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ONERA
THE FRENCH AEROSPACE LAB

Introduction

User day OpenTURNS

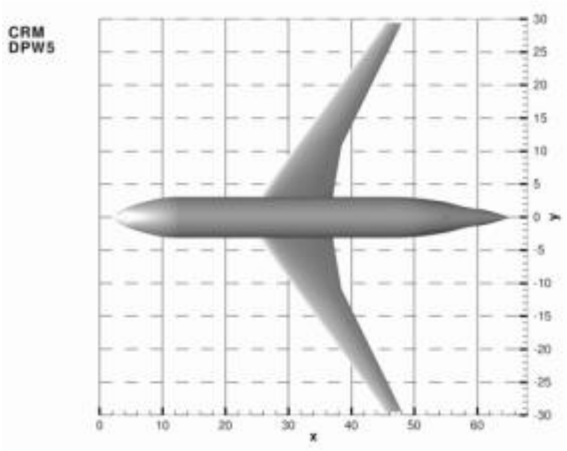
Laurent Cambier
Scientific director « Advanced Numerical Simulation »

UQ and CFD
UQ and aerospace

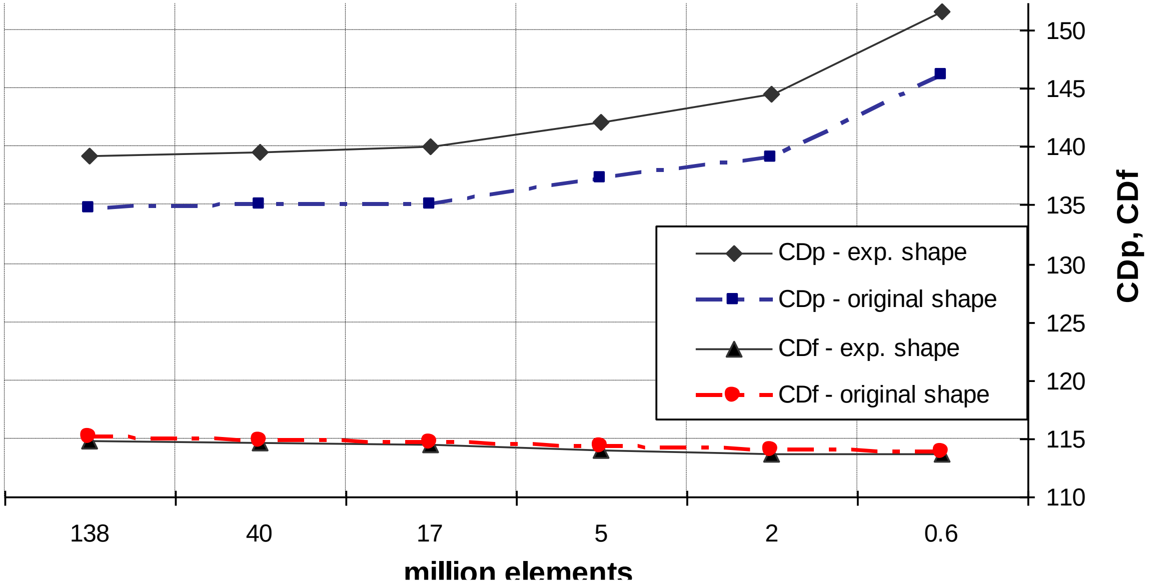
NASA CFD Vision 2030 Roadmap (defined in 2013)

- CFD workflows contain considerable uncertainty that is often not quantified.
- Many sources : geometry, grid resolution, flow modeling, boundary conditions, residual convergence…
- Although NASA and professional organizations such as ASME and AIAA have created standards for the verification and validation of CFD analyses, such techniques are not widely used in the aerospace industry
- While uncertainty quantification is being investigated in the broad research community, most notably through DOE and NSF led programs, the engineering community, and the aerospace community in particular, have had minimal investments to address these issues.
- Engineering judgment, conservatism into decision-making

Drag Prediction Workshop
elsA results

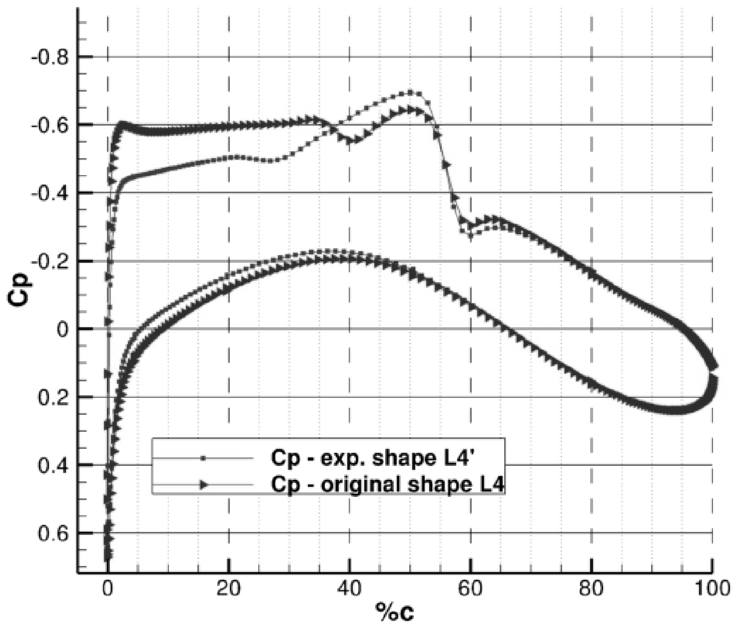


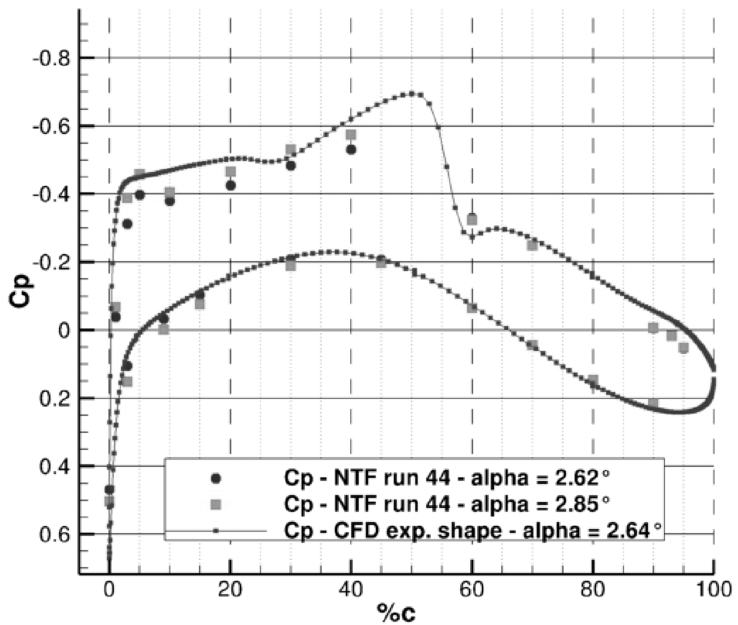
- Wing-Body CRM configuration of DPW5 :
-M = 0.85 ; C_L= 0.5 (± 0.001) ; Re = 5 10^6
- Deep refinement study
-from the tiny L1 multi-block grid (638,976 cells)
-to the super-fine L6 multi-block grid (138,018,816 cells)
- Mesh deformation aimed at matching the experimental wing twist → new grids named L1' to L6'
- RANS computations from Onera Applied Aerodynamics Department : Jameson scheme, backward Euler with implicit LU-SSOR relaxation, Spalart-Allmaras model
- Convergence criterion : lift variation less than 0.001 and drag variation less than 1 drag count over the last 1,000 iterations



Drag Prediction Workshop
elsA results

- **Pressure distribution (95% wingspan slice) agreement significantly improved by the wing twist correction ("experimental shape")**





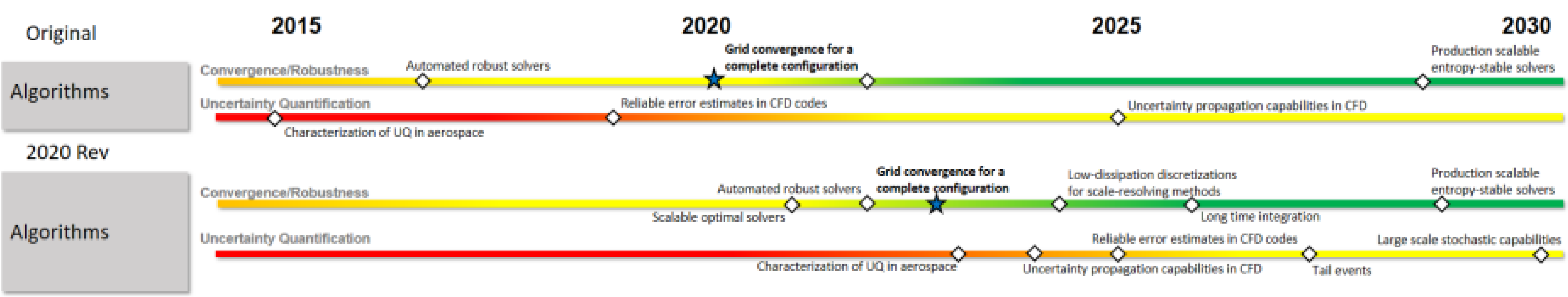
- **Numerical drag value obtained with *elsA* and Onera drag extraction software ffd72 of 247.7 drag counts, very close to the experimental value from NTF (248 drag counts).**

→ Uncertainty reduction, but still uncertainty !

CFD Vision 2030 Roadmap : 2020 Status

- « Increases in penetration of UQ have been made since the publication of the Study **but it is not yet standard in the aerospace CFD industry** »
- 2016 : The JANNAF (Joint Army-Navy-NASA-Air Force) Simulation Credibility Guide on Verification, Uncertainty Propagation and Quantification, and Validation (530 p.)
- 2016: Fluid Dynamic Best Paper for Barth’s overview of application of uncertainty estimates to CFD computations
- « The community is still limited. »

« Efforts are underway to increase fluid dynamic community awareness of UQ »



Aerospace context

• Deep understanding of complex physical systems (*icing, lightning risk, buffeting, stall…)* often limited due to the presence of uncertainties (*models, parameters, operational environment, measurements*…).

• In aerospace industry, « deterministic margins » often defined to take into account the approximations of numerical simulations and to guarantee robustness and reliability of the system while ensuring a minimal performance

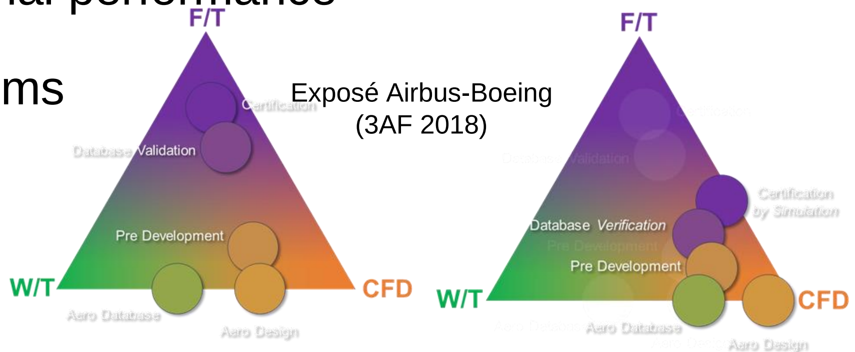
- Evolution in the design of aerospace systems

– Introduction of breakthrough technologies

– New constraints to consider

– Numerical simulation in increase

… and breakthrough configurations



Exposé Airbus-Boeing (3AF 2018)

Configuration DRAGON @ONERA

- Need to rely on a mathematical framework ***(*)*** to improve :

- the characterization of complex physical phenomena
- the design of systems by a stochastical approach

In stake : safety, competitiveness

(*) Experience and instinct are poor substitutes for careful analysis of uncertainty (JANNAF G.)

Examples of UQ problems at ONERA

Strategic challenges for coming years :

- To provide with a confidence measurement in the estimation of the aero-propulsive performances of an hypersonic vehicle (ramjet propulsion) taking into account uncertainties of multiphysics modeling (such as modeling of the atmosphere, modeling of the propulsive performances)
- To decarbonize aeronautics: to take into account and to propagate modeling uncertainties in the estimation of the environmental impact (radiative forcing) due to the emissions from transport aircraft (such as uncertainties of atmospheric modeling, of emissions predicted by CFD simulations)
- To model composite material laws from experimental data taking into account test uncertainties (such as material variability)
- To quantify and master the uncertainties is essential for the objectif of certification of numerical simulation tools and designed systems → could open the way to a change of paradigm compared with the present regulation approaches (for instance, electromagnetic certification of aircraft)

UQ at ONERA

Dynamics relying on a small kernel of UQ experts and engineers sensible to uncertainties

– Specialists in uncertainties
  (mostly in the LMA2S, the Applied Maths Lab of ONERA)
– Several applicative studies
  (materials, optics, aerodynamics)

Need of a better diffusion of the UQ culture inside ONERA

→ Two training sessions (15p. each) ⟶

→ Project under preparation at ONERA with the following objectives :

- To develop, structure and disseminate the UQ methods focusing on ONERA studies around advanced numerical simulation and experiments
- To capitalize methodologies and know-how
- To involve the 7 départments of ONERA to deal with future challenges in the three domains : aeronautics, space and defense

ORION

ONERA's platform for numerical simulation

pyCGNS

Modules partagés

- Assimilation données
- Propagation d'incertitudes
- …

ASTRE
Rayonnement

CHARME
SEG-Energétique

SPIREE
Particules, Eulerien

Z-set
Thermomécanique

Paradigma
Découpage/agglo.
Distance à la paroi
Interp., projection

Cassiopée
Pré-traitement
Post-traitement
Maillage

PaelaR
Algèbre linéaire

Thermolib
Bibliothèque thermodynamique

SPARTE
Particules, Lagrang.

Taranis
Plasma

elsA-SoNICS
Aérodynamique

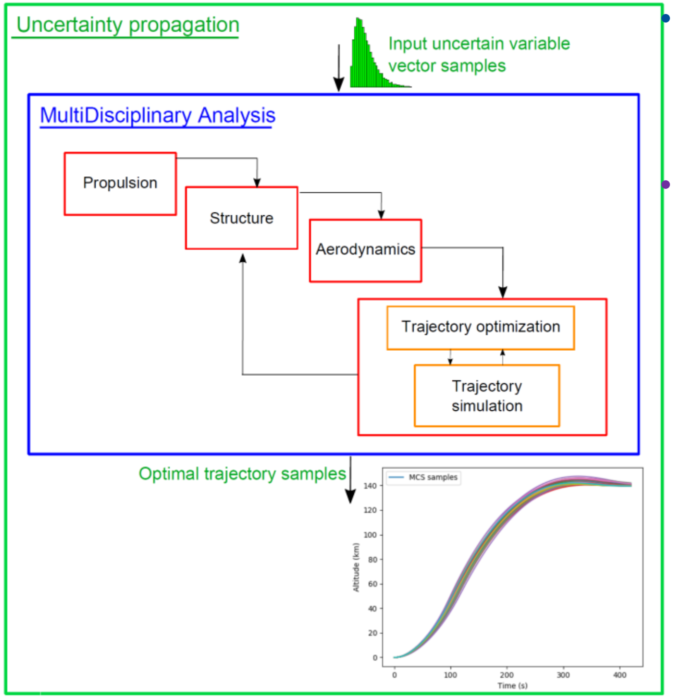
Maxwell 3D
Électromagnétisme

« Socle commun » partagé avec la plateforme Safran mosaic

Concluding remarks

- ONERA very pleased to have joined the OpenTURNS consortium in 2019
  - Community of researchers develop. and using recent advances for real-world applis
  - Integration in OpenTURNS of methods and algorithms developed at ONERA
  - OpenTURNS : model of capitalisation
- Still a challenge today to go from demonstration to current practice, from kernel of specialists to all who need UQ
- Future of aerospace requires to rely on a solid framework including UQ.
- ONERA as the national research establishment in the field has to lighten the future and to convince industry partners to increase their interest in UQ
- Huge progress of HPDA architectures
- OpenTURNS consortium, GIS LARTISSTE and ONERA project both in preparation, is / should be powerful contributions to the success.

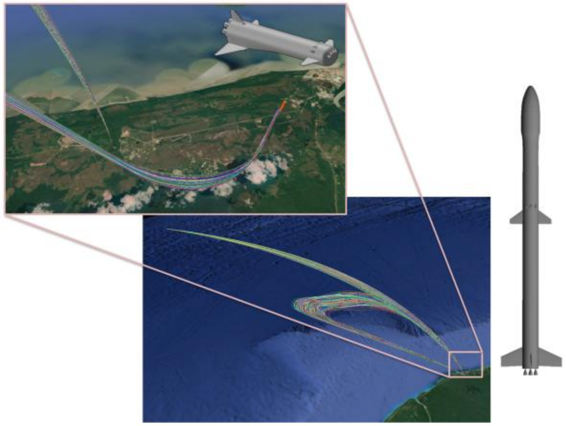
Estimation of flight envelopes of launch vehicles

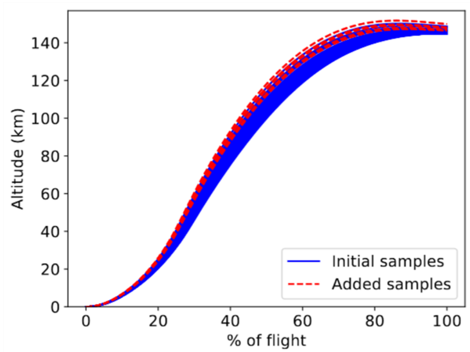


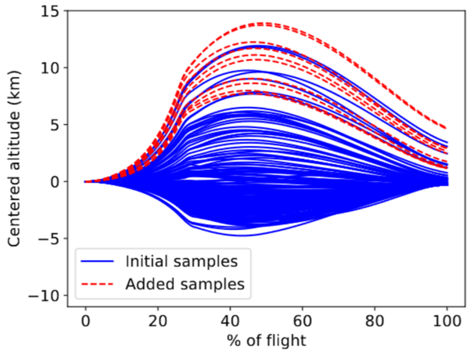
- Characterization **of flight envelopes of launchers under uncertainties by estimation of quantiles**

- Methodology based on combination of model reduction (Karhunen-Loève) and Gaussian process

- Devel. of an **adaptive enrichment strategy**
  → adaptive selection of CPU-costly multidisciplinary simulations to improve the accuracy of the estimation of quantiles







« HPC SATOR Grand challenges for young scientists » (November 2021)
→ 6×10^5h CPU on 4500 cores, use of OpenTURNS

Even if the world is full of uncertainties,
I have no doubt that you are going to attend
a very exciting OpenTURNS User Day !

Bonne journée à tous !