AutoCFD5 TFG:

Noise Factors

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Overview

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TFG: Noise Factors – Definition

Definition of Noise Factors

- Automotive OEMs typically define standardized „Best Practices“ which define
  - all aspects of the CFD methods used, including solver, volume mesh „design“, turbulence model, solving strategy → minimize the overall result variability
  - the choice of the CFD runtime and averaging time → minimize the statistical error

- **The Noise Factor TFG will focus on factors which have impact on CFD results but which are potentially not defined/controlled via „Best Practices“**
  - The number of CPUs used for a simulation (partitioning) → might be part of BP for some OEMs
  - Choice of the CPU-type (e.g. Intel vs. AMD)
  - Order of parts in the CAD model used to build a CFD model
  - Minor (?) surface mesh changes (e.g. relocating individual nodes)
  - Minor (?) volume mesh changes (e.g. slightly shifting the volume mesh relative to the vehicle)
  - Handling of minor (?) geometric details in the CAD model (nuts & bolts, mirror glass positions, electrical wiring, …)
  - …

TFG: Noise Factors – Things to keep in mind!

Noise Factors Studies

- Typically noise factors only have small but still relevant impact on CFD results
  - Noise factors which change the aero force predictions by a very few counts matter (1ct ≡ ΔC_D=0.001)

- To study the impact of noise factors on CFD results it is required to
  - Use a strictly applied Best Practice method which defines all aspects of a CFD method
  - Use a method which minimizes the statistical error of a CFD analysis
  - Focus on only one noise factor at a time (actively manage all other potential noise factors)

TFG: Noise Factors – Goals

1. Establish a common understanding of the relevance of noise factors
2. Establish an overview of the noise factors and quantify the impact
3. Understand CFD code to code differences in their sensitivity to noise factors
4. Investigate measures to minimize the noise factor impact
5. Provide guidance to software vendors and researches regarding the relevance of noise factors

TFG Noise Factor: Result Overview (1/2)

	Participant	Testcase			Grid		Solver		MeanCalc confirmed		Study description	Aero Force impact [cts = ΔC_D=0.001)				Result Impact - Observations
		1	2a	Other	Committee	Other	Name	Type	Yes	No		ΔC_D	ΔC_{LF}	ΔC_{LR}	ΔC_S	
CPU type	Ford (Nils Thome)		x		x		ICONCFD	FVM	x		- Running the same (identical) testcase on different types of CPUs available at Ford	0	0	0		- Only similar CPUs from one vendor have been investigated
	Skoda		x		x		StarCCM+	FVM		x	Running a case on a different CPU type (AMD vs Intel). ACFD4 mesh, fixed averaging from 2 s to 8 s. 10 tries in total for various settings: Always comparing the difference between a noise factor (change of HW) influenced run and a default run for various distinctive settings such as time step change.	2.8	n.a.	n.a.	n.a.	Very limited scope compared to other noise factors tried. Still, the maximum impact is similar, as expected.
	3DS Simulia		x		x	x	PowerFLOW	LBM			- Investigation of CPU/GPU effect with several surface mesh approaches					
	Bramble (Matheus Marques)										- steady state					
											Maximum Noise Factor impact on Aero forces:	2.8	0	0	0	
# of CPUs / Partitioning	Ford (Nils Thome)		x		x		ICONCFD	FVM	x		- Running the same (identical) testcase on different # of CPUs available at Ford (always on the sme type of CPU)	2	2	2		- Visible surface pressure changes (ΔCp ~ 0.01)
	3DS Simulia		x			x	PowerFLOW	LBM	x		- Reference 2a case, simulated with different CPUs number (same architecture Skylake) 400 vs 320. Standard 3DS Best Practice stop criteria: 1.0ct Cx accuracy @90% Confidence Level with powerFLOW monitor.	0.1	0.4	1.4	0.5	- Differences contained in the accuracy prescribed for Cx. Only Cz2 is higher. '- Differences reduces drastically with tighter accuracy hence longer simulation time (except for Cs).
	3DS Simulia		x			x	PowerFLOW	LBM	x		- Reference 2a case, simulated with different CPUs number (same architecture Skylake) 400 vs 320. Tighter stop criteria: 0.5ct Cx accuracy @90% Confidence Level with powerFLOW monitor.	0.2	0.2	0.1	0.9	- As differences reduce with longer simulation time, the effect seems more related to the transient inherit uncertainty than to CPU number. - No big changes in surface values over the vehicle and only small differences in the more unsteady flow region seems to confirm the
	3DS Simulia		x			x	PowerFLOW	LBM	x		- Reference 2a case, simulated on 2 GPU (NVidia H100) Simulation stop criteria: 1.0ct Cx accuracy @90% Confidence Level with powerFLOW monitor.	0.4	0.6	1.6	2.8	- Differences contained in the accuracy prescribed for Cx. Only Cz2 is higher. - Differences reduces drastically with tighter accuracy i.e. longer simulation time.
	3DS Simulia		x			x	PowerFLOW	LBM	x		- Reference 2a case, simulated on 2 GPU (NVidia H100). Tighter stop criteria: 0.5ct Cx accuracy @90% Confidence Level with powerFLOW monitor.	0.1	0.1	0	0.6	- As differences reduce with longer simulation time, the variations seems more related to the transient inherit uncertainty rather than to
	Numeric Systems (E. Riegel)		x			x	Pacefish	LBM	x		- Running the same (identical) testcase 2a using using 3 instead of 4 GPUs	0.4	0.5	0.7	0	All deltas are below one count. Due to constrains the mesh on 3 GPUs is slightly different at the interfaces form the 4 GPUs' mesh. Pacefish supports a flag to implement "Decomposition Independent Refinement" which achieves similar mesh regardless of number and size of subdomains. However, this mesh deviates from the refinement definition at many locations (in favour of the finer regions).
	Skoda		x		x		StarCCM+	FVM		x	Running a case using a different number of CPU cores (same HW). ACFD4 mesh, fixed averaging from 2 s to 8 s. >40 tries in total for various settings: Always comparing the difference between a noise factor (change in number of CPU cores) influenced run and a default run for various distinctive settings such as time step change.	2.4	n.a.	n.a.	n.a.	The maximum impact is similar to using other noise factors.
	Skoda		x		x		StarCCM+	FVM		x	Running a case using different partitioning (saving a file using different CPU count, then running the simulation using one universal CPU count). ACFD4 mesh, fixed averaging from 2 s to 8 s. >10 tries in total for various settings: Always comparing the difference between a noise factor (change in partitioning) influenced run and a default run for various distinctive settings such as time step change.	2.5	n.a.	n.a.	n.a.	The maximum impact is similar to using other noise factors.
	Siemens		x	x		x	Simcenter STAR-CCM+	FVM		x	- running identical test cases (2a, 2b) on different # of CPUs and timestep convergence criteria x - impact number given for best converged case that was investigated	0.1	-	-	-	- we could not get rid of partitioning dependence on results - better convergence results in more statistically similar signal
											Maximum Noise Factor impact on Aero forces:	2.5	2	2	2.8	
Operating Condition	Skoda		x		x		StarCCM+	FVM		x	Running a case with different inlet velocity (change at third dec.place). ACFD4 mesh, fixed averaging form 2 s to 8 s. >20 tries in total for various settings: Always comparing the difference between a noise factor (change in inlet velocity) influenced run and a default run for various distinctive settings such as time step change.	3	n.a.	n.a.	n.a.	The maximum impact is similar to using other noise factors.
	Skoda		x		x		StarCCM+	FVM		x	Running a case with different density (change at third dec.place, incompressible solver). ACFD4 mesh, fixed averaging form 2 s to 8 s. >20 tries in total for various settings: Always comparing the difference between a noise factor (change in density) influenced run and a default run for various distinctive settings such as time step change.	2.2	n.a.	n.a.	n.a.	The maximum impact is similar to using other noise factors.
	Ford															
											Maximum Noise Factor impact on Aero forces:	3	0	0	0	

TFG Noise Factor: Result Overview (2/2)

Observations:

- Multiple types of noise factors can have a significant 2 - 4 ct impact on C_D predictions!!
- Noise Factors have to be carefully considered when applying CFD in automotive aerodynamics.

ATTENTION:

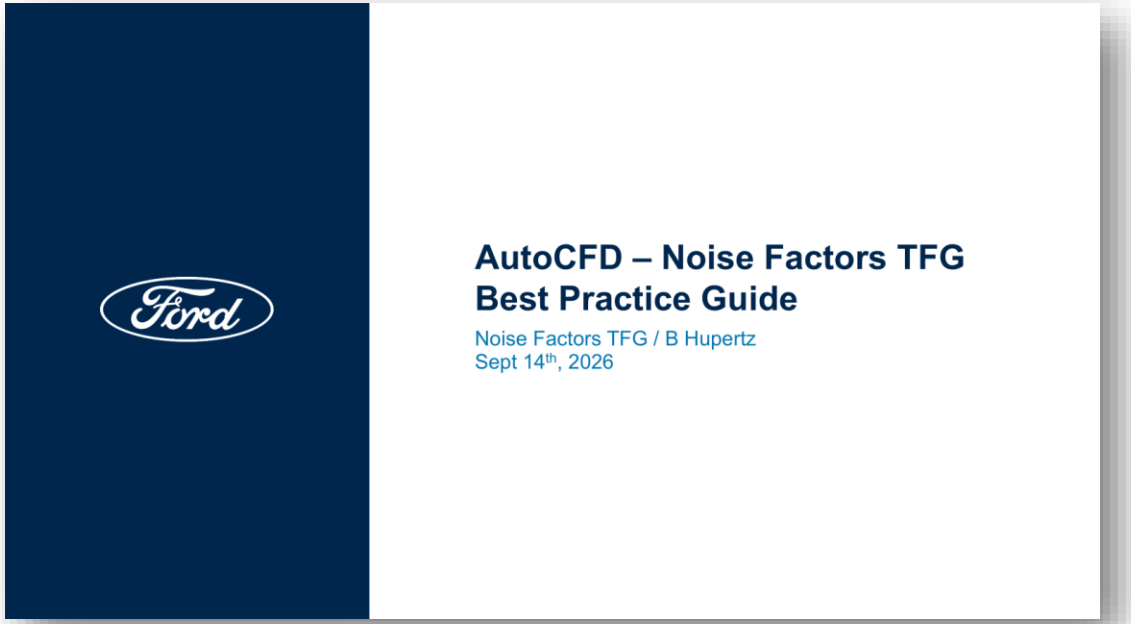
- There is evidence that noise factors can have a significantly larger impact on vehicles which are aerodynamically very sensitive/instable.

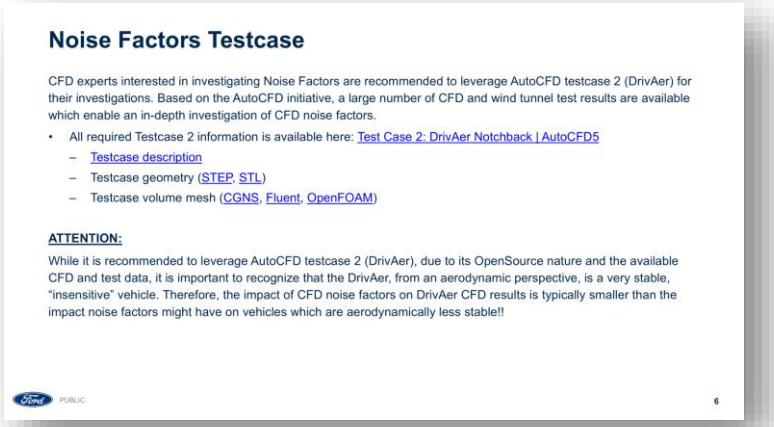
	Aero Force impact [cts = ΔC_D=0.001)			
	ΔC_D	ΔC_{LF}	ΔC_{LR}	ΔC_S
CPU type	2.8	0	0	0
# of CPUs / Partitioning	2.5	2	2	2.8
CFD Method inherent	3	0	0	0
Operating Condition	1.8	0	0	0
Initialization	3.2	2	2	0
CAD part ordering	1.3	0	0	0
Surface mesh	1.5	3	5.1	1.7
Volume mesh	(6)/2	8	5	5
Geometric details	4	18	2	4

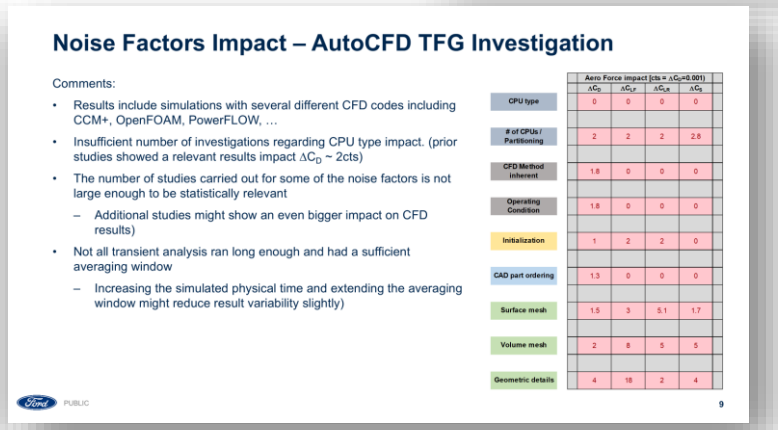
TFG: Noise Factors – Best Practice Guide

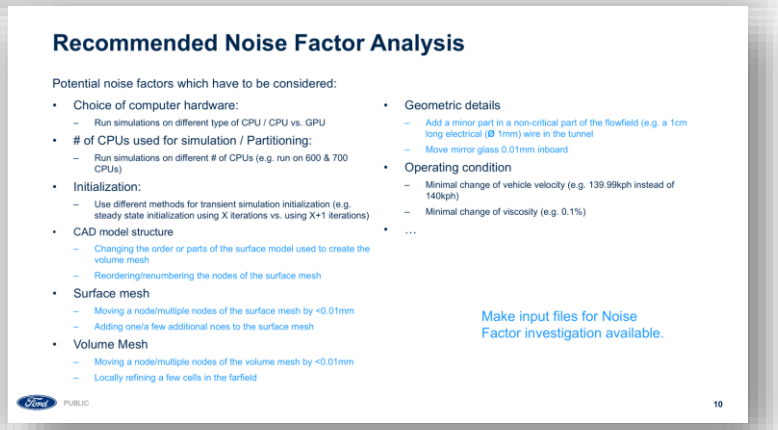
Purpose of Best Practice Guide

- Summarize outcome of TFG studies
- Identify relevant Noise Factors
- Quantify potential impact of Noise Factors
- Provide guidance how to investigate Noise Factors
- Provide access to test cases

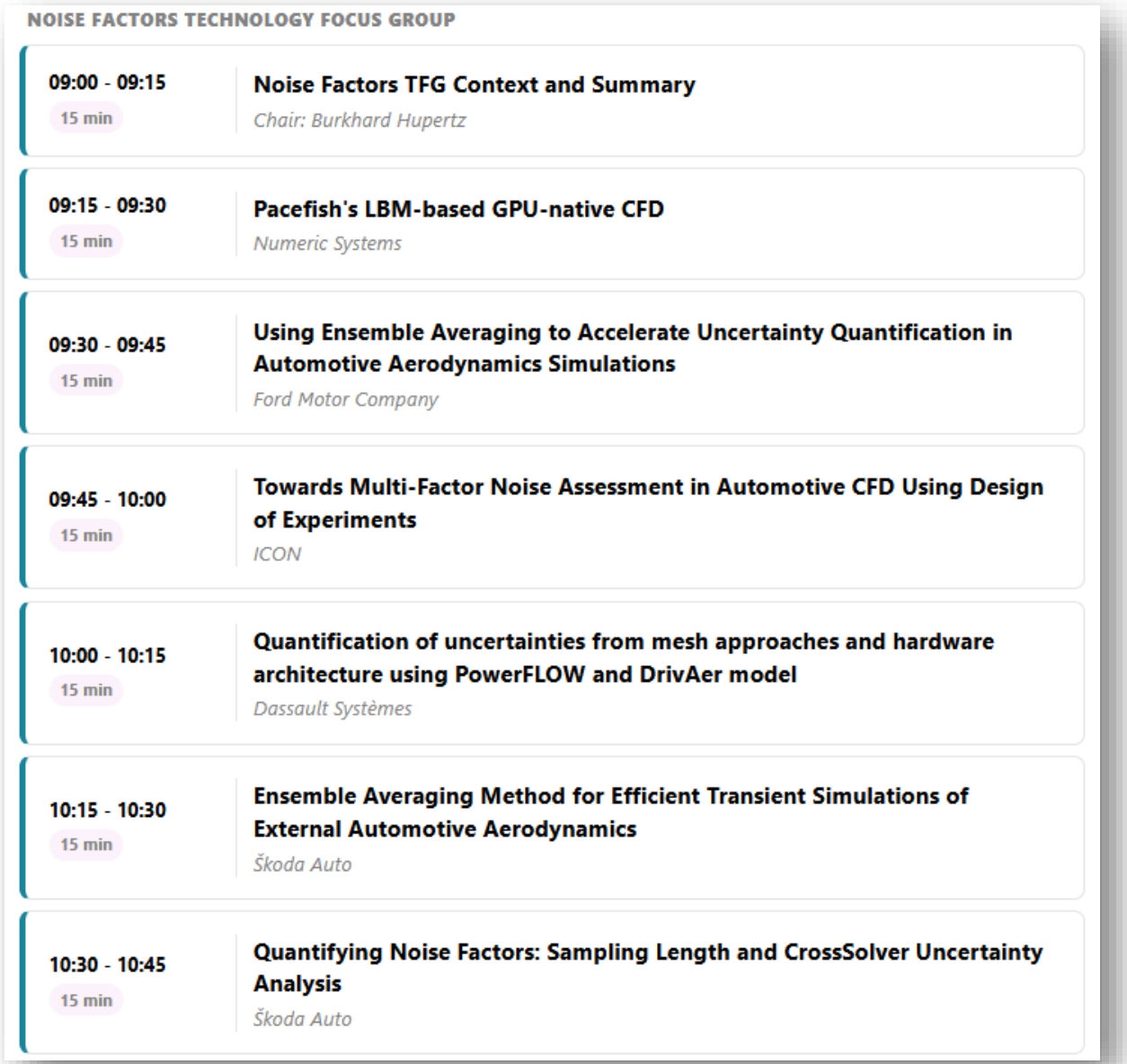








TFG: Noise Factors – Session Agenda



NOISE FACTORS TECHNOLOGY FOCUS GROUP

09:00 - 09:15	15 min	**Noise Factors TFG Context and Summary** *Chair: Burkhard Hupertz*
09:15 - 09:30	15 min	**Pacefish's LBM-based GPU-native CFD** *Numeric Systems*
09:30 - 09:45	15 min	**Using Ensemble Averaging to Accelerate Uncertainty Quantification in Automotive Aerodynamics Simulations** *Ford Motor Company*
09:45 - 10:00	15 min	**Towards Multi-Factor Noise Assessment in Automotive CFD Using Design of Experiments** *ICON*
10:00 - 10:15	15 min	**Quantification of uncertainties from mesh approaches and hardware architecture using PowerFLOW and DrivAer model** *Dassault Systèmes*
10:15 - 10:30	15 min	**Ensemble Averaging Method for Efficient Transient Simulations of External Automotive Aerodynamics** *Škoda Auto*
10:30 - 10:45	15 min	**Quantifying Noise Factors: Sampling Length and CrossSolver Uncertainty Analysis** *Škoda Auto*

Appendix



Turn Around
Automotive Operations



Modernize
Everywhere



Disrupt
Ourselves

Ford