The Special Technology Sessions at the Large ECCOMAS Conferences and the CFD Research Development in Aeronautics

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Abstract

ECCOMAS, the European Community on Computational Methods in Applied Sciences brought together the scientific associations on numerical and computational methods in Europe. With its large conferences ECCOMAS created a world-wide recognized forum for scientific exchange of new methods and their applications. Within ECCOMAS, the Industry Interest Group (IIG), created in 2015, takes care for the link of science and industry.

The Special Technology Session (STS) were organized at these big events since 1996. Their aim was and still is creating presentation possibilities for topics and applications of industrial relevance, in particular in aeronautics with its peculiar relation to computational methods, but also for other industrial sectors.

This paper provides and overview over the development of STS and gives examples of the changes and improvements of numerical methods in their application to aeronautics. The experience, the focus on challenges and the effort for keep the momentum of industry /academy cooperation through the STS at the ECCOMAS events are addressed.

1. ECCOMAS and the Special Technology Sessions (STS)

The European Community on Computational Methods in Applied Sciences (ECCOMAS) was founded in 1993. As a scientific organization, ECCOMAS groups together 23 associations from all over Europe with interests in the development and applications of computational methods in science and technology.

Although the focus of many member associations was and still is more on upstream scientific work, already the ECCOMAS Congress 1996 in Paris presented the first Special Technology Sessions (STS), which placed an emphasis on technologies and research of industrial relevance. The STS addressed different application areas as energy efficiency, civil engineering, metal forming and different numerical methods beside aeronautics research. Since then, the ECCOMAS Congress and aeronautics research developed. long traditional links. At each major ECCOMAS conference numerous STS for aeronautics applications were organised in nearly all key technology areas. The aeronautics industry of Europe was and still is a front runner in the application of advanced numerical methods especially in design. Aeronautics still has a need for advanced computational methods especially in fluid dynamics and structure mechanics, but also in aeroacoustics and overall optimisation.

For the ECCOMAS conferences, senior experts of the most relevant aeronautics technology areas were invited to organise their STS together with knowledgeable specialists as speakers from industry, the major aerospace research establishments (CIRA, DLR, NLR, ONERA, INTA, VKI, …) and numerous universities. The organizers of STS ensured a high scientific and technical quality of their sessions by their selection of speakers. Therefore, STS do not have the necessity of a review process as it is the case of Mini Symposia (MS).

The aim of the aeronautics related STS is to provide an overview on the state-of-the-art and the technology trends, especially of numerical methods for aeronautics applications and their related validations.

The network of Europe's aerospace associations E-CAero, to which ECCOMAS and its member association ERCOFTAC belonged, supported this technology dissemination by STS

at the different ECCOMAS conferences or at the WCCM-ECCOMAS Congresses, when the ECCOMAS Congress was combined with the World Congress on Computational Mechanics (WCCM).

2. The ECCOMAS Industry Interest Group (IIG)

In 2015 the ECCOMAS Managing Board established the Industry Interest Group (IIG) with the mission to take care of intensifying the links between research and industry within ECCOMAS. Among the different activities of the IIG linked to industrial applications some initiatives should be mentioned.

The increasing digitalization changes methods, tools and technologies for design optimization in industry, especially in aviation and surface transport modes. The need for the development of innovative aircraft for drastic emissions reduction requires the optimization with novel airframes and propulsion configurations. On initiative of the IIG a series of thematic conferences and workshop was launched addressing multi-disciplinary approach of CM3, which stands for Computational Multi Physics, Multi scales, Multi (big) data. Invited lecturers from research and industries, mini-symposia and a discussion forum addressed new possibilities for innovative optimization methods using amongst others Artificial Intelligence (AI) and machine or deep learning.

Multi-disciplinary scientific computing is becoming one of the powerful design instruments used both in academic research and industrial innovations. This trend has been enhanced by the continuously increasing capabilities of computer hardware and software, of managing information and of handling big data. The handling and analysis of multi-disciplinary big data is also gaining extreme importance in the entire industrial production process, in operation and process control as well as in intelligent systems for surveillance and safety procedures.

In March 2015 the first thematic conference CM3 - New Challenges for the Greening of Transport was hosted by the University of Jyväskylä, Finland. Two workshops followed: CM 2017 on big data challenges in transport in Brussels and CM 2019 on digital technologies in transport in Barcelona.

In November 2021 at the Technical University of Catalonia UPC in Barcelona, CIMNE hosted the ECCCOMAS thematic workshop *CM3 Transport 2021 on Methods, Tools and Technologies for Design in Aviation.* It is planned to publish selected peer reviewed papers of this workshop in the established Springer series Computational Methods in Applied Sciences, which is published together with ECCOMAS [2].

On initiative of the IIG, the ECCOMAS thematic conference DIME21 - Digitalized Methods and Tools for Industry and Healthcare was held in December2021 in Jyväskylä, Finland. DIME21 was hosted by JAMK, the University of Applied Sciences of Jyväskylä.

Multi-disciplinary scientific computing has become basis of the many powerful digital solutions and technologies used both in academic and industrial communities. This trend has been enhanced by the ever-increasing capabilities of computational technologies, collecting and storing of information and signals online, the decreasing cost of computer hardware, availability of cloud-based solutions for mobile use and raise of the artificial intelligence application. Advanced computational methods and tools are extremely important in analysis of big data from manufacturing processes, quality control and other intelligent systems for healthcare and industry. The DIME21 conference on digitalized methods and tools for industry and healthcare is motivated by the urgency of interlinking latest methodological advances from the computational sciences in to the real-life applications.

Since IIG was established, its members took care for the organization of STS at all large ECCOMAS conferences. The majority of STS addressed technology topics of aeronautics, but also STS on automotive of industry technologies and on numerical methods were organized.

In order to keep the momentum of the exchanges between researchers and technologists at the different ECCOMAS conferences, the Industry Interest Group (IIG) is taking the initiative to create a new STS-platform. IIG will coordinate this new initiative, with the endorsement of the ECCOMAS Managing Board.

The STS-Platform will facilitate to discuss on challenges between industry, research institutions and universities and to identify solutions of new technical or societal problems. For this the STS-Platform aims to be:

- a cooperative tool facilitating on-going exchange at conferences and workshops preferably in areas of aviation, surface transport and energy for addressing computational challenging problems of Industry;
- a web-based communication platform with archive giving access to stored scientific/technical data information with an open dissemination;
- an instrument to jointly identify technology topics and areas of industry priorities;
- a way keeping alive a STS-network along the large ECCOMAS events.

3. Technology trends as presented in aeronautical STS at the large ECCOMAS conferences

3.1 Special Technology Sessions at ECCOMAS conferences

From the begin of ECCOMAS a special relation existed with the aeronautics sector. The reason for this was the fact that the aeronautics industry has been a front runner in the application of numerical methods for its aircraft design. In the early 90ties, many aerospace companies were still actively involved in the development of numerical methods. The challenging goals of drag minimization at high speed and the demand for extreme light-weight aircraft structures led to requirements for the used numerical design tools that were more demanding than for other industrial applications in the view of accuracy, grid independence or the reliability of the numerical results.

While at the first large ECCOMAS conference with STS in 1996 only five of 14 STS addressed aeronautics topics, and also at the ECCOMAS-CFD conference in 2001 in Swansea the aeronautics STS were a minority, in den following large ECCOMAS conferences, the vast majority of STS addressed aeronautics application and numerical methods. But some other industrial applications as on surface transport were addressed in the STS.

The majority of the STS and their papers resulted from European aeronautics research projects, which were funded by the different Research Framework Programmes of the European Union.

Many projects, especially those addressing numerical methods for aeronautics application, published their results in the scientific Springer book series Notes for Numerical Fluid Dynamics and Multi-disciplinary Design (NNFM).

The ECCOMAS conferences introduced also the possibility of mini-symposia (MS) beside the STS. The MS addressed often more fundamental research upstream to industrial applications. They had to follow a review process before being admitted to the conference. For the STS, alone the organizer takes care for the quality of the contributing papers. By experience this ensured a high quality in nearly all STS.

The addressed aeronautical topics and the addressed numerical methods changed over the years at the large ECCOMAS events. Reasons for this are not only the technological progress and its

industrial application, but also the rapid growth of the performance of the computer hardware up to the use massive parallel computing.

3.2 Technological development in aeronautics and numerical methods over 25 years ECCOMAS conferences

In the following some examples will be given from STS presentations.

At ECCOMAS 1996 in Paris, David P. Hills, British Aerospace (today BAESYSTEMS or Airbus Operations) presented a paper on past successes and future challenges in numerical aerodynamics within the STS on industrial CFD of different transport modes. While Euler codes with viscous coupling were still working design tools, the use of multi-block structured grids was investigated for the Reynolds Averaged Navier-Stokes applications (RANSMB) (Fig. 1). The use of vector computers and massive parallel processing were considered at that time, as well as the use of unstructured meshes [3].

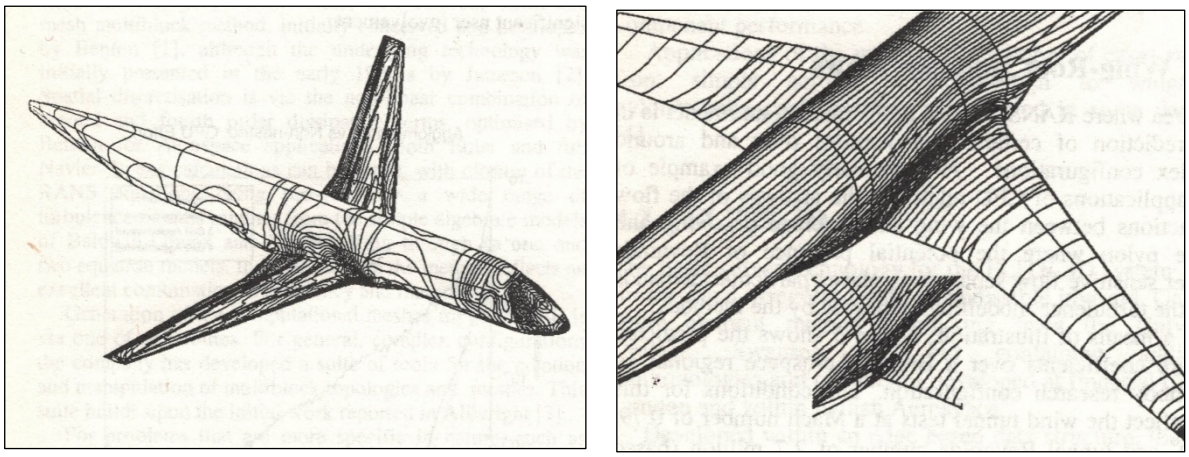

Fig. 1: RANS calculation of research wing body configuration at M = 0.79, alpha = 1°, Re = 2.7 million. Left: Pressure coefficients; right: Details on surface streamlines [3]

Eight years later in 2004 the significantly increased computer power and speed made RANS codes to the usual design tools even for complex 3D configurations. Automatic mesh generation and the capability of using high-resolution grids in the form of multi-block structures grids, unstructured meshes or hybrid meshes allowed the calculation of grid-independent results. The numerical solutions showed already very goog agreement with sophisticate wind tunnel tests.

At the ECCOMAS Congress 2004 in Jyväskylä in total 20 STS were presented [4]. Most of them presented the results of projects on aeronautics research from the Fifth Research Framework Programme of the EU.

Tab. 1: Overview of thematic areas of the STS at ECCOMAS 2004

ECCOMAS Congress 2004 in Jyväskylä, July 2004	
- Computational Fluid Dynamics:	**5 STS**
- Aeronautics Industrial Applications:	**12 STS**
- Other Industrial Applications:	**3 STS**

In their paper on advanced high-lift CFD analysis and design tools [5], Ralf Rudnik, DLR and Stefan Wallin, FOI showed the calculations by different RANS codes, using block structured, unstructured and hybrid high resolution meshes and the comparison with a low-speed wind

tunnel test at Airbus Bremen (Fig. 2). This shows that numerical simulations by advanced methods can reach a similar accuracy as the experiments in wind tunnels.

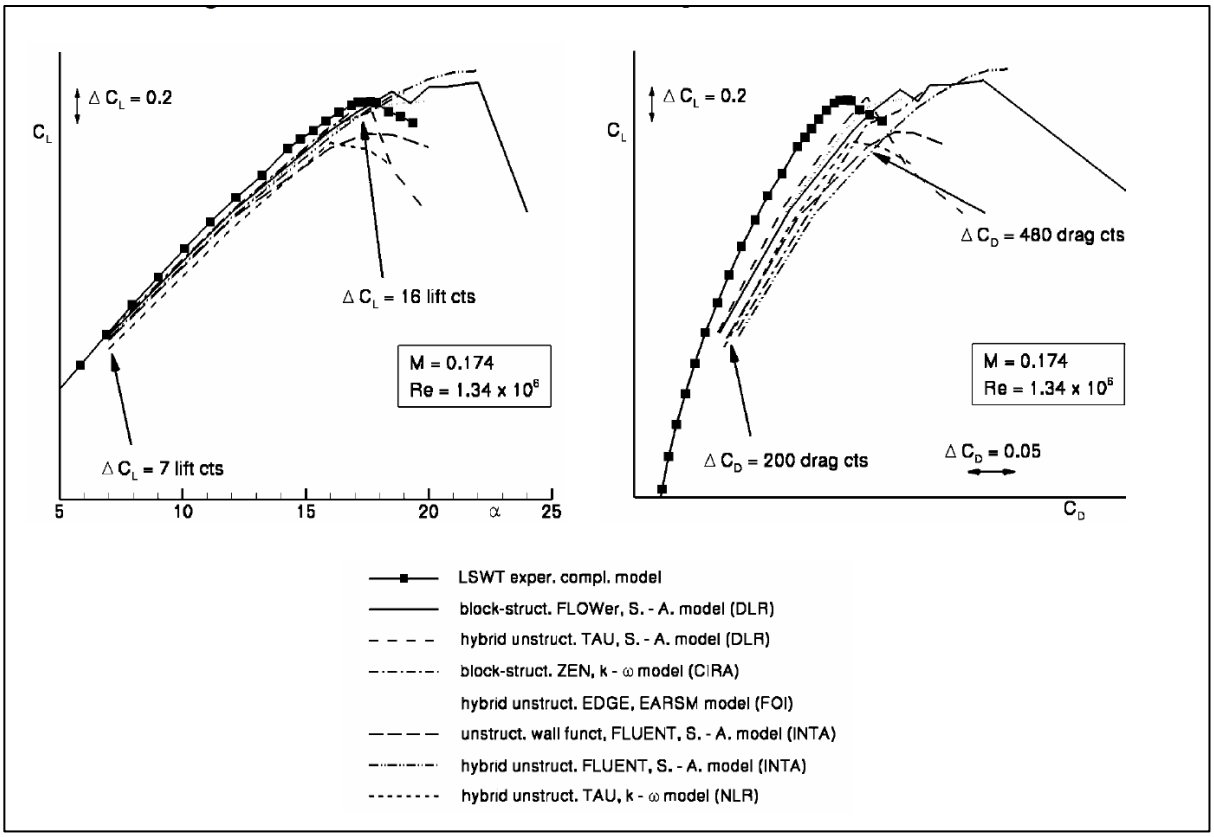

Fig. 2: Polar results of a benchmark calculation of the wing-fuselage model KH3Y in take-off configuration (source EUROLIFT project) [5]

The 5th ECCOMAS Congress in September 2008 had more than 2000 participants and saw a significant involvement of aeronautics in the programme. Andras Siegler, Director DG RTD-Transport, responsible for the European aeronautics research gave a keynote speech at the opening ceremony.

Tab. 2: Special Technology Sessions at 5th ECCOMAS Congress, Venice
30th June – 4th July 2008

STS	STS Title	Chairperson	Affiliation
STS-01	Flow Simulation and Validation in Aeronautics	Dietrich Knoerzer	European Commission
STS-02	Large Eddy Simulation - Research and Industrial Applications	Charles Hirsch	NUMECA Int.
STS-03	Drag Reduction Technologies	David Sawyers	Airbus-UK
STS-04	Introduction to Optimisation Methods and Tools for Multidisciplinary Design in Aeronautics and Turbo-machinery	Herman Deconinck	Von-Karman-Institute
STS-06	Wake Vortex Research in Europe	Thilo Schoenfeld	CERFACS
STS-07	MDO Tools for High Quality Design in Aeronautics (Part 1 - 3)	Jacques Periaux	CIMNE
STS-08	Advanced Simulation Tools for Aero Engines	Remy Denos	European Commission
STS-09	Simulation and Validation of the Combustion of Advanced Aero-engines	Ralf von der Bank	Rolls-Royce Deutschland
STS-10	Computational Aero-acoustics	Roland Ewert	DLR
STS-11	Design of a Supersonic Transport Aircraft with Reduced Impact on the Environment	Michel Mallet	Dassault Aviation
STS-12	High-Re Aerodynamics	Winfried Kühn	Airbus Deutschland
STS-13	Advanced Methods for Aerospace Structures	Peter Horst	TU Braunschweig

In his semi-plenary speech, Axel Flaig, Head of Flight Physics of Airbus addressed the need for eco-efficiency by design challenges in aerodynamics for future civil aircraft design. It was the introduction of the series of numerous aeronautics STS, which addressed the key areas of aeronautics technologies (Tab. 2).

At the ECCOMAS Congress 2012 in Vienna, Piotr Doerffer, IMP PAN Gdansk, Poland addressed in his STS the turbulent and transitional boundary layer interaction with a shock wave, a complex phenomenon, which is relevant for transonic wing design, nozzles, ducts or shock reflections. The papers of his STS presented the results of the EU-project UFAST and its successor TFAST, which were both coordinated by him. For capturing buffeting effect and shock oscillations, unsteady RANS codes (URANS) and - even more advanced – Large Eddy Simulations (LES) or delayed detached eddy simulation (DDES) methods were used, thanks to the performance of modern computers. In his paper George Barakos, Univ. of Liverpool addressed experimental and numerical investigations of unsteady shock wave / boundary layer interaction and its control. Fig. 3 shows the comparison of a transonic experiment of a biconvex wings in the INCAS wind tunnel with the numerical simulation, which EADS-Military performed by DDES methods [6]. Again, the high performance and good agreement with experiments could by shown for these advanced methods.

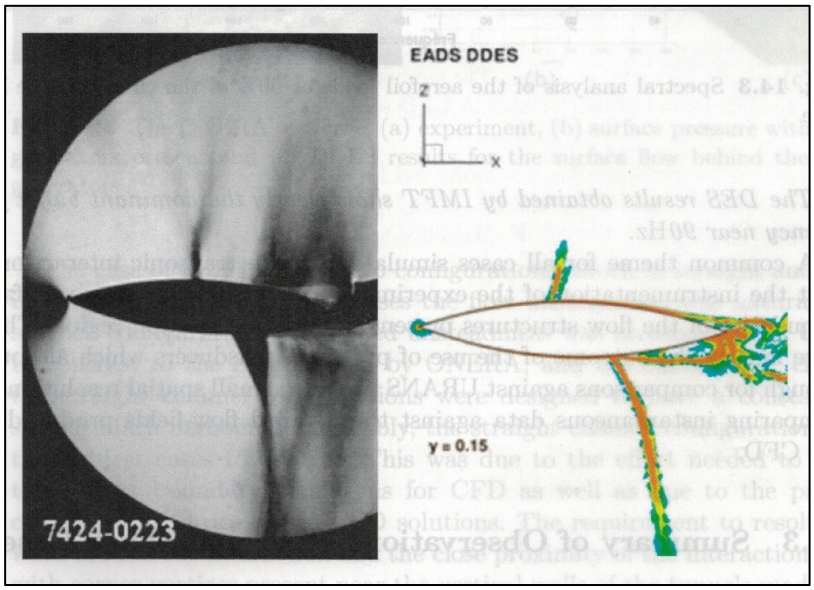

Fig. 3: Transonic testcase of biconvex aerofoil (upstream M = 0,76) [6]
Left: Experiment by INCAS; right: DDES calculation by EADS-M

At the ECCOMAS Congress 2016 on Crete/ Greece, eight STS on aeronautics and two for different transport modes addressed the relevant technology themes. Several of the aeronautics STS presented the technological achievements of projects from the 7th Framework Programme for Research and Innovation of the European Union: on shock wave boundary layer interaction presenting achievements of the TFAST project, on morphing technologies for aircraft wings showing SARISTU results or on wing high-lift systems of the DESIREH project.

In his semi-plenary speech, Cord Rossow, Head of the Institute of Aerodynamics and Flow Technology of DLR reviewed the technological perspectives for transport aircraft performance enhancement and identified two major challenges: how to efficiently simulate the whole flight envelope, and how to effectively employ numerical simulation in an unknown future hardware environment. At DLR, these challenges and the associated requirements have been addressed in the framework of the multidisciplinary project Digital-X [7]. The flight dynamics

simulations intended in Digital-X involved computations of the aircraft aerodynamics using CFD, its structural dynamics using computational structural mechanics (CSM), and its flight mechanics (FM). Fig. 4 shows the state of the aircraft in the transonic gust load case at the time of the peak load factor as predicted in Digital-X with CFD-FM-CSM coupling. The additional wing bending caused by the reaction to the gust load is clearly seen when compared to the shape of the trimmed aeroelastic equilibrium configuration.

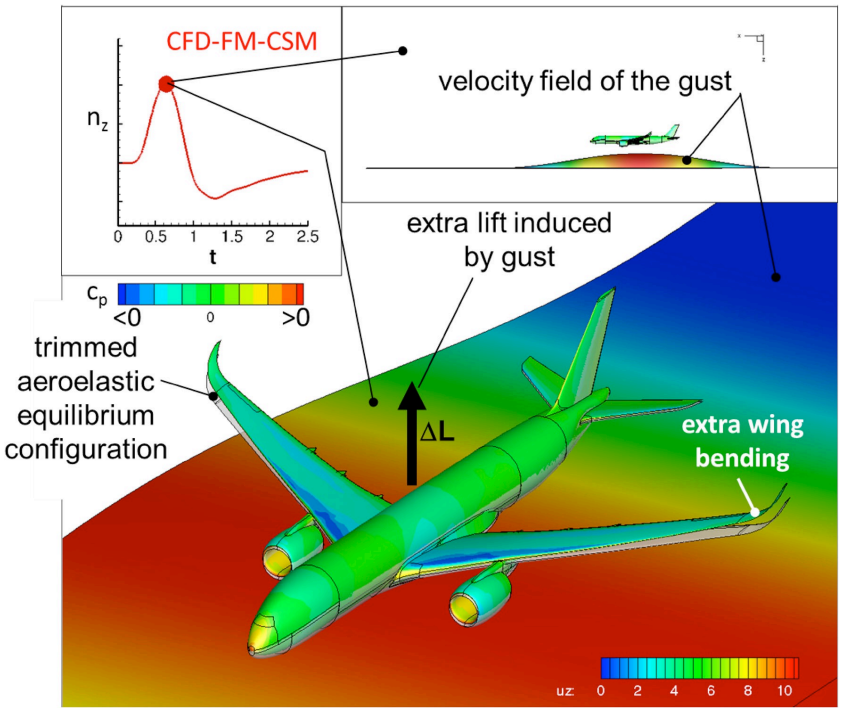

Fig. 4: Visualization of the gust response of the analysed aircraft as predicted by the Digital-X process (CFD-FM-CSM simulation of the transonic gust test case) [7]

At the ECCOMAS Congress 2016 on Crete, numerous mini-symposia had been organised partly with several sessions, which addressed mainly numerical methods that were also relevant for aeronautics application:

- ERCOFTAC SIG-45: Uncertainty Quantification in CFD and Fluid Structure Interaction,
- TOICA: Thermal Overall Integrated Concept Aircraft;
- Aerodynamic Strategies for the Global Optimization of Flying Configurations in Supersonic Flow;
- Order CFD Methods: Conclusions and Outlook;
- Surrogate-Assisted Evolutionary Algorithms in Aerodynamic Design/Optimization.

In order to help the conference participants in identifying the STS and MS of aeronautical relevance, a printed book of abstracts provided an overview on the aeronautics related sessions at the conference [8]. At the following large ECCOMAS conferences, such an STS book of abstract became a standard: at the ECCOMAS ECCM-ECFD Conference 2018 in Glasgow, UK and the WCCM-ECCOMAS Congress 2020 in Paris, France, which took place online in January 2021 because of the Corona-pandemic.

At the ECCOMAS ECCM-ECFD Conference 2018 in Glasgow, eight STS were organized partly together with the EU-China Platform of the international network ICARe. The STS addressed the technology areas:

- Alternative fuels and advanced propulsion technologies
- Aeronautics drag reduction technologies,
- Aircraft noise reduction technologies,
- New aircraft configurations,

- New aeronautical materials,
- Aircraft structures, structural health monitoring and smart and intelligent systems,
- Platform for Aircraft Drag Reduction Innovation – PADRI,
- Hybrid laminar flow, flow and vibration control in the EC-project AFLoNext.

Many papers of these STS presented the achievements of research and industrial activities within the EU Research Framework Programme of the European Union (FP7 and Horizon 2020).

Because of the Corona-pandemic, the WCCM-ECCOMAS Congress 2020 could be organized only in a virtual mode in January 2021. Nineteen STS with 67 papers were organized by senior experts from industry, research institutions, universities and the European Commission services [9]. They were focused on computational methods and their applications primarily in aviation, transport and industrial technologies. The virtual Congress allowed all registered participants to view all pre-recorded paper presentations at their convenience already in the week before the official conference. Instead of holding individual sessions, several STS were clustered to thematic live discussion panels with the STS chairpersons as moderators. The STS discussion sessions and their contributions provided an overview of the state of the art of technologies in computational and digitalized methods and tools for the application in aeronautics and other industries including related technology validations.

Several STS presented results of research projects from the Framework Programmes for Research and Innovation of the European Union (FP7 and Horizon 2020). The STS were clustered in the following groups:

- Aeronautics - Simulation and Validation (5 STS),
- Aeronautics - Design, Methods and Tools (7 STS),
- Automotive, Mobility and Environment (1 STS),
- Industrial Applications (6 STS).

With the support of the ECCOMAS IIG, the STS organizing committee decided to publish, selected contributions of the STS in the ECCOMAS-Springer series Computational Methods in Applied Sciences.

For the ECCOMAS Congress 2022 in Oslo, Norway in June 2022, the Industry Interest Group (IIG) organized again a number of STS, with an emphasis on research and technologies for greening future aviation and transport. The transition of aviation and transport towards climate neutrality by mid-century requires a significant increase in innovation.

Conclusion

Nearly 30 years ago ECCOMAS brought Europe's associations on computational sciences together and created with its large conferences a world-wide recognized forum for scientific and technological exchange in computational methods and their applications.

Since 1996 the Special Technology Sessions provided high quality sessions with special industrial relevance mainly in the field of aeronautics, but also for other industries.

The presentations given over the year in the STS at the ECCOMAS conferences provide an insight view on the development of numerical methods from the limiting computer performance in the 90ties up to the multi-disciplinary approach with big data handling today.

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