FUTURE SIMULATION CONCEPT

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OVERVIEW

Within Vision 2020, ambitious goals have been set for air traffic of the next decades. These include a reduction of emissions by 50% and a decrease of the perceived external noise level by 10-20 dB. Continuous improvement of conventional technologies will not be sufficient to achieve this goals, however, a technological leap forward is required. The combined efforts of industry and academia will be necessary to harness new flow control technologies and entirely new configurations for use in future aircraft design and development.
This will require a significant investment in enhancing the capabilities and tools of numerical simulation, which has become a key technology in recent years. Although numerical simulations of entire aircraft configurations are routinely performed in industry today, the time required is still on the order of hours and days, posing a significant obstacle to aerodynamic design.

To meet the above-mentioned challenges, it will finally be essential to be able to “flight-test” a virtual aircraft with all its multi-disciplinary interactions in a computer environment and to compile all of the data required for development and certification with guaranteed accuracy in a reduced time frame.

Numerical simulation is foreseen to provide a tremendous increase in efficiency and simulation quality over the next decade. Along with increasing capability to model and compute all major multi-disciplinary aspects of an aircraft, it will become possible to fly and investigate the complete aircraft in the computer. Progress in high performance computing (HPC) will essentially contribute to achieve this goal. Considerable changes of development processes within Airbus Engineering will lead to significant reduction of development times while including more and more disciplines from the early phases of design in order to find an overall optimum aircraft design.

Airbus – together with major research partners and companies in the field – has started an initiative to develop Airbus Aerodynamics and Flight Physics into a fully new paradigm of simulation. All aspects of simulation (physics, mathematics, algorithms, hardware, software, computer science, information technology, man-machine interface, overall system, data handling, applications, etc.) are supposed to deliver essential contributions and provide their input and support to a superior cooperative effort. Major centers of expertise in numerical simulation are being built up in each Airbus country that will enable concentrated work on this topic with emphasis on specific aspects of simulation technology and application.

1. FUTURE SIMULATION CONCEPT

In order to overcome the obstacles that presently prevent taking full advantage of the potential of numerical flow simulations, the following tools and technologies have to be developed and established:

- accurate physical modeling of flow phenomena throughout the entire flight envelope,
- robust, highly efficient algorithms for solving the resulting non-linear systems of equations,
- multi-disciplinary simulation tools that integrate all core disciplines involved,
- multi-disciplinary optimization methods capable of navigating high dimensional design spaces,
- methods and procedures for error quantification,
- massively parallel computers with highly efficient inter-processor communication,
- flexible, intelligent control systems for simulation software,
- optimum scheduling systems for efficient hardware utilization,
- efficient tools for handling and post-processing the huge amount of data resulting from simulations,
- intuitive 3D analysis tools for realistic presentation of results,

- design system capable of making effective use of vast quantities of multi-disciplinary data.

On top, intelligent means will have to be developed that could allow to reduce the number of computations required. So-called surrogate or reduced order models which were adapted to specifics of aerodynamic flow simulation could essentially help to accelerate comprehensive use of numerical simulation in aircraft design and optimization.

The combined effort of four development centers with all related research partners will finally produce a capability that will allow to achieve maximum use of the simulation potential in multi-disciplinary aircraft development.

2. WHERE ARE WE?

Today, aircraft industry is conducting a lot of numerical simulation in its daily design and development work [1]. On the forefront, Aerodynamics is using a variety of Computational Fluid Dynamics (CFD) methods and tools, which essentially help to analyze global as well as local flow behaviour about simplified and fully complex aircraft configurations. Reynolds Averaged Navier-Stokes (RANS) methods including 2-equation turbulence modeling is the most widespread approach to tackle even highly complex 3D take-off/landing configurations. Aerodynamic design as well as aerodynamic data production is heavily supported by these means.

In a wider sense, simulation is also approaching multiple interacting disciplines. Flexibility effects on aircraft aerodynamics and loads are in the direct scope of CFD simulations coupled with CSM (Computational Structural Mechanics) codes. This area also extends to use flight control modules in order to simulate trimmed aircraft configurations.

A further area where numerical simulation has already offered real benefit is design optimization. Although fast strategies to find the optimum for multi-disciplinary multipoint design in 3D are still under development the aircraft industry already uses optimization algorithms for detailed design tasks. However, there is a need to further explore available optimization techniques since they represent a significant potential in enhancing design.

2.1. CFD applications

A typical application of CFD is the prediction of the aircraft performance in cruise conditions. Latest developments have demonstrated that the predictive capability of CFD is just within the 1% accuracy range provided by high Reynolds number testing (FIG 1). Thus CFD has proved to be reliable in judging on design progress during shape design phases. This capability is also exploited through numerical optimization procedures applied to shape design.

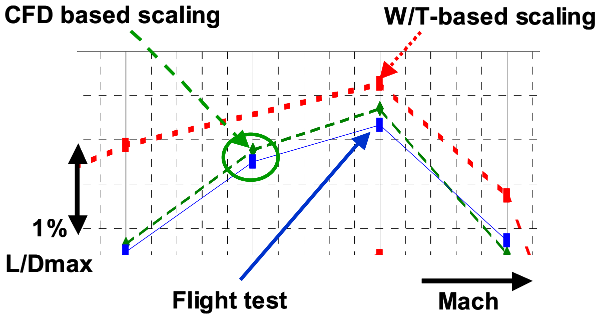

FIG 1. Flight performance prediction capability

Another field opened for use of CFD since some time: Massive use of advanced numerical methods enables the early production of basic sets of aerodynamic data which are relevant for establishing loads or handling quality purposes. Current aircraft development time has reduced quite a lot compared to earlier times. Therefore more effective means had to be found to produce aerodynamic data in a much shorter time scale than ever. CFD is contributing a lot in this area as it can already provide data before any wind tunnel model has been built.

For take-off and landing configurations, design tasks are more difficult because of the complexity of the aircraft geometry (deployed landing gears & high-lift devices) and the occurring flow phenomena. Flow separation is one of them and its prediction is still a challenge. However, significant progress has been made on the prediction of optimum settings for high lift components. CFD is also extensively used to elaborate aerodynamic data for ground effect (FIG 2), for example.

Application of static deformation analysis based on CFD/CSM coupling has also made big progress. Simplified models have been developed to simulate deformation also for individual components of the aircraft (FIG 3). This capability opens the way to include these effects in the optimization of aerodynamic design.

2.2. CFD Processing on HPC

Since the decline of vector processor technology aerodynamic code development is more and more concentrated on highly parallel computer systems.

Several aspects of this type of systems had to be understood in order to appropriately adapt methods and software. Currently, RANS CFD is available as parallel software based on grid partitioning, either in multi-block structured or in unstructured/hybrid form. Philosophies are different with respect to memory access, which is either following distributed memory or shared memory concepts.

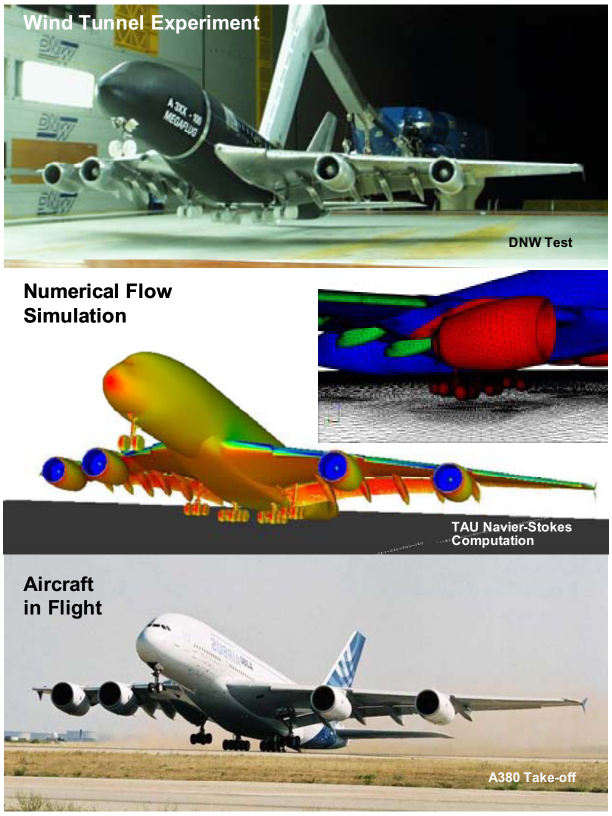

FIG 2. Use of RANS CFD for ground effect simulation

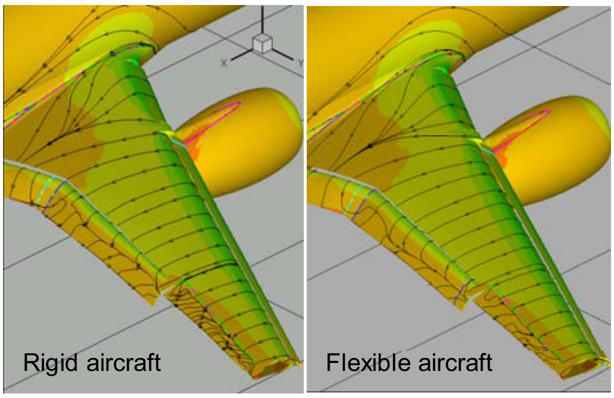

FIG 3. Full high lift CFD/CSM coupling

Current runs of RANS codes exhibit quite promising results on parallel efficiency. Both, the multi-block structured code elsA [2] (FIG 4) as well as the unstructured hybrid code TAU [3], [4] (FIG 5) provide a very good scalability for large computation problems (about 10-20M grid points). Conducting computations with up to 128 processors is the current practice for Aerodynamics.

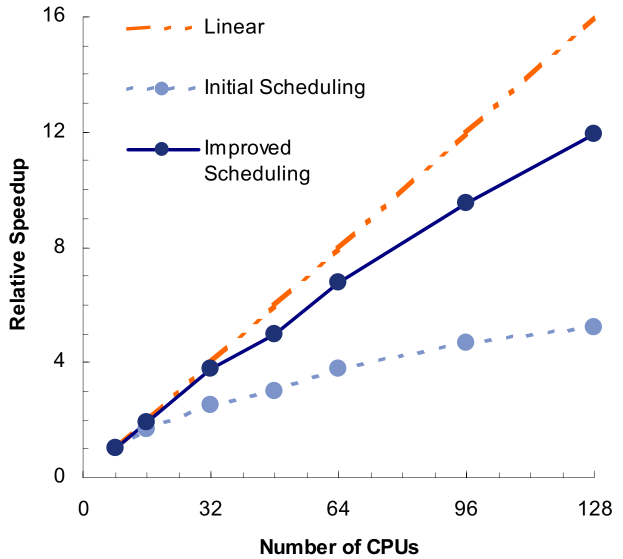

FIG 4. elsA parallel efficiency and scalability – speedup on different number of processors for a 25M mesh point case

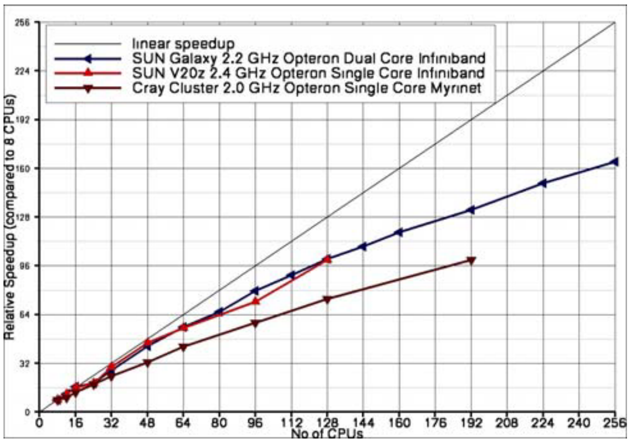

FIG 5. TAU parallel efficiency and scalability, speedup compared to 8 processor run on a 10M mesh point case

An important point to mention is the full simulation chain, which is more than just the CFD code dedicated to solving the physical governing equations. A standard software architecture has been created that allows to operate complete CFD processes including pre-/post-processing and mesh generation. This FlowSimulator software backbone allows to seamlessly integrate various tools without affecting their internal data structure. Communication in between these modules is secured via a neutral data structure concept operating inside main memory. It is essential here to ensure that there is no doubling of memory or file input/output needed.

In general, this backbone approach is suitable to implement multi-disciplinary processes and it will be used to organize coupling procedures of any necessary kind.

2.3. Processor technology

Looking at processor technology some recent technology jump is at the point of entry into service which involves the change from single core to multi-core processors. As for now the CFD codes have been optimized for single core processors being connected via Infiniband [5] or similar interconnects. Work is ongoing to optimize the simulation tools for multi-core operation, which in itself has some flexibility concerning CPUs, local memory and its relation within the overall machine.

2.4. Use of numerical simulation

Since some time Airbus has considered principle restructuring of its aircraft development processes. Due to the increase in numerical simulation capabilities it became possible to rearrange the aerodynamic design as well as aerodynamic data production processes considerably. Finally, these changes led to a drastic reduction of wind tunnel use (FIG 6).

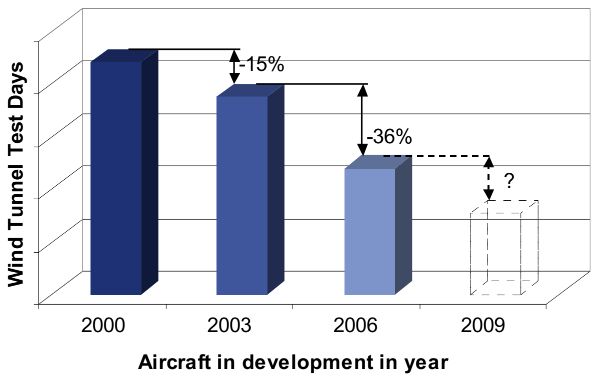

FIG 6. Use of wind tunnel for aircraft programs

FIG 7 shows that CFD is used on a wide variety of tasks. While essential design activities are largely based on CFD there is a more moderate use on topics dealing with increased complexity. Growing use of CFD can be found in areas that deal with highly complex geometries or need multi-disciplinary coupling, e.g. icing, aero-thermics, aero-acoustics.

FIG 7. Use of CFD at Airbus

3. OPPORTUNITIES IN NUMERICAL SIMULATION

Numerical simulation involves a long list of disciplines, all covering a variety of aspects. Each of them as well as the interplay are supposed to be significantly improved in the future. Although tremendous results have been achieved in the past decades, numerous areas remain to be explored. Aerodynamics and Flight Physics development of aircraft intends to make extensive use of what is going to be available, and has to prepare for it. This has also recently been documented quite extensively by Dimitri Mavriplis et al. [6].

3.1. Processor technology

Progress over the years shows that Moore's law from last century still seems to be valid, i.e. compute performance related to hardware improved by at least a factor of 2 every 18 months. Assuming a continuation of this trend we could at least expect a factor of 100 within the next 10 years. Various lines of development like multi-core processors, cell processors, FPGAs or other graphics processors could eventually deliver another substantial acceleration of numerical flow simulation.

3.2. HPC

For the future, considerable progress in High Performance Computing is foreseen. PC-Clusters with large number of processors and efficient interconnect will be available for routine applications. Currently, a large effort is devoted to improve cache efficiency and parallel scalability of the numerical methods used in industry. In order to fully exploit the capabilities of HPC the complete process chain for multi-disciplinary simulation will run in parallel. In addition, new developments in grid computing will allow the efficient use of distributed

HPC resources and will significantly increase available computing power.

3.3. Physical Models

Recent developments in turbulence and transition modeling in academia show the potential to reduce the uncertainties for predicting flows at the border of the flight envelope. However, for industrial applications the range of reliability of Reynolds stress models has to be explored. For more advanced hybrid RANS/LES methods best practice guidelines must be established for routine use prior to exploring the range of applicability. Sophisticated laminar-turbulent transition prediction methods have to be introduced into industrial process chains for routine use.

3.4. Numerical Algorithms

It is expected that improvements in numerical solution algorithms and innovative computational concepts will significantly reduce the simulation turn-around time for complex configurations. Essential ingredients are highly automated grid generation systems producing high quality meshes for complex configurations, higher-order adaptive methods with reliable error indicators ensuring prescribed accuracy with minimum number of degrees of freedom, efficient and robust iterative methods for large and stiff systems of equations occurring for large scale turbulent high Reynolds number flows as well as hybrid solution algorithms exploiting the potential of mixed structured/unstructured meshes.

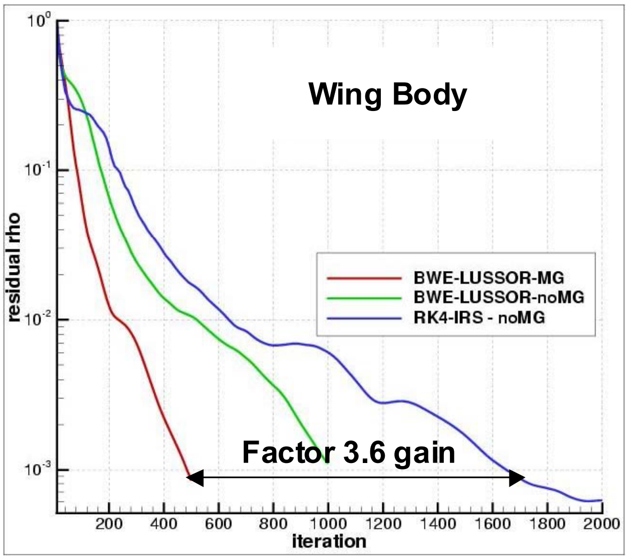

FIG 8. Performance gain by improved algorithms – convergence of density residual

In these areas considerable research effort is currently underway with promising results. Proper combination of implicit iteration schemes with multi-grid techniques for a linearized Euler solver, for example, resulted in a factor 3.6 performance gain (FIG 8).

3.5. Design of Experiments

Finally, aircraft design and data work requires a large amount of flow simulation data. However, this does not mean just a repetition by simulation of what has been done with the wind tunnel in the past. On the contrary, it is expected that new ways of sorting and organizing simulation processes will save quite a number of those computations. Sophisticated technologies like neural networks or other techniques mainly known from optimization will be used to provide a landscape of data at a minimum number of high fidelity simulations. Error estimators and error propagation control will enable provision of results at guaranteed accuracy.

3.6. Design System

Man-machine interface is also seen to undergo considerable improvement. If the capability is such that it provides results 10^6 times faster than today, the design engineer will practice a fully different way of working. One can expect that shape design can be done in interactive mode, based on full 3D Navier-Stokes judgment of aerodynamic impact. Tools will be provided that allow the engineer to steer through design space and help him find the optimum solution on the screen within the shortest time, while saving all relevant information for later use.

4. FUTURE SIMULATION CENTERS IN EUROPE

In order to concentrate research and development effort on numerical simulation technology and capability Airbus – together with a number of partners from industry and research organizations - initiated a process to concentrate respective activities in Europe. Airbus promoted the foundation of four centers that are dedicated to develop technologies, methods and tools with the objective to achieve an increase of 10^6 of the numerical simulation power within roughly a decade.

4.1. CFMS Framework

The CFMS Framework [7] - originally named “Centre for Fluid Mechanics Simulation” - has been put together, and will be managed, by a consortium with the common aim to deliver a comprehensive research portfolio on enabling technologies that will take design systems for fluid mechanics forward to a new level. It is recognized that engineering solutions required to meet the future stringent targets for cost, performance and environmental impact, will need to be highly optimized multi-disciplinary systems making use of revolutionary technologies, beyond the current boundaries of experience.

The CFMS Framework concept encompasses both development of technologies and also the provision of a 'capability laboratory', likely to be known as SWANS Laboratory. This facility will perform a number of functions:

- to act as a focal point, bringing together a variety of technology developers and end users,
- to provide the necessary IT resource and
- to facilitate demonstration and refining the complete system.

4.1.1. Objectives

The Vision 2020 targets demand a step change in aircraft configuration performance that will only be reached by applying 'game changing' technologies. Research and development into the tools and capability required to enable design with these emerging technologies needs to happen now, in order to have systems that can handle hugely complex design spaces with dimensionality far beyond today's optimization systems, in an effective and efficient manner.

For the 2020 aircraft with potentially alternative configuration layouts, or radical technical solutions, higher levels of understanding of the design space and constraints needs to be developed without the luxury of many decades time to gain this experience. The future design system has to have the ability to handle highly complex design spaces - model, navigate and communicate this information to the designer, to enable understanding and optimization to be achieved in short time periods.

4.1.2. Work Programme

Projects and activities are now running on a range of technologies with the "CFMS vision" as the objective. Activities are running looking at alternative hardware to enable a step change in simulation throughput. Industry cannot simply rely on exponential improvements in processor clock speed to provide the volume of numerical modeling that will be required. Activities are running on data modeling and representation. The huge increase in simulation throughput will allow engineering designers to generate Petabytes (10^{15}) of data during the design of a single product variant. Existing collaborative design processes are not configured to handle this magnitude of throughput. Research is starting on actively capturing, managing and exploitation of knowledge. This will be on a number of levels. Automatic knowledge gathering about the numeric simulations (with the volume of data generated, it will be impossible for the engineer to manually check each one), and knowledge about the design rationale – capturing the 'why' questions and processes engaged to answer these questions. Activities are starting looking at the human machine interface – we need to dramatically improve the way the engineer interfaces with the high dimensional complex design space, and remove as many physical barriers that may prevent efficient and innovative design.

4.1.3. Expected Results

The expected results from the CFMS activities are a demonstrated set of technologies providing the capability to design and optimize engineering solutions for aircraft aerodynamics. This will involve ability to automatically generate more accurate aerodynamic simulation data significantly faster, in order to map out, understand and navigate within the design space. It will involve the ability to handle the vast quantities of data required for design iteration, make better use of previously generated data, and capture more efficiently data pertaining to design rationale, again for future reuse. It will involve the ability to free the designer from non-value added activities and enable ability to effectively design in more complex and less familiar design spaces.

4.1.4. Partners

The market drivers for future design concepts are not restricted to aerospace. Requirements for ever-increasing environmental/performance demands on high technology engineered products exist in sectors, such as Formula1 cars design, gas turbines design, ships design, etc. The CFMS consortium will bring together industrial end-users, engineering service organizations, research institutions and IT capability providers, to overcome the many technology barriers to enable such a change in the way design systems are provided. This has led to a multi-sector and multi-partner consortium to share in developing technology for common benefits.

The first major project within the CFMS Framework is already underway. The so-called CFMS Core Programme is led by Airbus and is supported by the UK DTI's Technology Programme. It involves a significant number of partners. These include Rolls-Royce, MBDA UK, Microsoft, BAE Systems, QinetiQ, WilliamsF1, Aircraft Research Association, Frazer-Nash Consultancy, Eurostep, Quadrics, BMT Fluids, PCA Engineers and Westland Helicopters.

4.1.5. Key figures

The CFMS vision requires long-term development of technologies, and will be supported by a number of discrete projects/activities contributing to the overall aim.

The FoFluSim project is supported by the South West of England Regional Development Agency and started in early 2006. The CFMS Core Programme project will run for 3 years and is supported by the UK government (DTI). It is anticipated that the SWANS Laboratory will come on-line in the 4th Quarter of 2008.

4.2. Center for Computer Applications in AeroSpace Science and Engineering

The $C^2A^2S^2E$ center [8] is the German part of the overall Future Simulation initiative. It opened its doors at the research airport in Braunschweig in June 2007, linked to a branch office at Airbus in Bremen.

4.2.1. Objectives

The goal of $C^2A^2S^2E$ is to establish an interdisciplinary center of excellence in numerical aircraft simulation and optimization. The new center will develop numerical methods and processes for highly accurate, multi-disciplinary simulations of aircraft in an industrial context. The focus of $C^2A^2S^2E$ is on major application tasks which are in the center of aerodynamic and Flight Physic's interest. This will be essential to overcome the technological, economical and environmental barriers to future growth of the air transport system.

4.2.2. Work Programme

The research and development to be conducted at the $C^2A^2S^2E$ center shall address the following four challenges:

- real-time simulations of aircraft in flight based on the unsteady Navier-Stokes equations coupled with a finite-element description of the aircraft structure and the flight dynamics control laws
- calculation of the aerodynamic loads of the aircraft across the entire flight envelope, including extreme flight conditions
- numerical prediction of aircraft performance and handling qualities prior to the first flight
- preparation of certification prior to aircraft production based on numerical simulation data

Two transversal activities are planned to support the solution of these tasks. They will deal with compute process, automation and technology integration. Strict quality assurance will help to ensure development of qualified reliable tools.

$C^2A^2S^2E$ will be based on three pillars, the first one being the creation of a major new aerospace simulation center in northern Germany. The center will boast a goal-oriented research environment dedicated to promoting integrated research, development and industrial application activities. Latest developments and results in key areas of numerical simulation technology, such as physical modeling, numerical methods and information technology, will be transferred to industrial partners. Scientists and engineers will work together in an environment with long-term job perspectives.
The second pillar will be to foster a campus environment that will bring together world-renowned experts and guest scientists to stimulate top-level research in the field of numerical simulations.
The final pillar will be a professionally managed and operated high-end computer center that meets the growing demand of industry and applied research for computational power.

4.2.3. Expected Results

$C^2A^2S^2E$ will establish a permanent research facility that will attract and bring together worldwide competence in the field of numerical aircraft simulations. A proposed goal is to speed up numerical simulations by a factor of 10^5–10^6 over the next decade through interdisciplinary research, simulation technology integration and exploitation of the expected growth in computational power. These capabilities will be used to provide solutions to major aerodynamic application tasks.
This, together with improved modeling fidelity and a broader spectrum of applications, will accelerate the move towards more economical and environmentally friendly air transport.

4.2.4. Partners

DLR, Airbus and the State of Niedersachsen will participate in setting up and operating the $C^2A^2S^2E$ center. A liaison with the Digital Aircraft Center on virtual reality in Bremen is also being considered. Other potential partners include aerospace companies (EADS), companies from other sectors of industry (automotive and shipbuilding), and relevant suppliers.

4.2.5. Key figures

The $C^2A^2S^2E$ project is envisaged to run for at least 15 years, in three steps. It is supposed to provide a place of sustained research. For the first 5 years, the project is supported by the government of Niedersachsen.

4.3. MOSART

The French initiative MOSART (**MO**delisation and **S**imulation in **A**eronautics to **R**educe developmen**T** cycles) is developed in the context of competitiveness clusters Aerospace Valley (Midi-Pyrénées & Aquitaine) and System@tic (Paris region).

The development of technologies is supported by the research programs of these two competitiveness clusters through multi-sectorial projects, respectively MACAO [9] and EHPOC [10].

The cooperative research between different industrial sectors relies on already established cooperation frames at CERFACS (European Centre for Research and Advanced Training in Scientific Computing) [11] and TER@TEC high-performance computing center.

4.3.1. Objectives

The goal of the MOSART project is to provide aeronautics industry with a sustained development and intensive use of modeling and simulation for a dramatic time and cost reduction of design cycles of new products. The engineering productivity should be improved by a factor of 2-3 over the next five years thanks to high performance multi-disciplinary & multi-scale simulation. It includes the establishment of seamless access to high-end HPC capacity through secured grid computing technology and the development of new software paradigms being able to benefit from Petaflops-class computers.

4.3.2. Work Programme

The research and development to be conducted within MOSART project will focus on the following topics:

- Platform and software for multi-disciplinary & multi-scale simulation: multi-disciplinary coupling, infrastructure for intensive computing, High Performance Visualization, large scale mesh generation and adaptation, HPC environment integration for aeronautics,
- Algorithms and software development adapted to Petaflop simulation taking advantage of future generation of HPC based on multi-core hardware architecture,
- Grid computing strategies to optimally drive multi-disciplinary processes,
- Petaflop Challenge: Algorithms and solvers for “Very High Performance Computing” (VHPC) – a demonstrator for frontier simulations.

4.3.3. Expected Results

MOSART project will establish a new class of higher fidelity and faster numerical simulation capabilities which will allow to extend the current range of applications and substantially support new challenges and innovation in aircraft design.

4.3.4. Partners

A large number of industrial partners are involved in MOSART project (e.g. Airbus, Altran, CS, Dassault, EDF, Messier-Dowty, Renault, Snecma, Turbomeca), covering a wide range of applications and disciplines. All studies will be supported by main French Research Establishments and laboratories (CEA, CERFACS, CNES, INRIA, ONERA, Ecole Polytechnique, ENSICA, INSA, etc.).

4.3.5. Key figures

The first phase of MOSART project will run for a period of three years. All capabilities being developed during that phase shall be validated with industrial applications in a second phase afterwards. MOSART activities will be sponsored by French Pôles de Compétitivité governmental funding.

4.4. DOVRES

DOVRES stands for Design Optimization by Virtual Reality Simulation. It is a project sponsored by IMDEA-Mathematics [12], a Madrid Local Government Foundation aiming to be the framework for investigation, training and knowledge transfer, combining public and private funding.

4.4.1. Objectives

The objectives of DOVRES are to develop the technical capability for an Aerodynamic Designer to work in a virtual reality environment, with direct interaction between CAD-3D design and CFD direct/adjoint solver, in (almost) real-time. Another objective is to promote the development of an HPC Center within IMDEA and lead research towards next generation CFD simulation.

4.4.2. Work Programme

The research and development to be conducted within the DOVRES project shall address four major topics:

- Solver acceleration by new hardware/software integrated processor technology based on FPGAs (Field Programmable Gate Arrays)

- Adjoint optimization improvement: Sensitivity function interpretation and improved design framework
- Solver accuracy and robustness optimization by advanced numerical methods and expert system development
- Virtual reality environment development for design and post-processing

4.4.3. Expected Results

DOVRES pretends to create a collaborative framework among partners, national and international, to develop a fully new capability for aerodynamic work. Apart from the speed up of numerical simulations by a factor of 10^5–10^6 over the next decade, through interdisciplinary research and exploitation of the expected growth in computational power, DOVRES main objective is to put back the aerodynamic engineer fully into the man-in-the-loop optimized design process.

4.4.4. Partners

IMDEA-Mathematics will take care of the project management, apart from contributing with own research personnel. Airbus, EADS-CASA, together with INTA and three universities of Madrid (Polytechnic University, Autonomous University and Rey Juan Carlos University) will contribute to the project technical work.

4.4.5. Key figures

DOVRES project is envisaged to run for three years with an expected extension up to five years, according to project results. It is expected that DOVRES experience will help to establish follow-on projects. IMDEA-Mathematics will find its place in an all-new headquarters and HPC center in 2009, within the Autonomous University campus. In the meantime, the temporary offices were already disposed.

5. COLLABORATION

The four centers together form a body of targeted research (FIG 9) which is composed of heterogeneous projects, all being focused on aspects associated with numerical simulation. In order to achieve an overall progress on simulation capability, an agreement has been set up on cross-border collaboration. This includes regulations for use and exchange of tools and software.

Several groups among the projects already started to organize working on a common subject in complementary way. In order to progress in optimization technology, for example, it has been agreed to integrate development of CAD/shapes and meshing solutions with flow solver and adjoint technology.

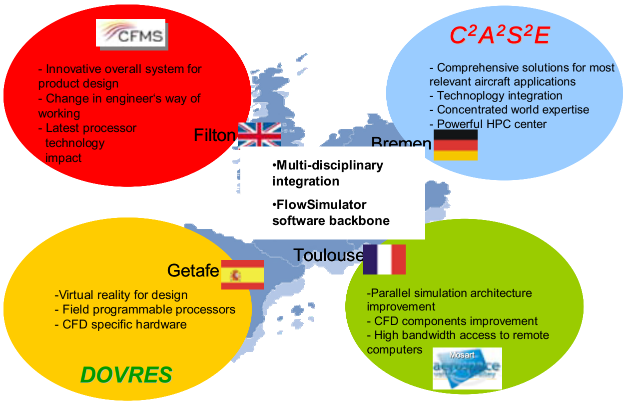

FIG 9. Future Simulation Centers in Europe

A major integration effect will be achieved through the use of a common software concept: the FlowSimulator backbone system (FIG 10) will be provided to all centers so that it can form the backbone for any parallel simulation process related development.

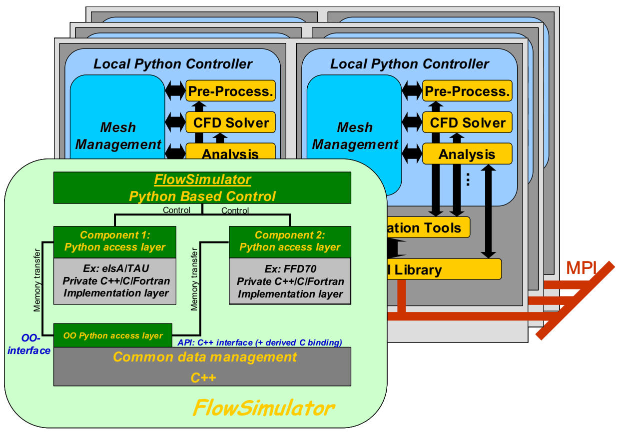

FIG 10. FlowSimulator backbone layout

Collaboration will also take place among disciplines. Major tasks will be dealing with simulation and optimization of the whole aircraft. This means that intensive collaboration is necessary between Aerodynamics, Aeroelastics, Structures, Flight Mechanics and Flight Control. FuSim forms a broad research platform to tackle the envisaged overall coupled simulation in an integrated way.

6. SUMMARY

Since last year, Airbus has initiated considerable research&development projects in all four European Airbus countries. These centers are supposed to deliver the future simulation and optimization technology that Airbus needs to develop superior aircraft. Concentration of research efforts and working towards specific targets are supposed to bring related capabilities a tremendous step forward, resulting in an acceleration factor of 10^6 within roughly a decade from now. Hopefully, this activity will attract researchers from all over the world to contribute and once find their development being applied to a prosperous product.

7. ACKNOWLEDGEMENTS

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