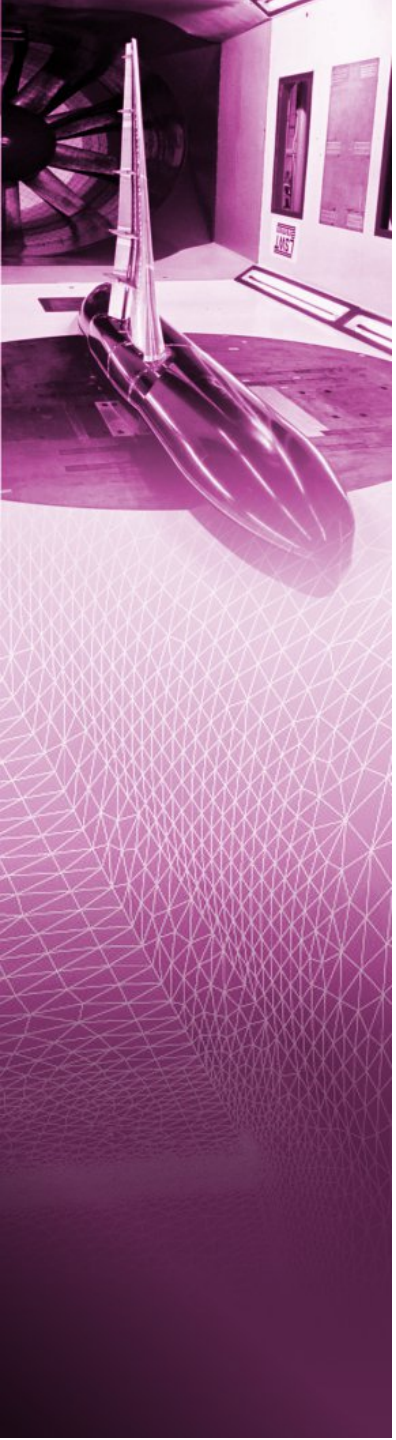


CFD High Lift Prediction Workshop

HiLiftPW-2
Overview and Grid Systems

Jeffrey Slotnick
The Boeing Company

Mark Chaffin
Cessna Aircraft Company

2nd AIAA CFD High Lift Prediction Workshop
San Diego, California, USA
22-23 June 2013

Outline

- **Organizing Committee**
- **Objectives**
- **Configuration**
- **Test Cases**
- **Agenda**
- **Participant Statistics**
- **Grid Systems**
- **AIAA Special Sessions**
- **Acknowledgments**

Organizing Committee

- **Jeffrey Slotnick and Tony Sclafani**
  The Boeing Company
- **David Levy* and Mark Chaffin**
  Cessna Aircraft Company
- **Ralf Rudnik and Kerstin Huber**
  DLR – German Aerospace Center
- **Thomas Wayman**
  Gulfstream Aerospace Corporation
- **Thomas Pulliam**
  NASA Ames Research Center
- **Chris Rumsey and Judi Hannon**
  NASA Langley Research Center
- **Carolyn Woeber**
  Pointwise, Inc.
- **Dimitri Mavriplis* and Michael Long**
  of Wyoming University

*** DPW organizing committee member**

Objectives

- Assess the numerical prediction capability (meshing, numerics, turbulence modeling, high-performance computing requirements, etc.) of current-generation CFD technology/codes for **swept, medium/high-aspect ratio wings in landing/take-off (high-lift) configurations**
- Develop practical **modeling guidelines** for CFD prediction of high-lift flowfields
- Advance the understanding of **high-lift flow physics** to enable development of more accurate prediction methods and tools
- Enhance CFD prediction capability to enable practical **high-lift aerodynamic design and optimization**

Configuration

- DLR F11 wing/body high-lift configuration
  - Used for EUROLIFT I test campaigns
  - Rich set of low- and high-Re test data
  - CAD model made available
  - Representative of modern transport high-lift systems

Test Cases

Case 1 – Grid Convergence Study (REQUIRED)

33 Datasets

DLR F11 "Config 2"

Slat 26.5 deg, Flap 32 deg (Wing/Body/HL system + SOB Flap Seal)

- Mach = 0.175
- Angles-of-attack to be computed (deg) = 7, 16 (OPTIONAL: 18.5, 20, 21, 22.4)
- Reynolds number = 15.1 million based on mean aerodynamic chord (MAC)
- RUN FULLY TURBULENT

Test Cases

Case 2 – Reynolds Number Study

DLR F11 "Config 4"

Slat 26.5 deg, Flap 32 deg (Config 2 + Slat Tracks and Flap Track Fairings)

Flow solutions on comparable medium mesh density from Grid Convergence Study

Case 2a (REQUIRED) - Low Reynolds Number Condition

19 Datasets

Mach = 0.175
Angles-of-attack to be computed (deg) = 0, 7, 12, 16, 18.5, 19, 20, 21
Reynolds number = 1.35 million based on mean aerodynamic chord (MAC)
RUN FULLY TURBULENT

Case 2b (REQUIRED) - High Reynolds Number Condition

20 Datasets

Mach = 0.175
Angles-of-attack to be computed (deg) = 0, 7, 12, 16, 18.5, 20, 21, 22.4
Reynolds number = 15.1 million based on mean aerodynamic chord (MAC)
RUN FULLY TURBULENT

Case 2c (OPTIONAL) - Low Reynolds Number Condition with Transition

4 Datasets

Mach = 0.175
Angles-of-attack to be computed (deg) = 0, 7, 12, 16, 18.5, 19, 20, 21
Reynolds number = 1.35 million based on mean aerodynamic chord (MAC)
RUN WITH SPECIFIED TRANSITION and/or TRANSITION PREDICTION METHODS

Test Cases

Case 3 – Full Configuration Study (OPTIONAL)

DLR F11 "Config 5"

Slat 26.5 deg, Flap 32 deg (Config 4 + Slat Pressure Tube Bundles)

Flow solutions on comparable medium mesh density from Grid Convergence Study

Case 3a - Low Reynolds Number Condition

3 Datasets

Mach = 0.175
Angles-of-attack to be computed (deg) = 0, 7, 12, 16, 18.5, 19, 20, 21
Reynolds number = 1.35 million based on mean aerodynamic chord (MAC)
RUN FULLY TURBULENT and/or RUN WITH TRANSITION

Case 3b - High Reynolds Number Condition

3 Datasets

Mach = 0.175
Angles-of-attack to be computed (deg) = 0, 7, 12, 16, 18.5, 20, 21, 22.4
Reynolds number = 15.1 million based on mean aerodynamic chord (MAC)
RUN FULLY TURBULENT and/or RUN WITH TRANSITION

Test Cases

Case 4 – Turbulence Model Grid-Convergence Verification Study (OPTIONAL)

3 Datasets

2-D bump from *http://turbmodels.larc.nasa.gov/bump.html*

The purpose of this case is to investigate the consistency in implementation of turbulence models in a controlled study. The grids supplied at the above website must be used.

Mach=0.2
Re=3 million per unit length
Tref=540°R
Participants must run at least the finest 3 supplied grids.
RUN FULLY TURBULENT

Datasets (37 Total)

CFD High Lift Prediction Workshop

Participant #	Grid Type	Flow Solver	Case 1	Case 2a	Case 2b	Case 2c	Case 3a	Case3b	Case 4
002.1	Uns	FUN3D	X	X	X				
002.2	Str-Blocked	CFL3D	X						
003.1	Str-Overset	OVERFLOW	X	X	X	X			
003.2	Str-Overset	OVERFLOW	X	X	X				
003.3	Str-Overset	OVERFLOW				X			
004	Uns	CFD++	X						
005.1	Uns	HiFUN	X						
005.2	Uns	HiFUN	X	X	X				
006	Uns	FUN3D	X						
007.1	Uns	UG3	X						X
007.2	Uns	Cflow	X						X
008	Uns	CRUNCH CFD	X	X	X				
009	Str-Overset	OVERFLOW	X	X	X				
010.1	Uns	CFD++	X	X	X				
010.2	Uns	CFD++	X						
010.3	Uns	CFD++	X						
011.1	Str-Blocked	NSMB	X						
011.2	Str-Blocked	NSMB	X						
012	Cartesian/LB	PowerFlow					X	X	
013	Str-Blocked	UPACS	X						
014	Uns	Unicorn			X				
015.1	Uns	CFX	X	X	X	X			
015.2	Uns	Fluent	X	X	X	X			
016	Str-Overset	elsA	X						
017	Str-Blocked	COBRA	X	X	X				
018	Str-Blocked	VULCAN	X						X
020	Str-Overset	OVERFLOW	X	X	X				
021	Uns	Tau	X	X	X		X	X	
022	Uns	PHASTA	X	X	X				
023	Uns	NSU3D	X	X	X				
024.1	Uns	Edge	X	X	X				
024.2	Uns	Edge	X	X	X				
025	Uns	NSU3D	X	X	X				
026	Str-Blocked	Mflow	X	X	X		X	X	
028	Uns	Fluent	X						
029	Lattice/LB	Xflow	X	X	X				

Agenda

AIAA CFD High Lift Prediction Workshop

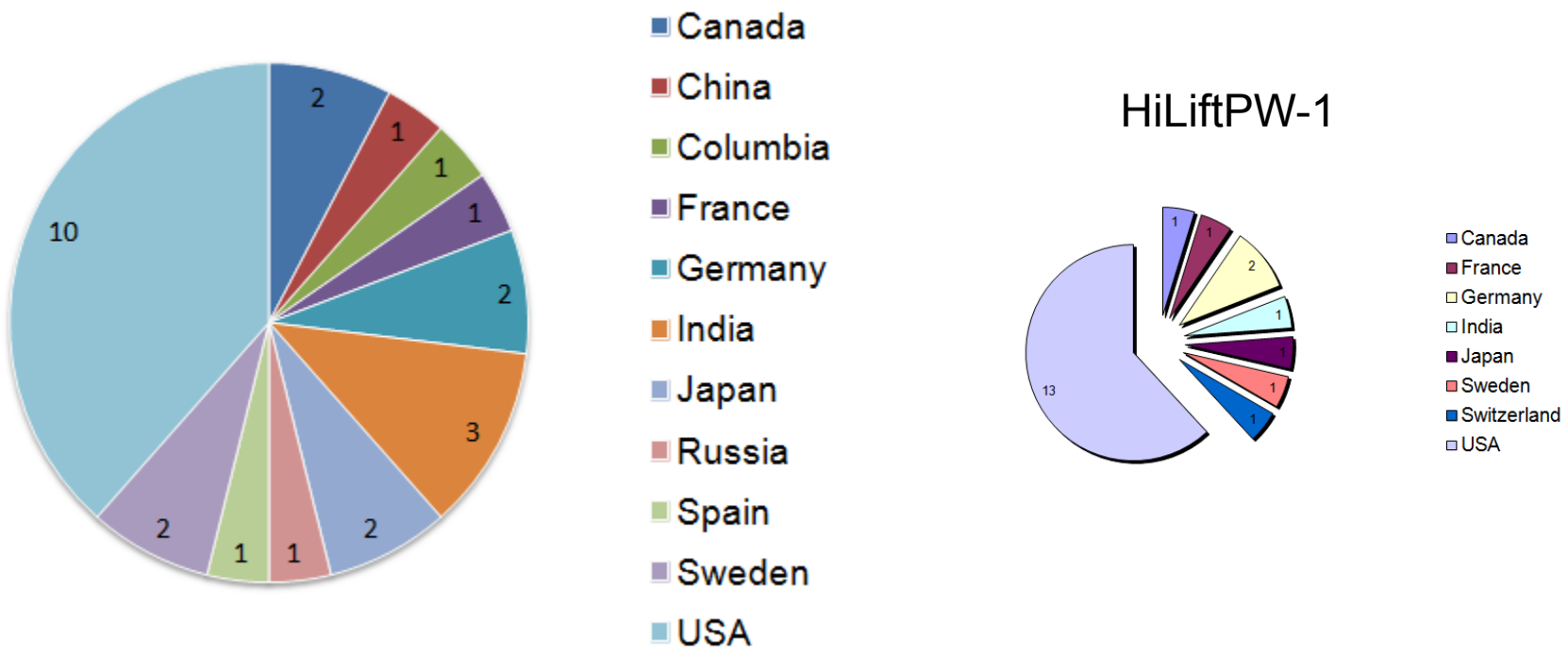
Start	End	DAY 1 - Saturday, June 22		DAY 2 - Sunday, June 23	
8:00 AM	8:20 AM	REGISTRATION		Intelligent Light	Duque
8:20 AM	8:40 AM			Penn State University	Coder
8:40 AM	9:00 AM			Boeing/NASA ARC	Sclafani/Pulliam
9:00 AM	9:20 AM	Overview/Grid Systems	Slotnick	ONERA	Wiart
9:20 AM	9:40 AM	Wind Tunnel/Test Data	Rudnik	BREAK	
9:40 AM	10:00 AM	Cessna Aircraft Company	Laflin		
10:00 AM	10:20 AM	NASA LaRC	Lee-Rausch	Exa GmbH	Konig
10:20 AM	10:40 AM	BREAK		Next Limit Technologies	Holman
10:40 AM	11:00 AM	DLR	Rudnik	Bombardier Aerospace	Langlois
11:00 AM	11:20 AM	University of Wyoming	Mavriplis	Kawasaki Heavy Industries	Nagata
11:20 AM	11:40 AM	FOI	Eliasson	Indian Institute of Science	Balakrishnan
11:40 AM	12:00 PM	CRAFT Tech	Cavallo	LUNCH	
12:00 PM	12:20 PM	LUNCH			
12:20 PM	12:40 PM				
12:40 PM	1:00 PM				
1:00 PM	1:20 PM			University of Colorado Boulder	Chitale
1:20 PM	1:40 PM	ANSYS	Sasanapuri	KTH	Hoffman
1:40 PM	2:00 PM	Metacomp Technologies	Goldberg	CARDC	Chen
2:00 PM	2:20 PM	JAXA	Murayama	BREAK	
2:20 PM	2:40 PM	TATA Consultancy Services	Moitra	Data Summary	Rumsey
2:40 PM	3:00 PM	BREAK			
3:00 PM	3:20 PM				
3:20 PM	3:40 PM	Polytechnique Montreal/Icube/CFS Eng	Deloze	Open Forum	HiLiftPW Committee
3:40 PM	4:00 PM	U de San Buenaventura/U de Los Andes	Escobar		
4:00 PM	4:20 PM	Texas A&M University	Girimaji		
4:20 PM	4:40 PM	Day 1 Wrap-Up	Slotnick		
4:40 PM	5:00 PM				

Participant Guidelines & Information

- All participant presentations will be 15 minutes with 5 minutes Q/A (please wait until speaker is finished to ask questions)
- Presentations will be uploaded to the HiLiftPW website (http://hiliftpw.larc.nasa.gov) after the workshop
- Updates (if desired) to the datasets will be collected after the workshop

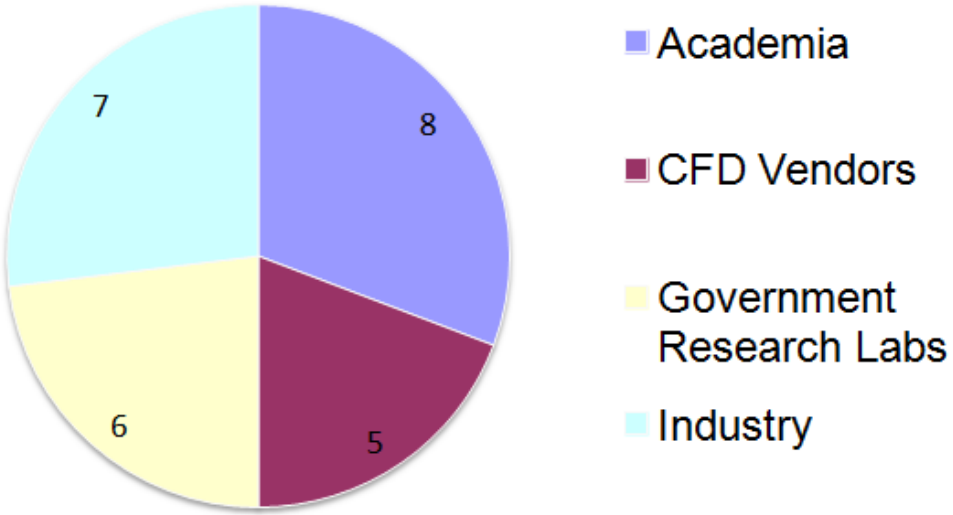
Participant Statistics

- **26** total presentations (24% increase from HiLiftPW-1)
- Representation from **11** countries (38% increase)
- **~60%** non-US participation (50% increase)

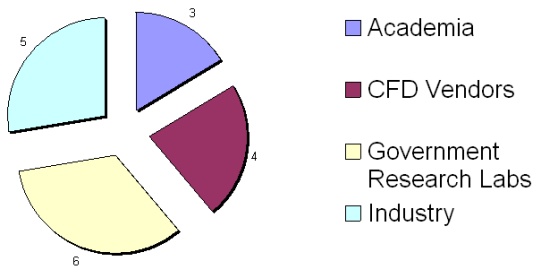


Participant Statistics (2)

- Broad participation from aerospace community
- Significant increase in participation from academia compared to HiLiftpW-1

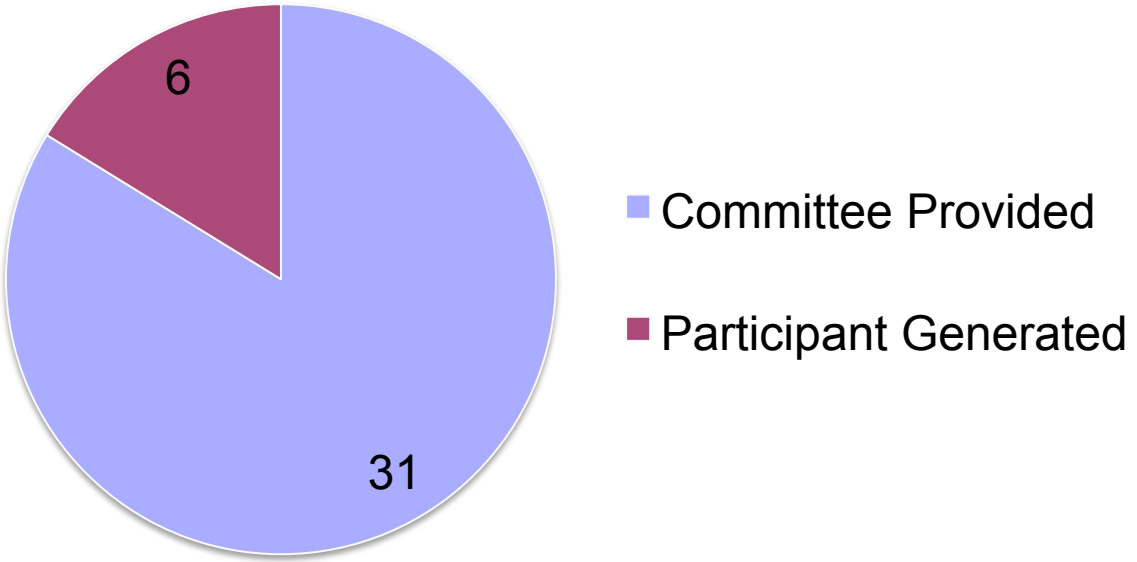


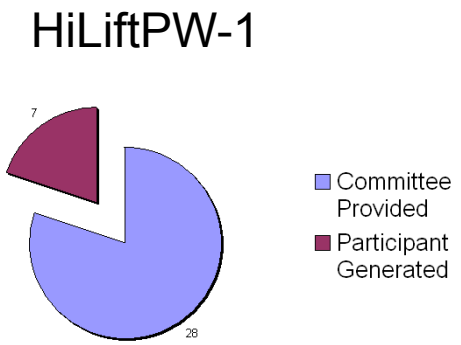
HiLiftPW-1



Participant Statistics (3)

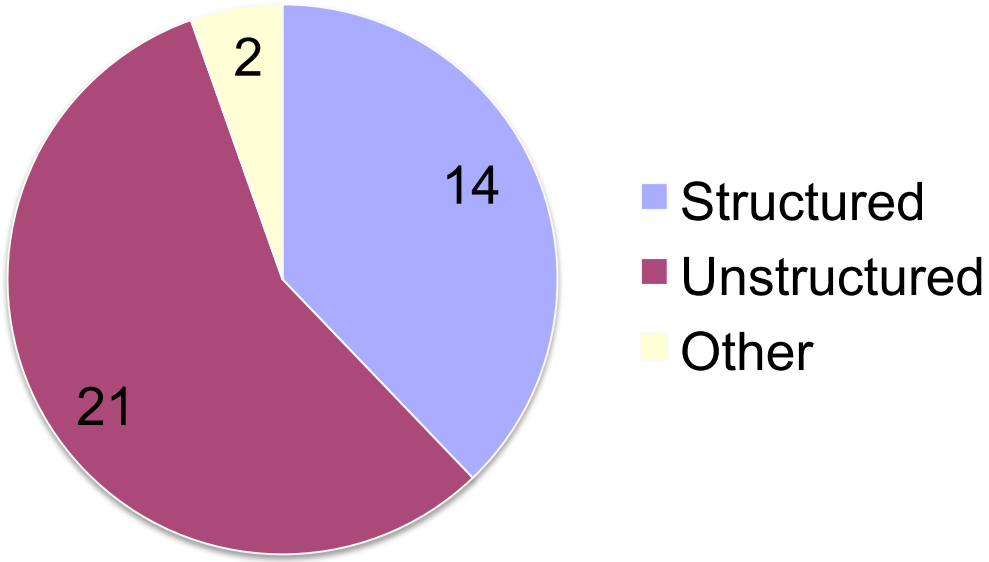
- **37** total datasets (+2 compared to HiLiftPW-1)
- Most participants used committee-generated grid systems



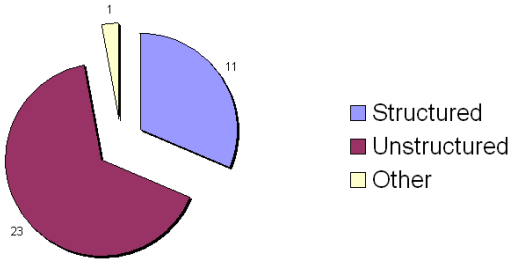


Participant Statistics (4)

- More balanced use of structured or unstructured grids compared to HiLiftPW-1



HiLiftPW-1



Outline

- Organizing Committee
- Objectives
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- Test Cases
- Agenda
- Participant Statistics
- **Grid Systems**
- AIAA Special Sessions
- Acknowledgments

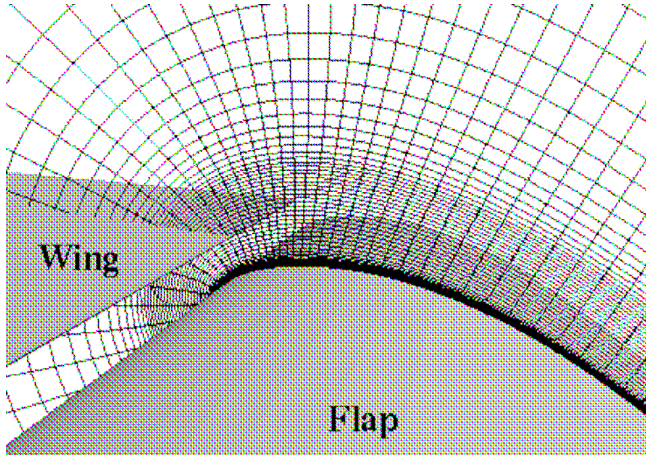
Gridding Guidelines

- Approximate initial spacing normal to all viscous walls (**Re=15.1M** based on CREF=MAC=347.09 mm):

Coarse:	y+ ~ 1.0 dy	~ 0.00055 mm
Medium:	y+ ~ 2/3 dy	~ 0.00037 mm
Fine:	y+ ~ 4/9 dy	~ 0.00024 mm
Extra-fine:	y+ ~ 8/27 dy	~ 0.00016 mm

- Same grids to be used for low Re (**1.35M**) cases
- Total grid size to grow ~3X between each grid level for grid convergence cases
  - For structured meshes, this growth is ~1.5X in each coordinate direction
- Growth rate of cell sizes in the viscous layer should be < 1.25
  - Include a region with constant cell spacing (growth rate = 1.0) to capture wakes from upstream elements
- Farfield located at ~100 C_{REF}'s for all grid levels
- For the Medium Baseline Grids:
  - Chordwise spacing for wing and tail leading edge (LE) and trailing edge (TE) ~0.1% local chord
  - Spanwise spacing at root and tip ~0.1% local semispan
  - Cell size near fuselage nose and after-body ~1.0% CREF
- Wing and Tail Trailing Edge Base:
  - Minimum of 4 cells across TE base for the coarse mesh
  - Minimum of 6 cells across TE base for the medium mesh
  - Minimum of 9 cells across TE base for the fine mesh
  - Minimum of 14 cells across TE base for the extra-fine mesh
- Be multi-grid friendly

No grid size targets specified

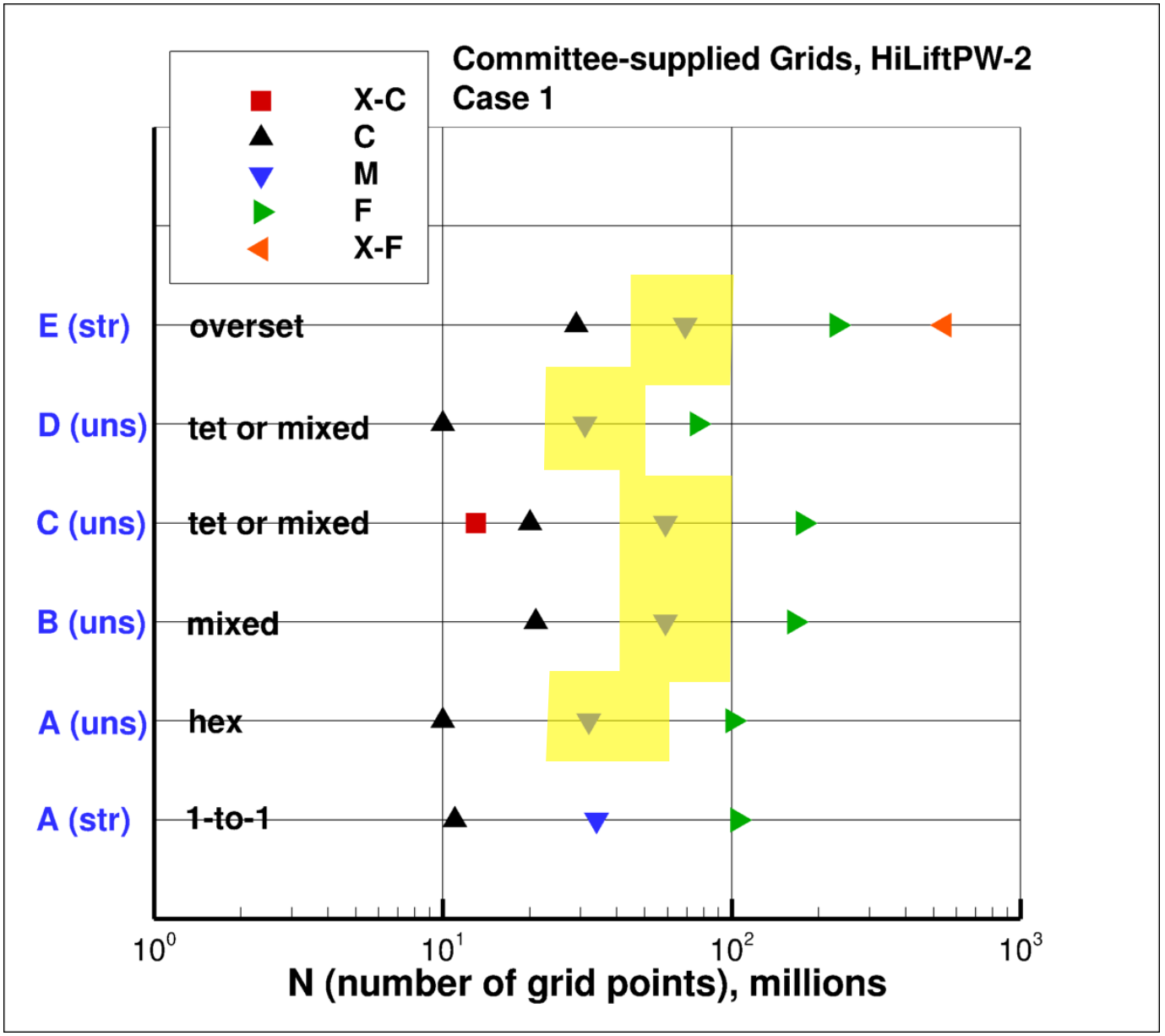


Grid Systems

Series	Type		Number of Points (M)*	Grid Level	Grid Developer (s)	Grid Tool(s)	Case 1	Case 2	Case 3
A	Structured	Point-Matched	**11**	Coarse	Boeing	ICEM	**X**		
			24	Medium					
			105	Fine					
A	Unstructured	Hexahedral	**10**	Coarse					
			32	Medium					
			101	Fine					
B	Unstructured	Mixed	**21**	Coarse	DLR	SOLAR	**X**	**X**	**X**
			59	Medium					
			165	Fine					
C	Unstructured	Tetrahedral / Mixed	**13**	X-Coarse	Pointwise	Pointwise	**X**	**X**	**X**
			20	Coarse					
			59	Medium					
			177	Fine					
D	Unstructured	Tetrahedral / Mixed	**10**	Coarse	Univ of Wyoming/Cessna	VGRID	**X**	**X**	**X**
			31	Medium					
			76	Fine					
E	Structured	Overset	**29**	Coarse	Boeing	CGT, OVERGRID, Others	**X**	**X**	
			69	Medium					
			231	Fine					
			545	X-Fine					

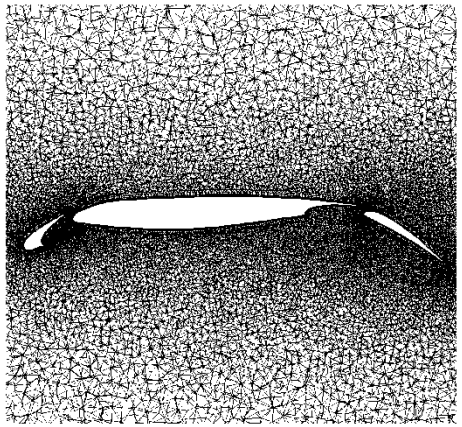
* Case 1

Grid Systems



Grid Systems

B



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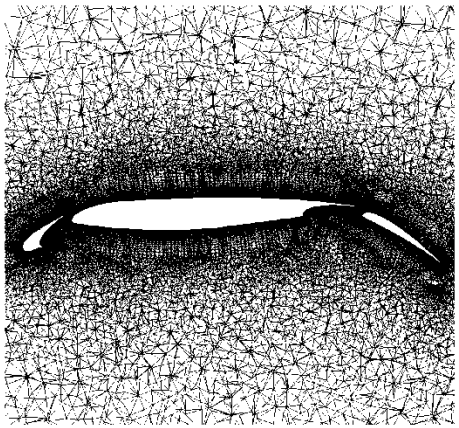

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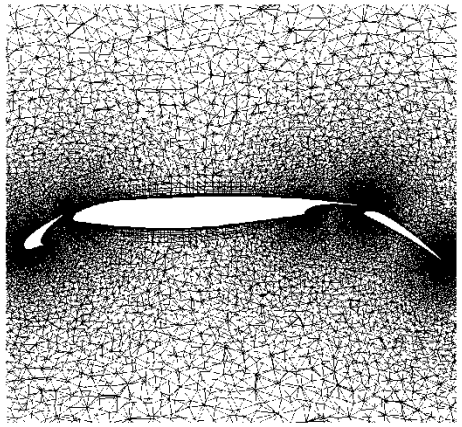

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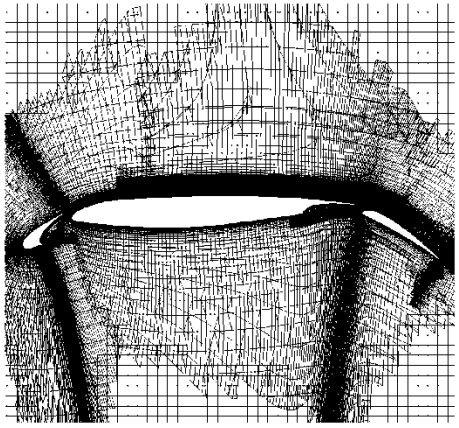
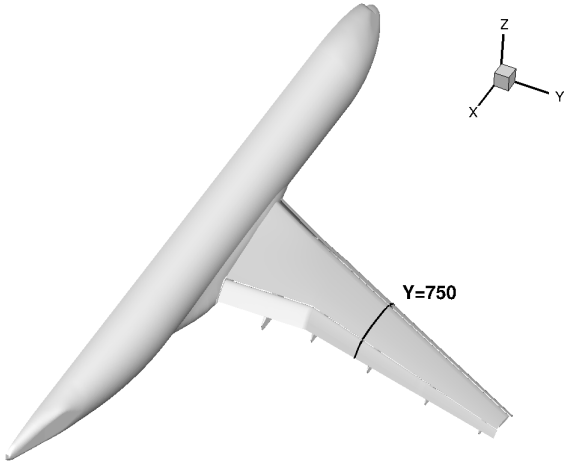
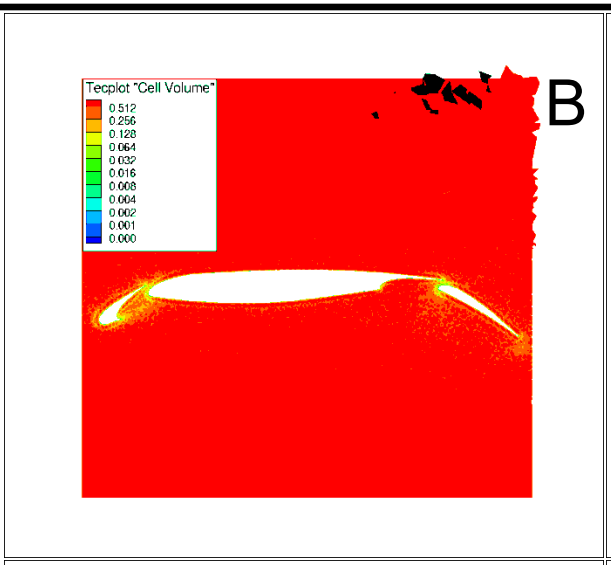


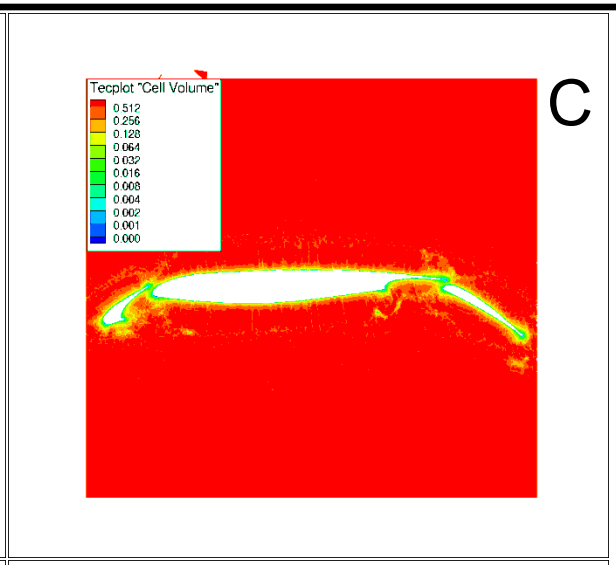
Case 2 Medium Grid
Spanwise Cut at 750mm
Wing

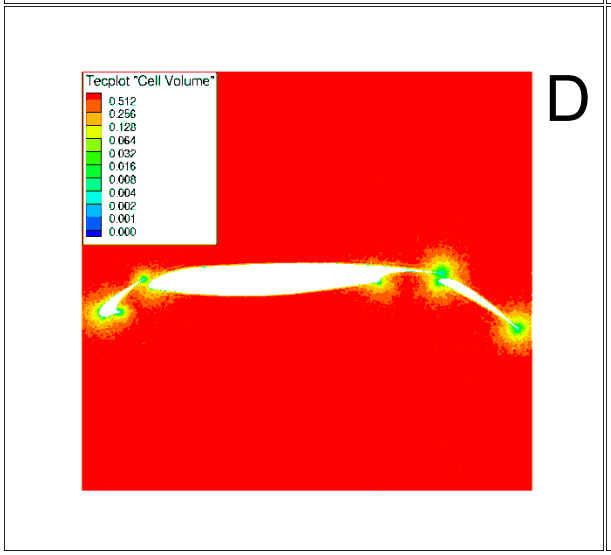


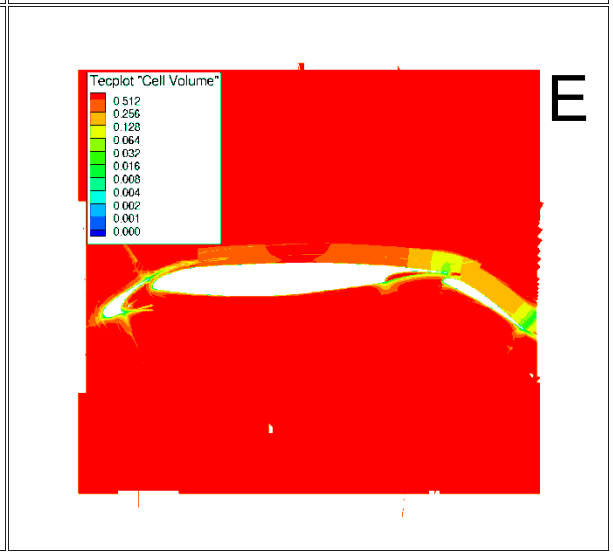
B SOLAR
C Pointwise
D VGRID
E Overset

Grid Systems



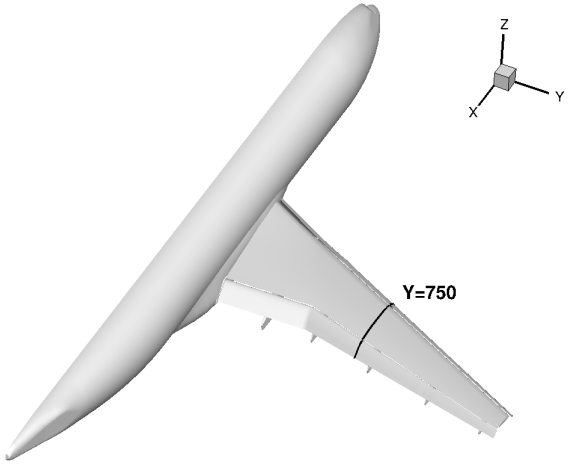






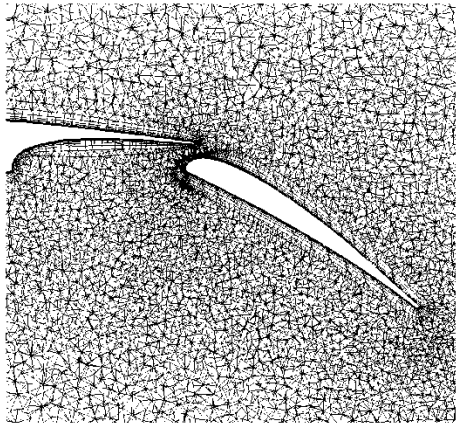
"Cell Volume" Metric

Case 2 Medium Grid
Spanwise Cut at 750mm
Wing



B SOLAR
C Pointwise
D VGRID
E Overset

Grid Systems



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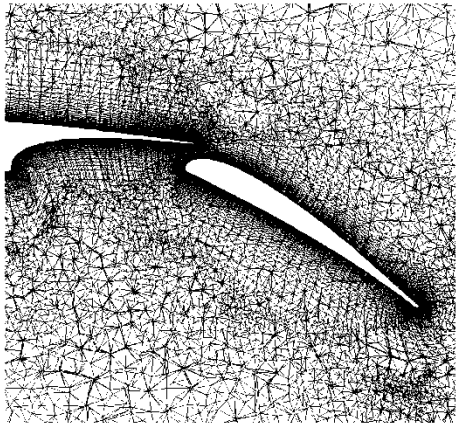

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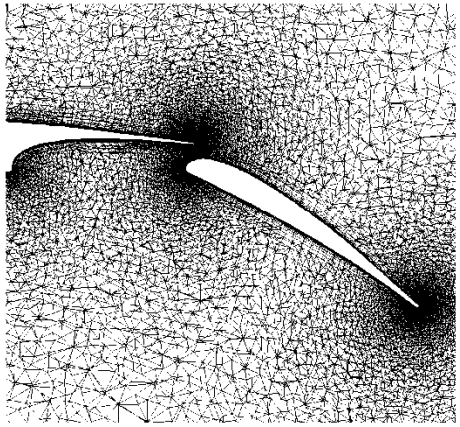

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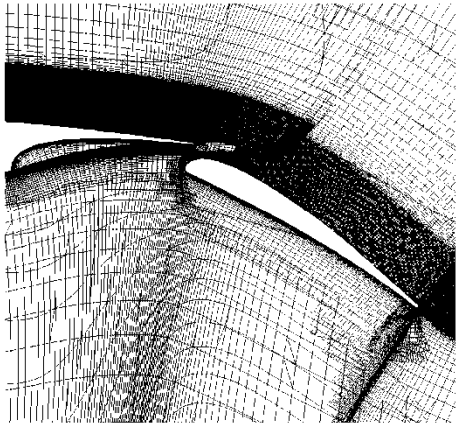
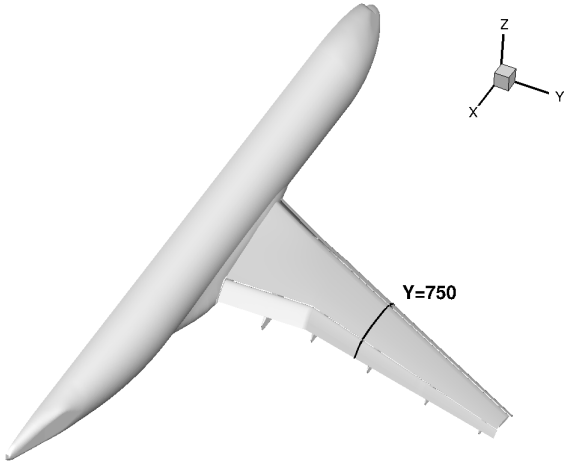


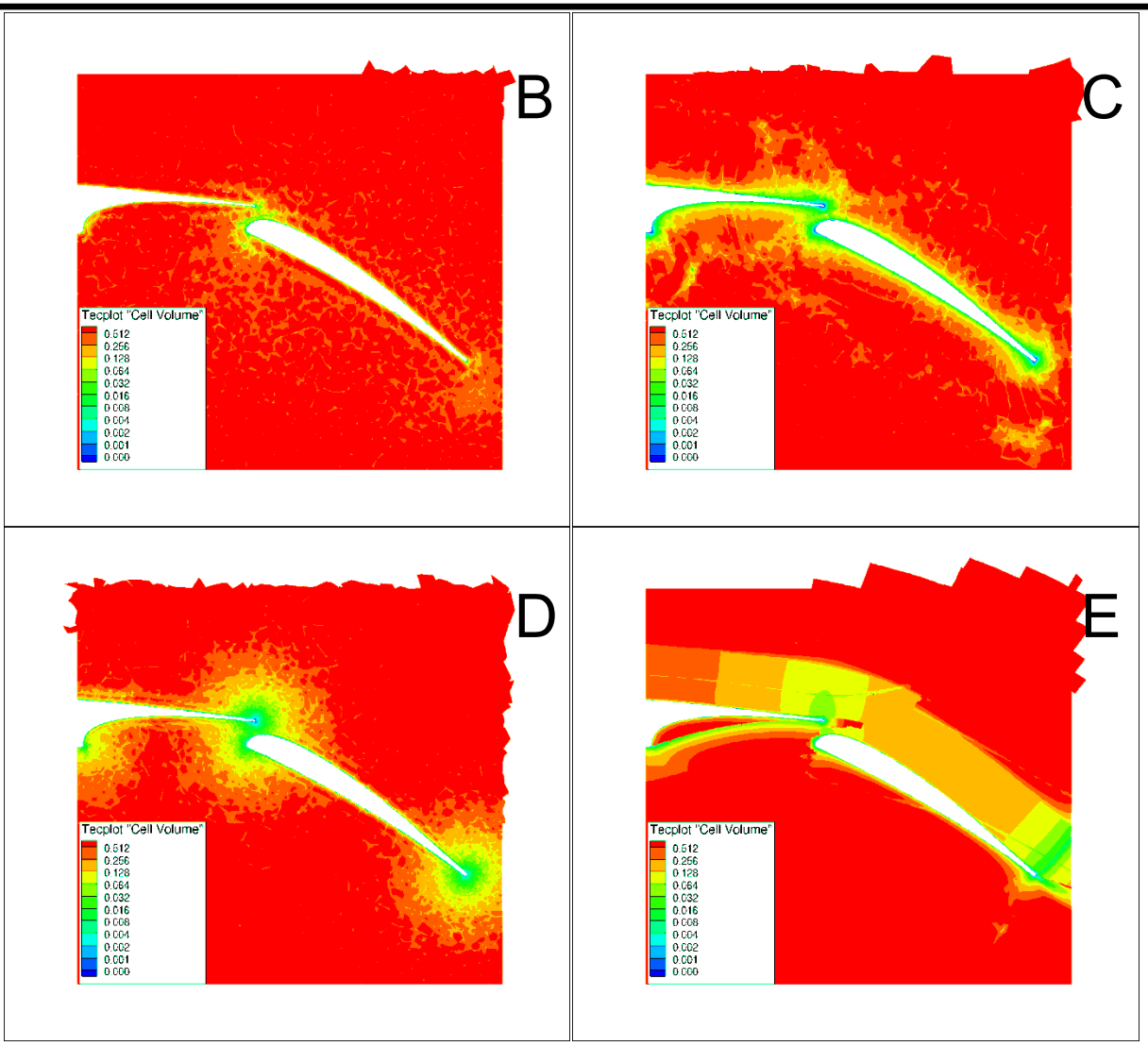
E

Case 2 Medium Grid
Spanwise Cut at 750mm Flap



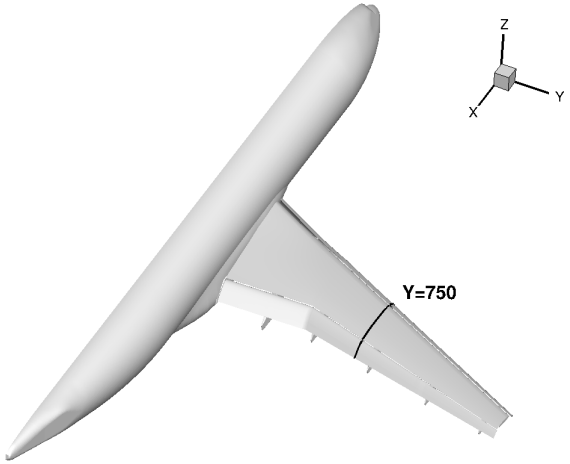
B SOLAR
C Pointwise
D VGRID
E Overset

Grid Systems



“Cell Volume” Metric

Case 2 Medium Grid
Spanwise Cut at 750mm Flap



B SOLAR
C Pointwise
D VGRID
E Overset

HiLiftPW Timeline

- **Chicago 2010** – HiLiftPW-1
  - SPECIAL SESSIONS – Orlando 2011
  - SPECIAL SESSIONS – New Orleans 2012
- **San Diego 2013** – HiLiftPW-2
  - SPECIAL SESSIONS (PLANNED) – National Harbor 2014
  - SPECIAL SESSIONS (PLANNED) – Atlanta 2014

AIAA Special Sessions

- **January 2014 (SciTech - National Harbor, MD, USA)**
  - **13 Papers + Forum** (1 six- and 1 eight-paper session)

Overview/Grid/Test Data	KTH
Univ of Wyoming	CD-adapco
CraftTech	Univ of Colorado
FOI	**Summary**
Exa	
DLR	**Forum Discussion**
Metacomp	
Polytechnique Montreal/Icube/CFS Eng	

- **Summer 2014 (APA – Atlanta, GA, USA)**
  - **14 Papers** (1 six- and 1 eight-paper session)

Intelligent Light	IIsc
NASA Langley	ONERA
Ansys	Penn State Univ
Next Limit	Texas A&M Univ
Boeing/NASA Ames	CIAM/JSC
Tata	U San Buena./U Los Andes
JAXA	
CARDC	

Acknowledgments

- **DLR**
  Stefan Melber-Wilkending
- **NASA Fundamental Aeronautics Subsonic Fixed Wing (SFW) Aerodynamics Technical Working Group (TWG)**
  Mike Rogers, Rich Wahls, Greg Gatlin
- **AIAA Applied Aerodynamics Technical Committee**
  Jim Guglielmo, Rob Vermeland, Aaron Altman, Hui Hu
- **AIAA Conference Planning Staff**
  Chris Brown, Carmela Brittingham, Megan Scheidt
- **The Boeing Company**
  Raul Mendoza, Karuna Rajagopal, Leonel Serrano, Neil Harrison, C-J Woan

Acknowledgments

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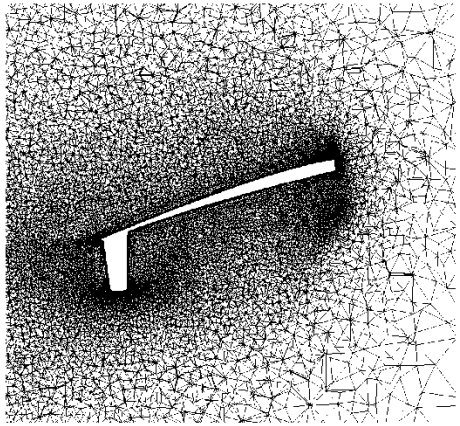
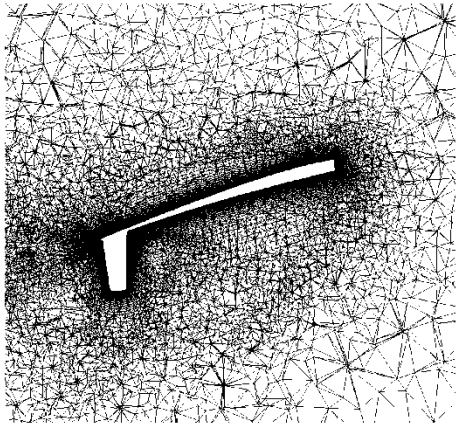
- Airbus-Germany (DASA GmbH)
- Airbus-France (Aerospatiale Matra-Airbus)
- Alenia Aeronautica
- CASA
- CIRA
- Dassault Aviation
- ETW (European Transonic Windtunnel GmbH)
- DLR
- FOI
- IBK (Ingenieurbüro Dr. Kretschmar)
- INTA
- NLR
- ONERA

* EUROLIFT was co-funded by the European Commission

Back-Up

Grid Systems


B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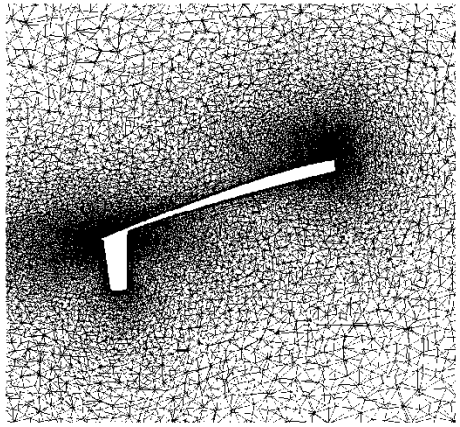
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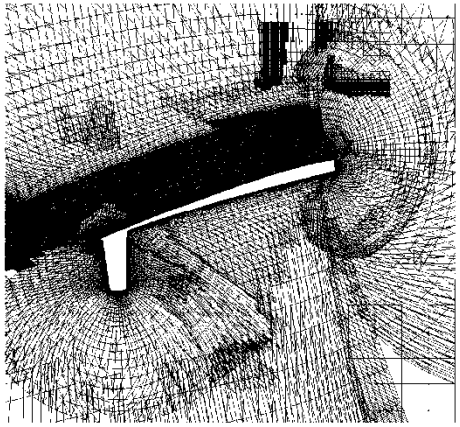
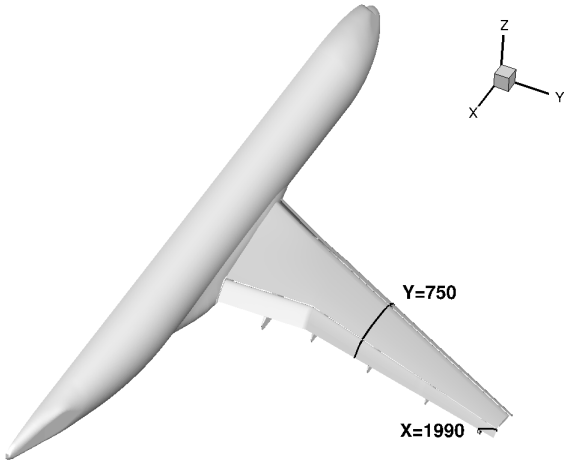
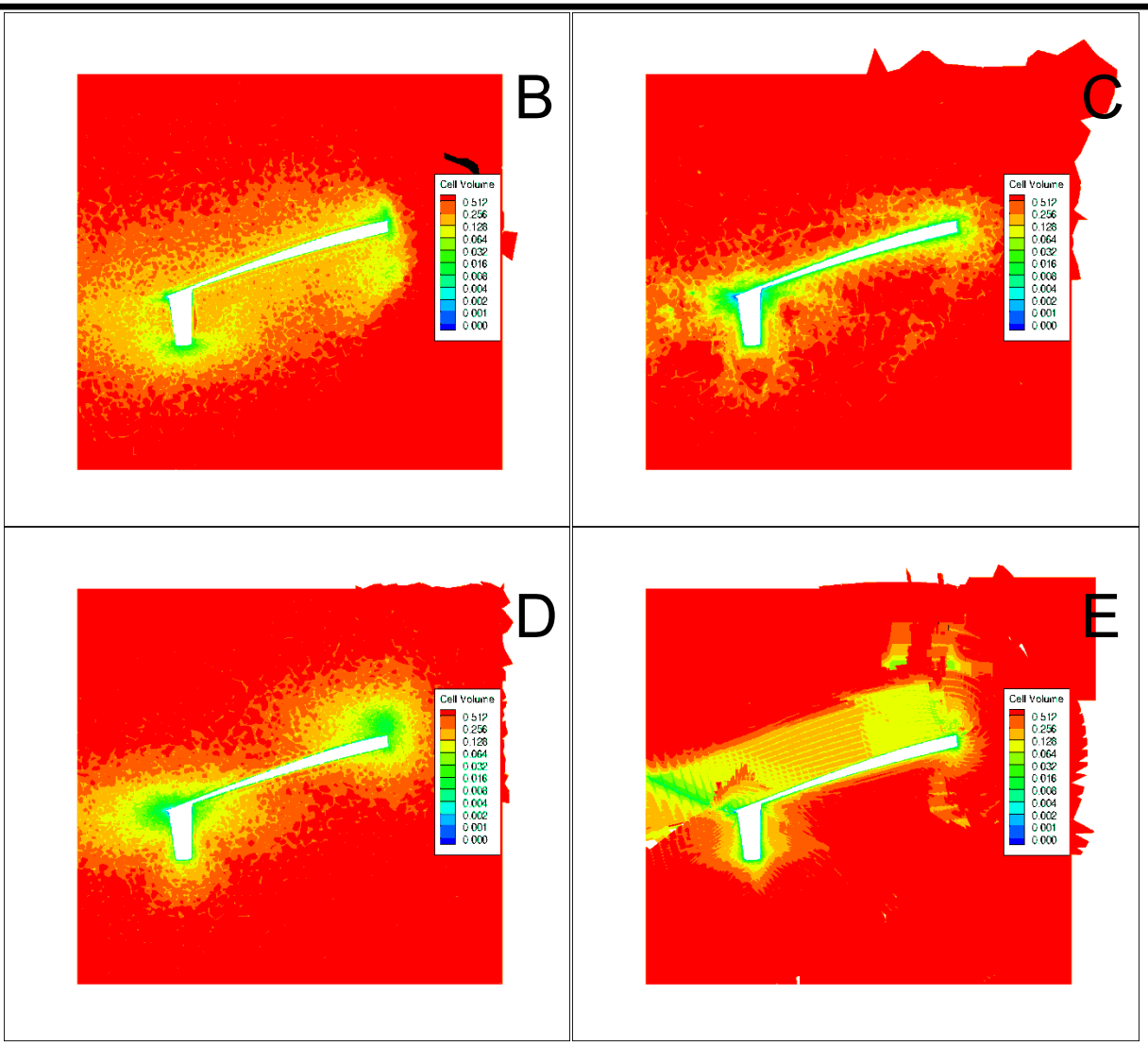

E

Case 2 Medium Grid
Cut at X=1990mm
Wing



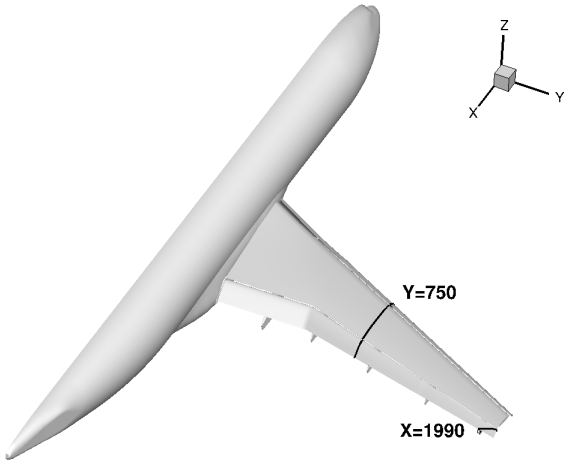
B SOLAR
C Pointwise
D VGRID
E Overset

Grid Systems



“Cell Volume” Metric

Case 2 Medium Grid
Cut at X=1990mm
Wing



B SOLAR
C Pointwise
D VGRID
E Overset