C^{2}A^{2}S^{2}E Newsletter

Issue 02 - December 2009

Center for Computer Applications in
AeroSpace Science and Engineering

DLR
**Deutsches Zentrum
für Luft- und Raumfahrt** e.V.
in der Helmholtz-Gemeinschaft

Niedersachsen

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C^{2}A^{2}S^{2}E
*Center for Computer
Applications in
AeroSpace Science
and Engineering*

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A Flexible Simulation Environment

With the wide range of research topics covered by C²A²S²E, a fairly flexible and expandable simulation environment must be available as a backbone on which to build future simulation scenarios. The FlowSimulator developed by Airbus, EADS-MAS and their research partners is based on the Plug-In concept: a common data-manager is used by diverse discipline-specific modules to efficiently handle parallel, in-memory data handling on HPC architectures.

Multi-Disciplinary design studies, such as Fluid-Structure-Interaction simulations, are an integral part in multiple phases of the aircraft design process. The FlowSimulator offers a flexible way to realize these simulation scenarios. The modular structure of the FlowSimulator allows one to compose a process chain of independent parts, circumventing the limitations imposed by solver-specific simulation processes.

A generic coupling module Plug-In (FSCouple) developed by EADS-MAS is available for the FlowSimulator Environment. This Plug-In offers an interface for the interpolation between fluid and structure grids, where users can implement their own interpolation routines using the FlowSimulator C++ API. The FSCouple Plug-In is designed to take advantage of the parallel capabilities offered by the FlowSimulator environment, although the exploitation of this capability depends on whether or not the interpolation routines are also capable of running in parallel mode.

The FlowSimulator also supports process chains which use legacy Fluid-Structure-Interaction simulation procedures that have been developed over the years at both Airbus and DLR. These procedures are based on code written in Python/NumPy, where matrices created by NASTRAN are used in combination with the surface data from the flow solver to determine the deflection of the structure. Although these codes are currently only capable of running in sequential mode, the FlowSimulator has the infrastructure to run the flow solver in massive-parallel mode on thousands of cores while supporting the sequential requirement of the structure process on a single core, with easy-to-use gather and distribute capabilities for the data.

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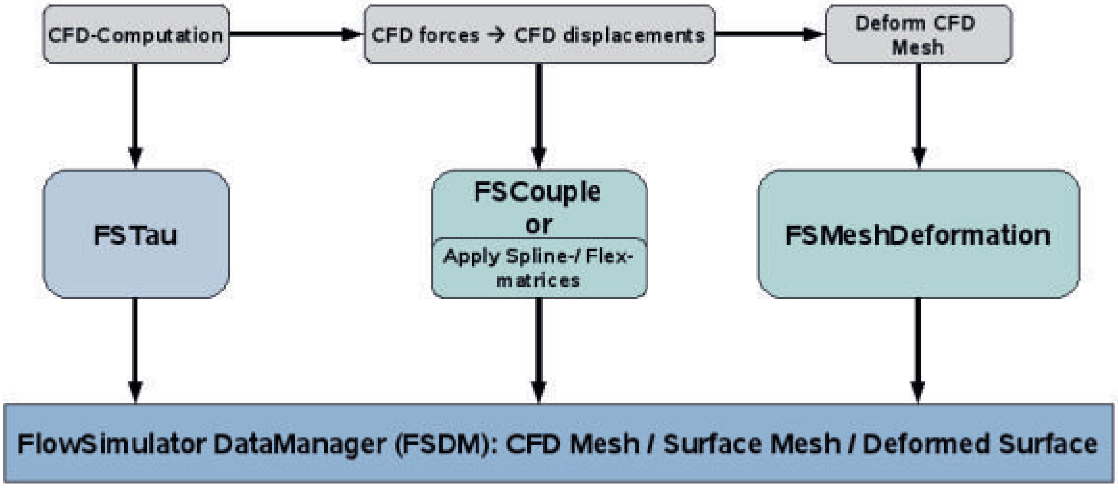
Fluid-Structure-Interaction within
the FlowSimulator Environment

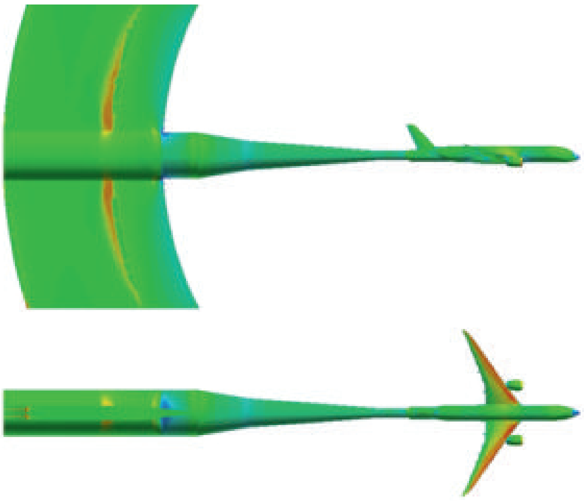


C²A²S²E- what does it deliver to the customer?

The C²A²S²E project is very much oriented towards requirements from the aircraft development process. It has been set up to deliver latest simulation technology according to the needs of Flight Physics engineers. Some examples of the continuous flow of improvements in efficiency and accuracy of CFD methods and tools may illustrate the productivity and effectiveness of the C²A²S²E approach:

Aircraft Aero Data Prediction

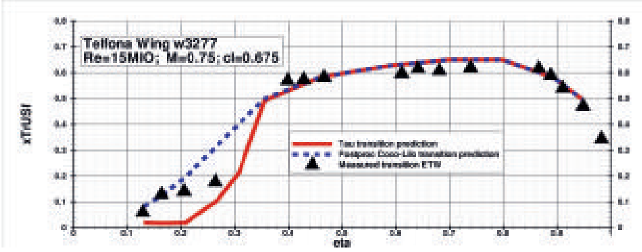
Latest Airbus Aerodynamic aircraft development turned to rely more and more on CFD. The trust in high fidelity CFD has increased so much that it is now used for the production of a major amount of aerodynamic data, including some kind of data never produced before. Thanks to the progress made in C²A²S²E wind tunnel testing could be reduced considerably – with CFD used to prepare tests and produce or control tunnel corrections. Customer's stated: "By including the sting into the CFD models at the correct Mach number, if model deformation effects are ignored, the CFD surface pressures now match the ETW wind tunnel results almost exactly. This gives significant confidence that the CFD flow predictions are essentially correct across the majority of the alpha range until excessive flow separation causes additional issues."



CFD solution for cruise configuration, including sting and support

Integrated transition prediction

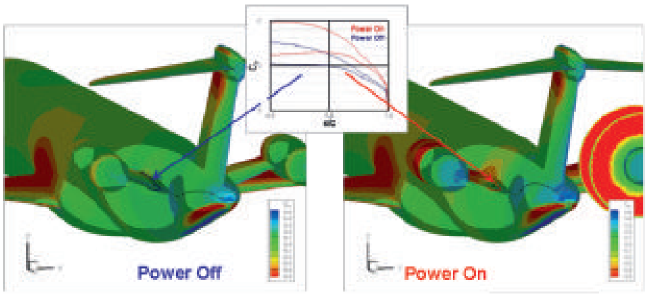
For the development of new aircraft drag reduction technologies play a dominant role. Therefore flow simulation has to include a prediction model for laminar/turbulent transition. Latest version of the TAU code provides such method, which can be used in an integrated manner with the RANS CFD calculation. A validation case has been exercised within C²A²S²E with the TELFONA experiments done in the ETW. Prediction quality is such that the integrated method is now used in Airbus Aerodynamic Design.



TAU integrated transition prediction – comparison to experimental results

Actuator disc model for counter-rotating props

New types of engines offer the potential for significant reduction of fuel burn. So-called counter-rotating propeller engines are very likely to be used as propulsion system on future aircraft. Therefore it is important to deliver a consistent and accurate model of this type of engine within the Navier-Stokes flow simulation. C²A²S²E has provided the integrated solution with its latest CFD capability delivery. A number of validation studies are ongoing to demonstrate the accuracy of the model and to develop a best practice data base. Airbus Aerodynamics now started to investigate power effects on local flow as well as on global aerodynamic data.



RANS CFD power effect investigation on counter-rotating prop

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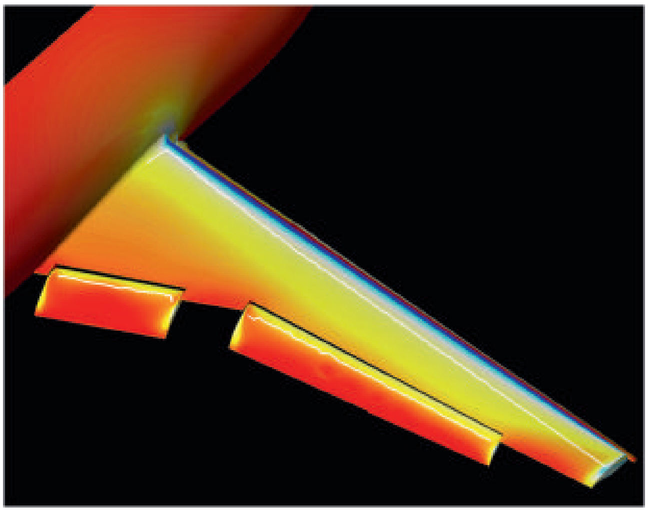
Automatic Transition Prediction in the TAU Code



Simulation result of the flow over the ALVAST high-lift model in landing configuration, surface pressure distribution and the laminar-turbulent transition lines (white).

During 2009 the automatic transition prediction functionality in the TAU code was used at Airbus as well as DLR for a variety of different cases where laminar-turbulent transition is of importance for the accuracy of the overall computational results. The prediction strategy has been developed in closed co-operation between DLR, University of Braunschweig and Airbus. It is based on the linear stability theory for the analysis of the laminar boundary layers and the e^N-method for the determination of the transition points. An iteration process is embedded in the iteration of the RANS equations and is carried out automatically during the ongoing computation without intervention of the user. The laminar boundary layers are computed highly accurate using a compressible laminar boundary-layer code. Transition due to Tollmien-Schlichting or cross flow instabilities is detected by a fully automated stability code applying the two-N-factor method. The transition prediction functionality is parallelized in order to be used on large compute clusters. The transonic prediction method is currently deployed at Airbus for both cruise and high-lift configurations. DLR and Airbus are in close contact with regard to communication and execution of customer needs leading to an increasing level of maturity during the ongoing industrialization process.

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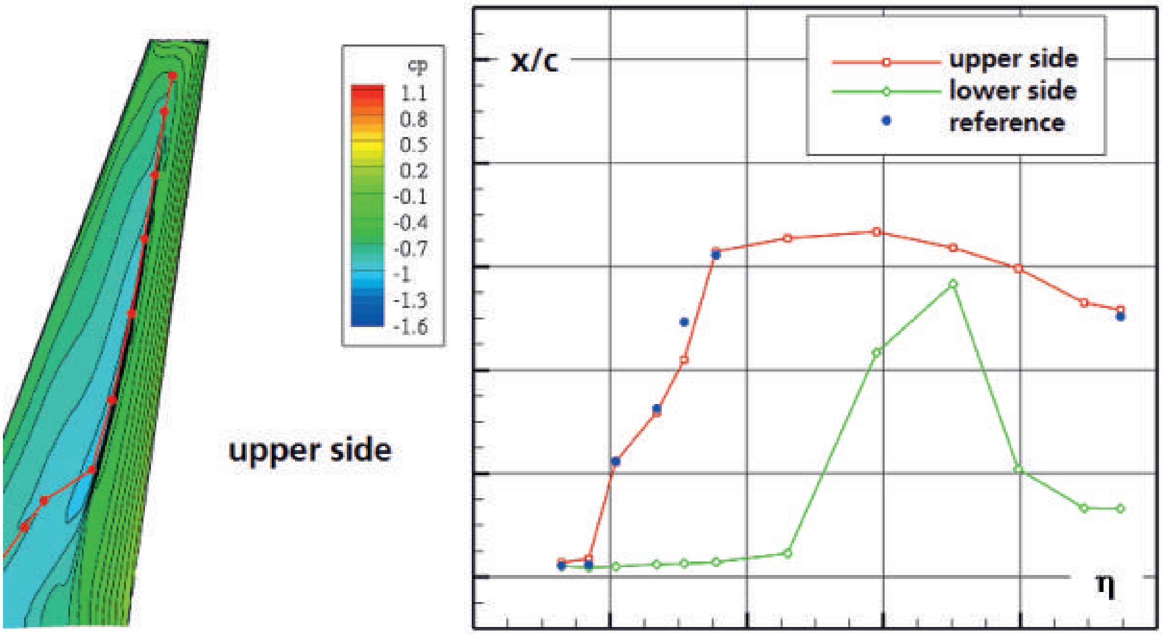
Predicted laminar-turbulent transition lines and surface pressure distribution on a transonic wing compared to reference data



C^{2}A^{2}S^{2}E Symposium "CFD on future Architectures"

On 14th and 15th of October 2009 C^{2}A^{2}S^{2}E has organized a Symposium "CFD on future Architectures" at the DLR-site in Braunschweig. The aim was to bring together HPC hardware and CFD experts for discussing actual and future trends. As we see Moore's law still continuing for (at least some) years to come, more and more parallelism is introduced to all computing platforms and on all levels of integration and programming. Especially in the area of High-Performance Computing (HPC), more and more users face a combination of different parallel hardware architectures and parallel programming environments. Those technologies range from vectorization and SIMD computation over shared-memory multi-threading to distributed-memory message passing on cluster architectures. Furthermore, a move is taking place to multi/many-core processors as building blocks for high performance and energy efficient solutions and its related potential for new hardware technologies. Cluster architectures will likely change in future to heterogeneous many-core processors, with on-core co-processors or other accelerators like GPGPUs or FPGAs. Thus, HPC requires more and more hardware-specific code optimization for the efficient use of such hardware. The problem is that it is difficult to anticipate which type of architecture will be the target platform for CFD applications in medium-term future.

Computer architectures are market driven. Impact on hardware-design decisions come from various aspects, like energy efficiency needed to design Exa-Flop-Computers, computer-gamer needs or SAP applications. Certainly, the needs of CFD application codes do not play an important role for hardware design. Thus, it is not obvious to which type of architecture CFD codes have to be adopted. Probably due to this fact, another trend was established, which deals with intermediate software layers for (semi-) automated optimization of legacy codes for future architectures. Ideas how such a technology might look like were also presented at the symposium. Compilers or code-to-code transformations for runtime optimization are believed to be one possible way to go.

C^{2}A^{2}S^{2}E cluster in Braunschweig

At the symposium, two of the major hardware manufactures provided overviews of their upcoming and future hardware. Nvidia's Timothy Lanfear gave some HPC-relevant details of the upcoming "Fermi" architecture for general purpose GPU computing, whereas Intel's Herbert Cornelius focused on future many-core processors with full x86-instruction set as well as on Intel's quick path interface, a fast interconnect for attaching accelerator cards. Both agreed that energy efficiency is a major design goal for future architectures. Energy-efficient computing was also one of the topics in Christian Simmendinger's talk (T-Systems Solutions for Research). His main point, however, was that using upcoming accelerator hardware will critically depend on how user-friendly the respective APIs will be. As a resort, an API independent representation of algorithms in connection with a (semi)automatic transformation into target source code, which is eventually compiled using hardware/accelerator-specific compilers, was proposed. How such an approach may work out for CFD was presented by Tobias Brandvik (Whittle Laboratory at the University of Cambridge). An existing solver had been ported to an abstract description language (based on Python) which can be transformed, e.g., into Cuda code, suitable for using Nvidia's GPGPUs. A substantial speedup was reported for this re-coding of a structured CFD solver. Also in several other talks, the potential of using GPGPUs as well as FPGA-based accelerators for CFD was demonstrated – also for solvers using unstructured grids, for example by Jamil Appa (BAE Systems) as well as by Mario J. Martin (National Institute of Aerospace Technology, Spain). As a baseline, the energy efficiency as well as the usability/programmability of future architectures turned out to be the crucial aspects for CFD on future architectures.

The talks given on the symposium are available to the public at http://tau.dlr.de

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Responsible in the sense of § 55, 2nd paragraph of Rundfunkstaatsvertrag (German Interstate Treaty on Broadcasting):

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AIRBUS

Together towards the "Digital Aircraft" – Cooperation between DLR and Forschungszentrum Jülich

Courtesy of FZJ

In order to allow aerospace research to break new ground in the area of High Performance Computing, the two leading German research institutions in numerical simulation, the German Aerospace Center (DLR) and the Forschungszentrum Jülich (FZJ), signed a Memorandum of Understanding. The Forschungszentrum Jülich operates JUGENE, Europe's fastest supercomputer und coordinates national and international HPC projects to tackle cutting edge problems in various areas of basic research and computational sciences. The cooperation between DLR and FZJ will enable grand challenge simulations in aerospace, for example a more accurate and detailed prediction of the physical phenomena of an aircraft. Further objectives of the cooperation are the customization of numerical methods to new computer architectures, the training of qualified young academics as well as the initiation of joint research activities.

JUGENE
(Jülicher Blue Gene)

Type:	**IBM Blue Gene/P**
Peak performance:	**1 petaflop/s**
Processors:	**294,912**
Processor type:	**32-bit PowerPC 450 core 850 MHz**
Compute node:	**4-way SMP processor**
Main memory:	**144 terabytes**
Racks (water-cooled):	**72**
Network latency:	**160 Nanoseconds**
Network bandwidth:	**5.1 gigabyte/s**
Power input:	**2.2 megawatts**