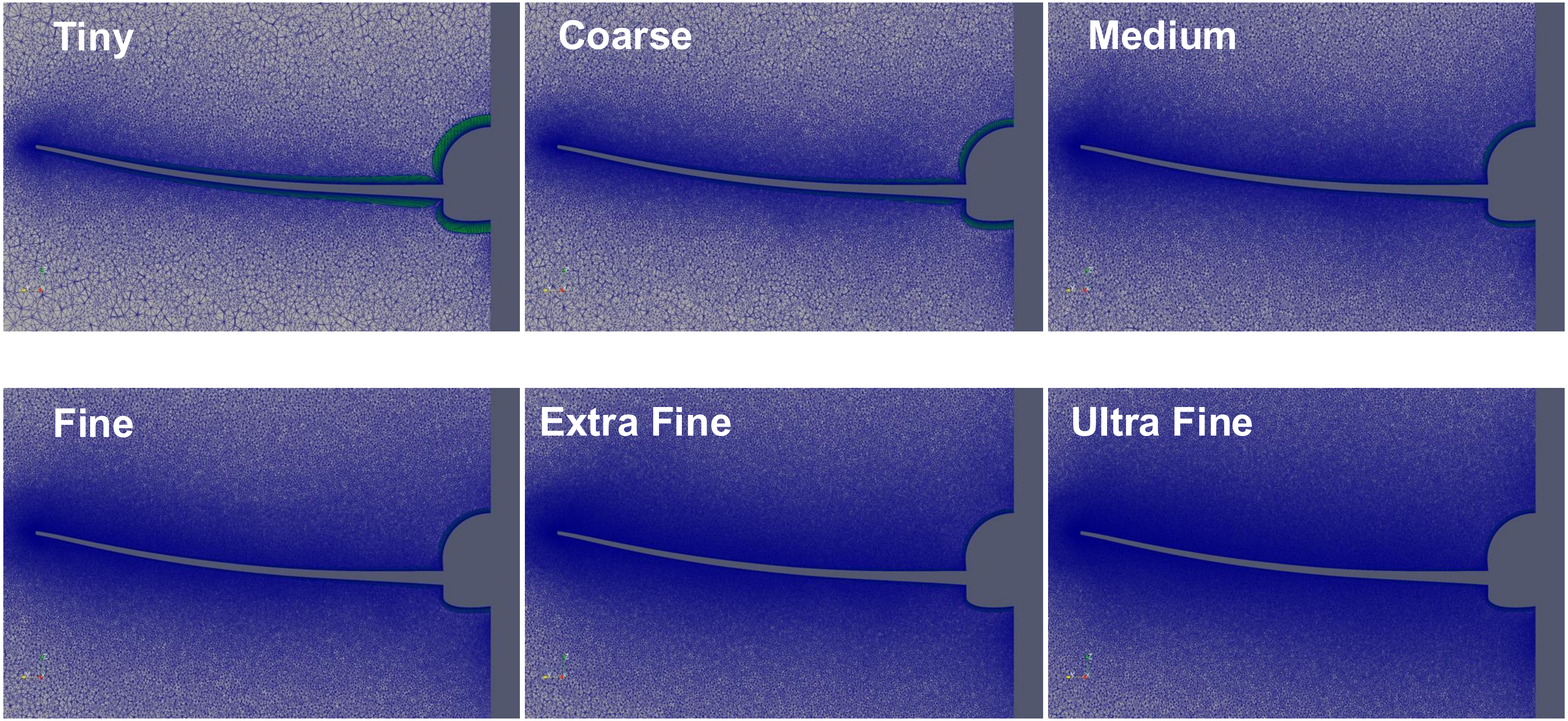
- SOLAR for Surface Mesh
- ANSA (BETA CAE Systems, USA) for Boundary Layer / Farfield Mesh

Grids available on DPW-7 Website


Tiny
0.51x10⁶ Points
Coarse
0.84x10⁶ Points
Medium
1.3x10⁶ Points
Fine
1.9x10⁶ Points
Extra Fine
2.7x10⁶ Point
Ultra Fine
3.5x10⁶ Point



Boundary Layer Height reduced from coarser to finer Meshes
due to automatic Stopping when Cell Aspect Ratio reaches 1


Tiny
Coarse
Medium
Fine
Extra Fine
Ultra Fine

Questions?

DPW-VII Workshop
25-26 June 2022

AIAA Aviation 2022
Applied Aerodynamics Conference

Chicago, IL

CFD DRAG PREDICTION WORKSHOP SERIES

DPW

ESTABLISHED 2000