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PREDICTING THE AIRFLOW AROUND AIRCRAFT LANDING GEAR TO REDUCE GASEOUS EMISSIONS AND NOISE

Aircraft Research Association Ltd (ARA) have utilised the computational power of ARCHER, the UK's national supercomputing service, to carry out their largest simulation of civil aircraft landing gear, using a technique called Computational Fluid Dynamics (CFD).

Simulations such as this will pave the way for increased use of CFD in landing gear assembly design, leading to improved designs which are more environmentally friendly.

ARA is an independent research and development organisation providing a range of specialist services to the aerospace industry; including high speed wind tunnel testing, Computational Fluid Dynamics and high precision wind tunnel model design and manufacture.

THE PROBLEM

There is a strong drive within the aircraft industry for vehicles that are more environmentally friendly, in terms of both noise and gaseous emissions. Reducing noise requires an understanding of the sources of aerodynamic noise, how noise propagates, and how designs can alleviate the impact. Reducing gaseous emissions presents challenges in terms of designing both leaner engines and airframes with reduced drag. Part of the airframe drag problem becomes a focus on reducing aircraft weight, which implies that structures should not be designed to be overly-conservative in carrying the required loads.

The airflow around a deployed aircraft landing gear is extremely complex. As the landing gear traverses from its fully-retracted to fully-deployed position, landing gear bay doors are opened, revealing a cavity, and then partially closed, adding to the flow field complexity. All these structures carry significant aerodynamic loading. In addition, the inherently unsteady nature of the flow around the landing gear/doors/cavity combination implies that the assembly generates significant aerodynamic noise.

Today, Computational Fluid Dynamics (CFD) software tools play a major part in the aerodynamic design of the external shape of an airframe, and aerodynamic forces predicted by the CFD are input into the design of the aircraft structure. However, this is only possible when validation, mainly using wind-tunnel data, allows sufficient confidence to be placed in these tools, and when the tools are affordable and the run times are consistent with design timescales.

Due to the complexity described above, the flow physics of landing gear assemblies and the attendant loading and noise characteristics are not well understood. This results in the increased likelihood of structures being designed overly conservatively, i.e. too heavy, implying increased fuel burn and more emissions. CFD is not used routinely by engineers in this area. The level of modelling integrity necessary to provide acceptable CFD predictions implies the need for very significant computational resource, with elapsed run times measured in weeks or even months. However, there is naturally a strong desire in the future to embed more CFD into landing gear/door design. With advances in HPC architecture, the CFD tools will get faster, so it is still appropriate to validate the modelling being used, in order to pave the way for the future.

THE PROJECT

Against this background, ARA received funding from the UK government's Department for Business, Innovation and Skills to perform a project entitled 'Landing gear/cavity aerodynamics and acoustics'. The project had two parts. The first part was to design and construct a wind-tunnel model of a generic nose landing gear assembly and to test this in the ARA Transonic Wind Tunnel. The extensive dataset produced is expected to be of value in improving the understanding of the flow field phenomena – and also in validating CFD predictions. The second part of the project was to attempt the challenge of computing the flow field using ARA's CFD tools.

THE SOLUTION

ARA has used its standard CFD process to compute the landing gear flow field, but with some novel features. The geometry used was chosen to be the fully-deployed landing gear case tested in the wind tunnel. Figure 1 shows that no geometry approximations were made for the simulation, giving a complex geometrical simulation problem.
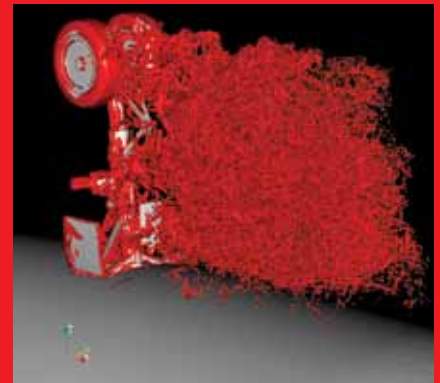

Fig 1: CFD geometry and wind-tunnel geometry

Fig 2: A snapshot in time of an iso-surface of the Q- criterion, which is a measure of the rotation in the fluid.

The flow solver used was the TAU code, developed by the German aerospace research laboratory DLR. This is a domain decomposition code that uses message-passing to allow parallel processing on HPC architectures.

The CFD simulation, with its enormous richness in flow field data, can be used to understand better the evolution of the turbulent structures in the neighbourhood of the landing gear. Figure 2 shows the complexity of the flow in the landing gear wake.
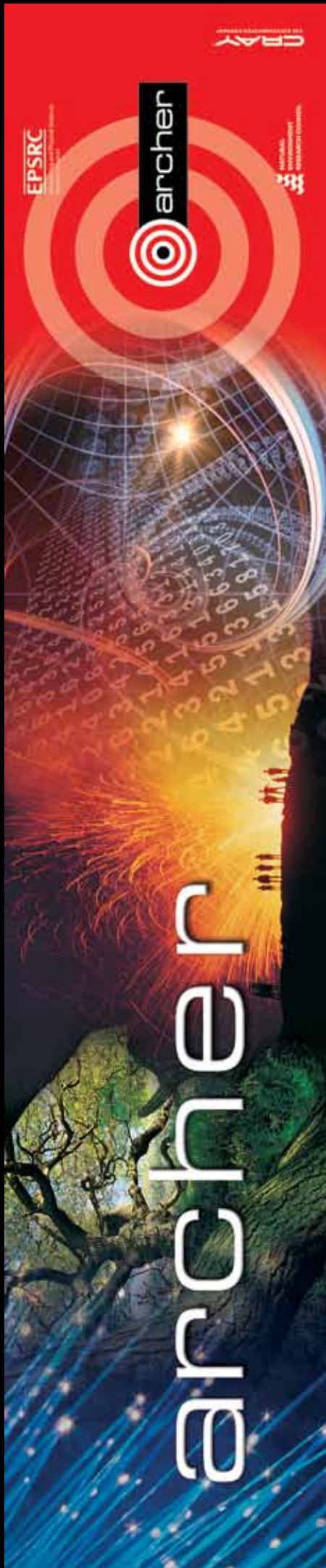
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ARA's internal computing resource is of the order of a few hundred cores, so it was clear from the outset that this resource would not be adequate for performing the landing gear simulation. It was estimated that at least 2000 cores would be needed to obtain even a modest time signal within the time constraints of the project. After discussion with several potential resource providers, it became clear to ARA that the ARCHER National UK Supercomputing Service was the best option to meet the HPC requirements, at a cost consistent with the available project budget.

It was decided to perform the mesh generation phase of the CFD process at ARA and then export the TAU flow simulation phase to ARCHER. ARA moved onto ARCHER in early February 2014 and the landing gear simulation was commenced immediately, using 88 nodes of the Cray XC30, i.e. 2112 cores. This significant increase in capability was instrumental in accelerating time to results and ultimately leading to a successful project outcome.

SUMMARY

The ARCHER National UK Supercomputing Service enabled ARA to perform its largest CFD simulation ever: the simulation would never have taken place if ARA had had to rely on its in-house computing resource.

The simulation results for the civil aircraft landing gear geometry, alongside the wind-tunnel data taken in a companion experimental test, allowed the numerical approach to be validated and additionally insight into the complex flow physics to be obtained. Computations such as this will pave the way for increased use of CFD in landing gear assembly design, leading to improved designs which are more environmentally friendly.
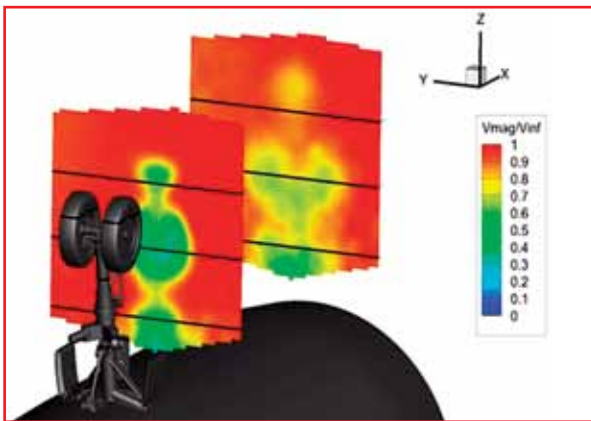
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About ARCHER

ARCHER is the UK National Supercomputing Service. The service is provided to the UK research community by EPSRC, UoE HPCx Ltd and its subcontractors: EPCC and STFC's Daresbury Laboratory, and by Cray Inc.

The Computational Science and Engineering (CSE) partners provide expertise to support the UK research community in the use of ARCHER, and researchers can also apply for longer-term software development support through the Embedded CSE (eCSE) programme. The ARCHER CSE partners are EPSRC and EPCC at the University of Edinburgh.

The Case Study Series

The ARCHER service facilitates high quality science from a broad range of disciplines across EPSRC's and NERC's remits. The outcome is science that generates significant societal impact, improving health and overall quality of life in the UK and beyond. This science influences policy and impacts on the UK's economy.

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