USE CASES

McLaren front wing

The McLaren front wing combines the challenge of modelling both highly separated and turbulent flows around a complex industrial geometry. We aim at correlating simulation results to experimental, and track data. Based on the McLaren 17D, this geometry is representative of one of the major points of interest in Formula 1 Aerodynamics, namely the interaction of vortical structures generated by the front wing end-plate with the front wheel wake.
CODE USED: Nektar++

Wing profile NACA4412

In addition to the high-Reynolds-number turbulent wall-bounded flow, the compressible variant includes laminar separation, vortex shedding and sound generation from the trailing edge. Set up in the context of the development of a "virtual wind tunnel", the NACA4412 wing section constitutes an ideal platform to test high-order spectral methods in simulations of turbulent flows around geometries of industrial interest.
CODE USED: Nek5000, SBLI

Jet in crossflow

This generic flow case of high practical relevance is obtained when a fluid jet through the wall enters a boundary layer flow along a wall. Due to its complex, fully three-dimensional dynamics it provides a perfect case for testing numerical algorithms and tools.
CODES USED: Nek5000, NS3D

Automotive

The automotive use case focuses on the simulation of an unsteady turbulent flow, which originates from the separation of the flow on the rear part of the Opel Astra GTC. This flow is characterised by the three-dimensional movement of vortical structures appearing near the rear roof spoiler. It is of interest to understand the behavior of the turbulent structures in this highly sensitive region.
CODES USED: Nektar++, ANSYS-Fluent

CONTACT DETAILS

www.exaflow-project.eu
exaflow-contact@pdc.kth.se
@ExaFLOWproject

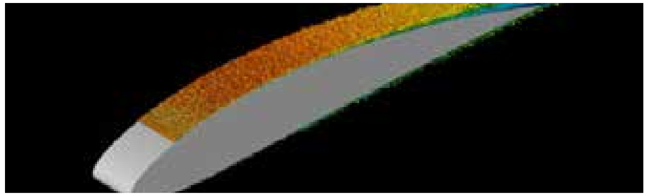
PROJECT DETAILS

Funding: € 3,3 million
Duration: October 2015 – September 2018

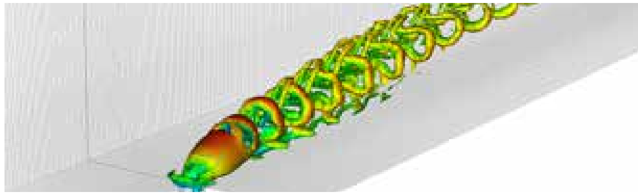
PARTNERS

KTH Royal Institute of Technology
Imperial College London
University of Southampton
University of Edinburgh
University of Stuttgart
Ecole Polytechnique Federale de Lausanne
McLaren Racing Limited
Automotive Simulation Center Stuttgart eV

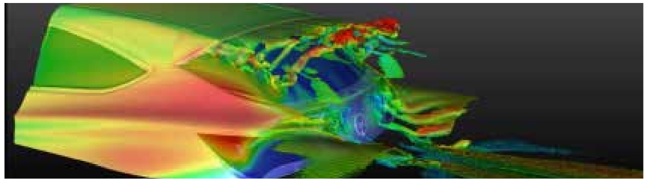
McLaren front wing



Wing profile NACA4412



Jet in crossflow



Automotive

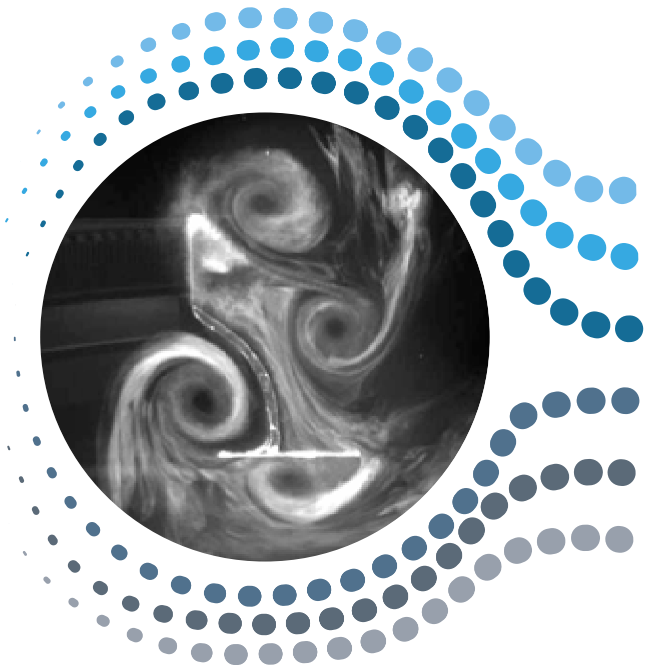
ENABLING EXASCALE FLUID DYNAMICS SIMULATIONS

ExaFLOW

The ExaFLOW project has received funding from the European Union's Horizon 2020 (H2020) research and innovation programme, under the grant agreement number 671571.

THE CHALLENGE

We are surrounded by moving fluids (gases and liquids), be it breathing or the blood flow in our arteries; the flow around cars, ships, and airplanes; the changes in cloud formations or plankton transport in oceans; even formations of stars and galaxies are modelled as phenomena in fluid dynamics. Fluid dynamics simulations provide a powerful tool for the analysis of fluid flows and are an essential element of many industrial and academic problems. In fluid dynamics there is no limit to the size of the systems to be studied via numerical simulations.



The complexities and nature of fluid flows, often combined with problems set in open domains, imply that the resources needed to computationally model problems of industrial and academic relevance are virtually unbounded. The main goal of this project is to address algorithmic challenges to enable the use of accurate simulation models in exascale environments.

GOALS

The main goal of ExaFLOW is to address key algorithmic challenges in CFD (Computational Fluid Dynamics) to enable simulation at exascale, guided by a number of use cases of industrial relevance, and to provide open-source pilot implementations.

Thus, driven by problems of practical engineering interest we focus on important simulation aspects, including:

- error control and adaptive mesh refinement in complex computational domains
- resilience and fault tolerance in complex simulations
- solver efficiency via mixed discontinuous and continuous Galerkin methods and appropriate optimised preconditioners
- heterogeneous modelling to allow for different solution algorithms in different domain zones
- evaluation of energy efficiency in solver design
- parallel input/output and in-situ compression for extreme data.

RESULTS

ExaFLOW targets clearly defined innovations in the area of exascale computing and CFD, with the aim to enhance the efficiency and exploitability of an important class of applications on large-scale (exascale) systems.

Innovation 1: Mesh adaptivity, heterogeneous modelling, and resilience: Mesh adaptivity will reduce the cost of large-scale simulation through a more efficient use of resources, simplified grid generation and correctly calculated results. A heterogeneous modelling approach combining LES and quasi-DNS has accurately captured turbulent flow physics using only a fraction of the number of grid points required for a full DNS. To prevent losses in performance and efficiency when hardware errors occur, a library for multi-level in-memory checksum checkpointing and automatic recovery has been developed and is currently being tested.

Innovation 2: Strong scaling at exascale through a mixed CG-HDG: This approach will exploit the benefits of next-generation exascale computing resources by allowing individual jobs to be executed efficiently on a larger number of cores than presently possible. This will in turn allow large-scale complex flow simulations to be executed in shorter wall-clock times. Time reductions for execution of high-fidelity simulations will accelerate the design cycle for a range of industrial applications.

Innovation 3: I/O data reduction via filtering: The alleviation of the I/O bottleneck by considerable data-reduction before I/O has been successful for smaller data sets using Singular Value Decomposition (SVD) as a data compression method, which performs feature extraction in raw data. With exascale in mind, this method is currently being tested on large data sets.

Innovation 4: Energy-efficient algorithms: Energy and timing implications of reducing the clock frequency in different phases of Nektar++ have been investigated, highlighting the importance of appropriate parallelism.