Challenges and Opportunities for CFD at ONERA

Presented by Vincent Couaillier

Safer and cheaper aircrafts require new concepts and increasingly complex physical and numerical modeling, integrating the multi-physics interactions of aerodynamics, propulsion, structures and materials. These new models have to be carefully validated in order to reduce testing and associated development costs as well as certification costs. Within this framework, a main challenge of CFD at ONERA for the horizon 2020/2030 is to develop a global simulation strategy associating software components, based on high-quality modeling, chained or coupled, validated by experiments at all scales, relying on very high performance computing capabilities.
Today, *elsA* for fluid mechanics, Cedre for combustion, aero-thermal and aero-thermo-mechanics, Sabrina, Space for aeroacoustics, are all strategic software tools for ONERA and its industrial partners. They capitalize on expertise in simulation and physical modeling validated by ONERA's multi-level experimental potential.
ONERA is also preparing the future by developing a set of robust, reliable and innovative physical and numerical models, as well as methodologies for building and steering coupled, multi-physics, multi-model and multi-scale simulations, which can be integrated into easy-to-use modeling systems adapted to large computing machine architectures.
These new methods will be gradually integrated into future multi-physics platforms and made available to aerospace industry. Among these methods we can mention the Aghora HPC software prototype based on high order adaptive discontinuous Galerkin methods and the FAST HPC software prototype based on optimized programming of finite volume methods on advanced parallel architectures.

This context leads ONERA to identify priorities for the 2020/2030 ONERA roadmap, listed below, which will be presented at the workshop and illustrated by first demonstrative results :
<u>Integrate CFD platforms for research and industry</u> : A major objective concerns the development of a software architecture with interoperable components, coupling ONERA codes as well as external partner modules, for multidisciplinary simulations, dealing with a large number of advanced configurations. This architecture will integrate adjoint approaches necessary for optimization and assimilation.
<u>Take into account geometric complexity with high accuracy</u> : For the meshing process of more and more detailed configurations, development of a structured/unstructured hybrid solver for aerodynamics integrating high-order representations via finite element methods with different levels of turbulence modeling.
<u>Manage errors and uncertainties for the introduction of CFD into certification processes</u>
The verification and validation processes of codes must be more automatically integrated into the development process of high level software, with high quality error estimation, development of uncertainty propagation methods. This should also include exploitation of wind tunnel tests, in collaboration with industry, to quantify uncertainties and biases due to operational and geometrical parameters.
<u>Develop and validate multi-physics and multiscale models</u>
The development of high quality predicting tools requires reliable multi-physics and multiscale methods. In the mean-term, hybrid RANS / LES simulations on complete components (such as an aircraft engine, from the air intake to the exhaust up to the contrails), based on interface standards for code coupling using various mesh topologies, will be developed and assessed on HPC environments.
<u>Leverage experience-simulation coupling beyond validation</u>
Assimilation processes and algorithms will be developed for the hybridization of experiment with CFD in order to refine the understanding of flows, regularize the measurements and make them more exhaustive, up to the production of aerodynamic data representative of the model in flight.
<u>Manage exaflopic for advanced numerical simulations</u>
Prepare the arrival of exaflopic machines by optimized algorithms on efficient parallel and heterogeneous architecture including the use of accelerators as GPU, in the framework of close cooperation with computer manufacturers and of access to large national and European infrastructures.