RTO SCIENTIFIC ACHIEVEMENT AWARD
TEAM NOMINATION FORM

Proposal of the candidature of

NATO/RTO/AVT-161

January 2012

Technical Team Reference Number: AVT-161

Type of activity: RTO Task Group

Title:
Assessment of Stability and Control Prediction Methods for NATO Air & Sea Vehicles

Background: The ability to accurately predict both static and dynamic stability of air and sea vehicles using computational fluid dynamics (CFD) methods could revolutionize the vehicle design process for NATO air and sea vehicles. A validated CFD capability would significantly reduce the number of ground tests required to verify vehicle concepts and, in general, could eliminate costly vehicle 'repair' campaigns required to fix performance anomalies that were not adequately predicted prior to full-scale vehicle development. As a result, significant reductions in acquisition cost, schedule, and risk could be realized. For both air and maritime vehicles, CFD has found its way into the design process especially for cruise performance where flows are generally characterized by attached steady flows (aircraft) or flat sea state (ships). Unfortunately military vehicles routinely operate well outside of these benign conditions. In fact, a significant portion of the vehicle preliminary design effort and cost is directed to those areas outside of the 'steady, attached flow or steady sea state' regime to ensure the vehicle operates as designed and can be qualified at the edges of the operating envelope. Aircraft must be qualified at many transient states that contain unsteady, highly separated flows over the vehicle. Maritime vehicles must operate in heavy sea states that are very difficult to accurately model. Unsteady fluid flows coupled with vehicle motions make this task a real challenge for current computational methods. However, significant progress is being made as documented in the recent NATO AVT-123 Symposium on "Flow Induced Unsteady Loads and the Impact on Military Applications". The dramatic increase in computing power and the affordability of PC clusters now make it feasible for the majority of NATO nations to undertake time-accurate CFD simulations and it is timely to carry out an assessment of the state-of-the-art.

Overall Objective: The objective of AVT-161 was to assess the state-of-the-art in computational fluid dynamics methods for the prediction of static and dynamic stability and control characteristics of military vehicles in the air and sea domains. The aim is to identify shortcomings of current methods and identify areas requiring further development.

Specific aero vehicle objectives: The Task Group evaluated CFD codes against comprehensive well documented data sets from wind tunnel, towing tank and flight trials. The team concentrated on stability and control issues and the prediction of vehicle motions, specifically in the flowing areas:

1) New stability and control data for a generic UCAV configuration. For this purpose new wind tunnel models were designed, built and tested by some of the participating nations.

2) The exchange of measured and computed data by means of the concept of virtual laboratory.
3) Best practice recommendations.

Specific naval vehicle objectives: The objectives for sea vehicles were to benchmark the prediction capabilities of systems-based (SB), potential flow (PF), and URANS CFD ship maneuvering simulation methods through systematic quantitative comparisons and validation against experimental data for course keeping in waves and low- and high-speed shallow calm water maneuvering. This approach built on the experience gained from the SIMMAN 2008 Workshop on "Verification & Validation of Ship Maneuvering Simulation Methods" and extended the calm/deep water test cases for low-speed KVLCC 1 & 2 tanker, medium speed KCS container, and medium speed 5415 surface combatant hull forms. Free-running model wave basin and captive model towing tank experimental data were identified and adopted as test cases, including simulation submission instructions to facilitate the comparisons. The simulation methods and experimental data were compared for assessment of simulation method capabilities and quality of the experimental data for:

1. Surface combatant course keeping in waves;
2. Low-speed tanker KVLCC2 shallow calm water maneuvering; and
3. High-speed catamaran shallow calm water maneuvering.

High-value science and technology achievements were accomplished due to naval-naval and naval-aero synergy, which was only possible under the auspices NATO AVT-161 through collaboration on experimental and computational methodologies and analysis.

Impact Statement:

Never in the history of AVT, have so many scientists and researchers (46 total) from so many NATO nations (14) gathered together to produce such a comprehensive package of both experimental and analytical data, for both air and sea domain vehicles. These data sets will have a great impact with regard to the development of future NATO air and sea platforms, thus, directly and indirectly supporting warfighters needs. In the four years that AVT-161 existed, it is estimated that the participating nations spent over €10 million on building and testing both wind tunnel and water tank models, to compile a database of experimental results, while running large computer models to produce analytical data comparisons. In addition to producing an enormous database of test and analytical results which will be used for years to come, AVT-161 spawned an unprecedented number of documented results. The work of this Task Group has produced one PhD dissertation, and several M.S.E. theses, plus 13 journal articles and 33 conference papers. There were also a significant number of spin-off activities, including 2 new Task Groups, one Specialist Meeting, and one Exploratory Team to further the work. The organizational methods alone which were developed by AVT-161 to achieve its goals have set a new benchmark for future Task Groups to build upon. It is abundantly clear that AVT-161 is a shining example of the mission of RTO to conduct co-operative research and information exchange and also exemplifies the mission of AVT improve the performance, affordability and safety of vehicles through the

advancement of technology. AVT-161 has produced a truly significant scientific contribution to the NATO knowledge base, with a direct measurable impact on defense vehicles, with an unprecedented level of international collaboration.

Technical Team Leader:

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Co-Chair: Dipl.-Ing. Andreas Schütte, German Aerospace Center – DLR, DEU

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Period of Activity: 2008-2011

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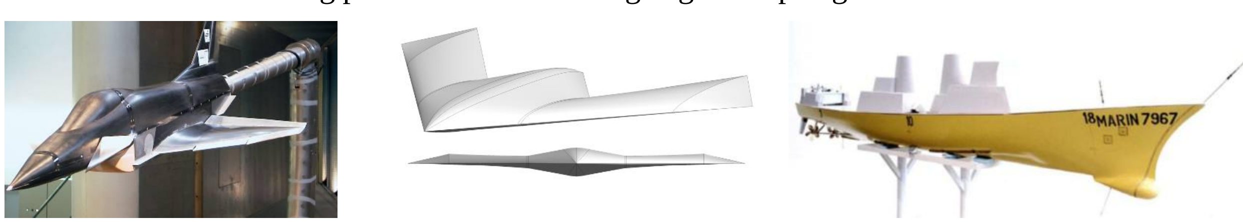
Details of Technical Achievement Warranting Nomination (three criteria):

1) Quality of science and technology

The objectives of AVT-161 included assessing the state-of-the-art in computational fluid dynamics methods for the prediction of static and dynamic stability and control characteristics of military vehicles in the air and sea domains. Regarding the air domain the focus are high agile UAV with a medium to long time flight performance. In implies a compromise between a high angle of attack performance capability and a sufficient wing aspect ratio. Furthermore, due to low signature requirements the shape of these kinds of configurations results into blended wing body configurations without tail planes or fins as well as a medium to high leading edge sweep angle. The latter is supporting the high AoA capabilities which leads to a vortex dominated flow field for medium to high AoA. The vertical flow characteristic dominating the aerodynamic performance depends on the leading edge sweep angle, leading edge shape and the flow parameters like Mach and Reynolds number. The aerodynamics is non linear in a wide range of AoA and is only captured by flight test or high fidelity state-of-the-art computational methods. These boundary conditions led to the major scientific task within AVT-161 as follows:

The whole concept of the AVT-161 Task Group was based on an integrated approach between computational methods and experiments. The philosophy was to apply CFD and experimental methods in parallel to support each other, get a common picture of the flow physics and aerodynamics and to verify the CFD results with the experiment. This integrated approach started initially by the use of CFD methods to define the shape of the target configuration and assessing the flight conditions of interest for further experimental wind tunnel tests and finalized in the interpretation of the entire flow physics and the assessment of the stability and control capabilities and recommendations regarding the computational methods.
Regarding the sea domain, a comparable strategy was followed. The prediction capabilities of ship maneuvering simulation methods were investigated through systematic quantitative comparisons and validation against experimental data. And for the ship domain the experimental data were gathered for three different geometries to benchmark the prediction capabilities of systems-based (SB), potential flow (PF), and URANS CFD ship maneuvering simulation method.

Within AVT-161 the first task was to come up with a sufficient target configuration, which had to be defined, designed and manufactured to produce high quality and high accurate aerodynamic performance and flow field data for computer code validations. For the see domain, different ship models were used to provide the experimental data for different purposes. The first air domain configuration was the DLR X-31 wind tunnel model with a double delta wing configuration with canard. The inner delta wing has a sweep angle of 57º and the outer 45º. The X-31 wind tunnel test delivered static and dynamic aerodynamic performance data simulating a real fighter aircraft configuration. The second and main configuration was a generic UCAV with a lambda wing plan form and a leading edge sweep angle of 53º.

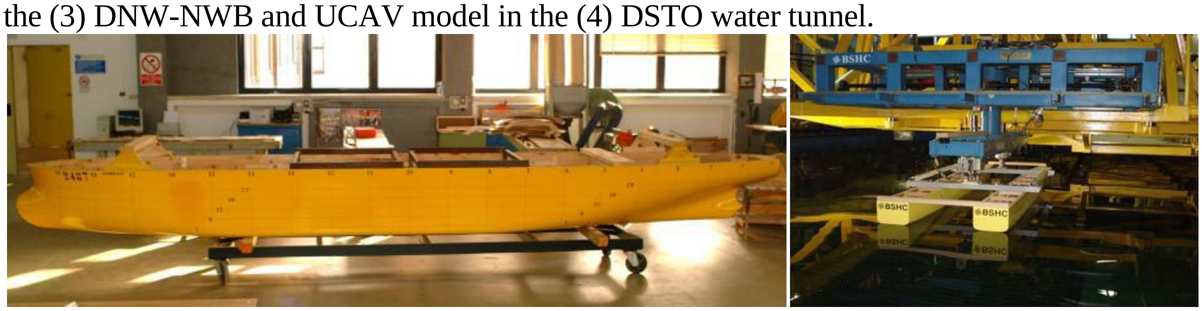


(1) X-31 experimental aircraft model, (2) Generic UCAV Configuration, (3) 5415M Ship model.

The model configurations, designed by DLR and EADS were manufactured at NASA LaRC. Both models were equipped with steady state and unsteady surface pressure sensors and an internal strain gauge. The design was based on a lightweight CFRP structure which was necessary for high speed dynamic tests in the wind tunnel. The UCAV model was modular with exchangeable leading edges and was prepared to establish control devices for further investigations.
For the sea domain the experimental data included 5415M model experiments for course keeping in waves, low-speed tanker KVLCC2 shallow, calm water manoeuvring and high-speed Delf Catamaran shallow, calm water manoeuvring. For 5415M, the experiments are conducted in the MARIN seakeeping and manoeuvring basin.

The second task was to set up appropriate wind tunnel tests to assess steady state and unsteady dynamic data from the wind tunnel for the air domain and water tunnel facilities for the see domain. This task also included the definition of measurement techniques and equipment for the test configurations and the test environment or setup within the wind tunnel and water test facilities. The first wind tunnel used was the low speed facility at DLR in Braunschweig which is part of the German-Dutch Wind Tunnel Association (DNW-NWB). The wind tunnel is equipped with a unique dynamic test capability for test aircraft models in maneuvering flight. At the DNW-NWB, steady state and dynamic maneuver tests were done with the X-31 and UCAV models. The test contained high accurate model positing measurements, surface pressure distributions, as well as aerodynamic forces and moment measurements, recorded simultaneously. For the UCAV models, additional infrared transition measurements were done. To determine the flow physics and three dimensional flow structure PIV measurements were done by two different PIV measurements teams from DEU (DLR) and FRA (ONERA) providing steady state and dynamic flow field data for a wide range of AoA and positions over the model configuration.

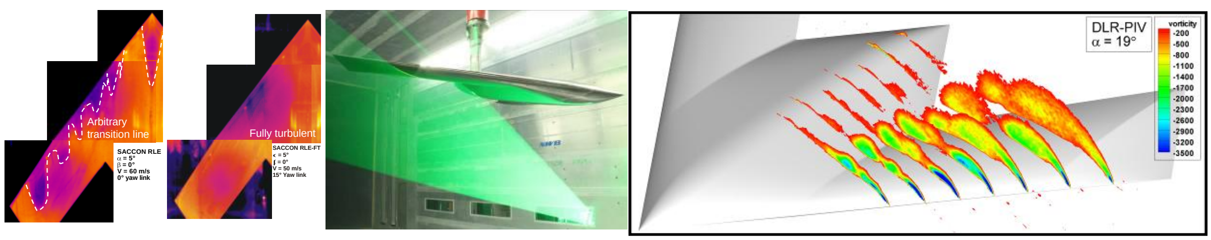
UCAV in the wind tunnel of the (1) DNW-NWB in Braunschweig and at (2) NASA LaRC, X-31 in the (3) DNW-NWB and UCAV model in the (4) DSTO water tunnel.



The experimental ship hulls: (1) KVLCC2 (INSEAN), (2) Delf Catamaran (BSHC)

For sea domain the experiments with the 5415M model, are conducted in the MARIN seakeeping and maneuvering basin. The model was appended with skeg, twin split bilge keels, roll stabilizer fins, twin rudders and rudder seats slanted outwards, shafts and struts, and counter-rotating propellers. In calm water, a self-propelled free model with passive, active, or no fin stabilizers under either damped or forced roll was tested and the course keeping of the model was investigated. In the presence of waves, the course keeping of the ship in different wave types such as regular waves and bi-chromatic waves were considered. The validation data included the wave elevation, ship motions, ship accelerations, rudder and fin angles and propellers revolutions. Also, propeller torque and thrust, and loads on bilge keels, rudders and fins were recorded. The seakeeping tests provided excellent information about the roll damping of the model. Valuable insight into the influence of the rudders and stabiliser fins on the roll behaviour was obtained. The tests in waves were conducted in various wave conditions with increasing complexity, which provided unique opportunities to validate computational methods.

The third task was to apply the different computational methods and the validations process. For this purpose a common validation matrix had to be setup again in an integrated approach together with the experimental tests. Eventually, an appropriate methodology to compare the results among each other was defined. On the air application side participants from 7 nations were involved comparing 9 different high fidelity CFD methods with each other and with the experimental data set. Within the sea domain, participants from 6 nations involving 4 different high fidelity CFD methods compared their results to each other and evaluated them against experimental data. The comparisons between so many different approaches led to a very confident benchmarking and assessment in terms of best practice approach selecting among others the right computational grids and applying the right physical models. Furthermore, this approach led to the assessment to identify gaps and to describe recommendations for further development.

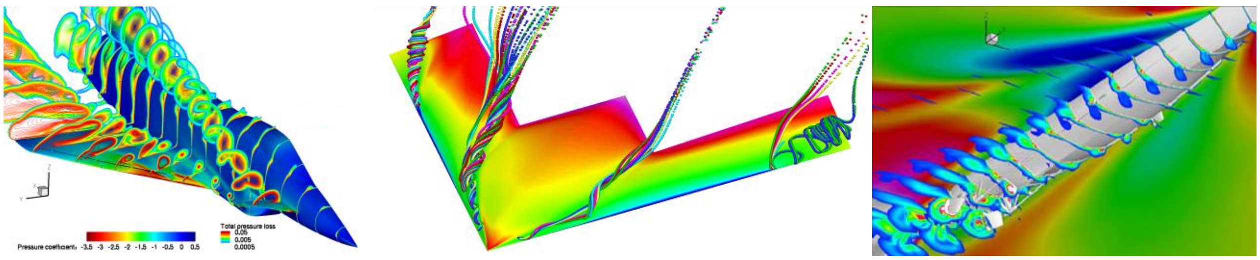


(1) Infrared surface measurement for transition detection, (2) PIV laser light sheet, (3) PIV results showing the vortex pattern over the UCAV.

Finally, the assessments were completed by taking alternative approaches into account like engineering methods, extended nonlinear system identification methods as well as advanced interpolation or prediction methods.

Summarizing:

AVT-161 utilized state-of-the-art computational and experimental tools to determine the ability to accurately predict the aerodynamics of maneuvering aircraft and ships for stability and control purposes. This was accomplished for aircraft by investigating the static and dynamic aerodynamics of two vehicles: the X-31 and SACCON, a generic UCAV. The integrated approach for conducting this research has been described, including the initial planning of the wind tunnel tests and the design of the SACCON UCAV configuration, which incorporated CFD, lower-order prediction methods, and wind tunnel capabilities. The CFD researchers have been actively involved in the planning of the test, and have all of the details of the experiments readily available via a Task Group website. In addition, common test cases (both static and dynamic) have been identified for both aircraft to form a basis for comparing the various computational and modeling approaches. This approach has shown itself to greatly enhance the interaction among the various sub-teams of the Task Group to predict, measure, and analyze the flight mechanics of these aircraft. Detailed results for the aircraft have been compared between researchers, including both numerical predictions and experimental data, on common cross plots so that discussions and knowledge building occurred among the team members. While the overall goal was to determine the state-of-the-art for computational capabilities in predicting stability and control parameters for aircraft, AVT-161 also conducted detailed “experiments” to assess the ability of grids, turbulence models, and time integration approaches to accurately predict these complex unsteady flow fields. The end products of this work have greatly increased the understanding of both aerodynamics and the ability to predict complex flow fields with various approaches.



CFD: (1) X-31 vortical structures by total pressure losses, (2) UCAV streamlines over the wing, (3) Under water ship hull vertical wake water structures.

<u>AVT-161 acquired a fundamental knowledge in steady state unsteady aerodynamics regarding medium swept delta wing with variable rounded leading edge geometries:</u>

- Greatly improved understanding of the flow physics around the X-31, UCAV and several ship hull forms.
- Established an integrated CFD/Experiment approach to enhance the knowledge transfer from both disciplines to an entire picture of aerodynamic performance and flow physics.
- Clearly demonstrated the ability to predict the aerodynamic stability and control performance of fighter aircraft and UCAV configurations in a certain range of the flight envelope and evaluated the limits.
- By comparing results from different nations/establishments using different numerical methods an extended benchmarking process was established and a knowledge transfer between each other regarding best practice procedures and common capabilities and fields of further development.

<u>AVT-161 provided necessary insight to enable framing of emerging research questions:</u>

- Challenged the ability of current turbulence models to accurately predict the complex, multi-vortex flow field which can develop on configurations with approximately fifty degrees of sweep; this led to detailed comparisons of various turbulence models and will eventually lead to improved capabilities for these types of flows.
- Reinforced the importance of the flow field in the vicinity of the leading edge of swept wing configurations and led to the creation of AVT-183 which will investigate these flows in detail. This will supply essential benchmark experimental results to aid in the improvement of turbulence models.
- Showed that current CFD capabilities are challenged to accurately and affordably predict the aerodynamics of maneuvering aircraft and ships; the requirements for performing such

simulations were established and future researchers will be able to improve predictions based on these findings.

- o Developed initial requirements for performing System Identification of maneuvering vehicles, which will lead to an affordable and fast method for estimating the stability of vehicles, especially for determining non-linear characteristics which could hamper a vehicle from succeeding at its mission.

2) Significance of results for defense

The Task Group also addressed in a broader view one of the RTB Emerged/Emerging Disruptive Technologies on "Autonomous Intelligent Technologies". UCAV platforms focused on in AVT-161 are capable to provide both high agility, combined with a good flight performance for long range and medium time mission capabilities. AVT-161 supported the development of autonomous combat platforms to reduce manning requirements in a Future Combat Air System, platforms to carry sensors within a full autonomous and cognitive system deployable in extreme conditions during special operations or irregular circumstances and platforms to carry ISR and weapon systems to dramatically reduce response times.

<u>Summarizing:</u>

AVT-161 established an important benchmark for simulating the flow around complex air and sea vehicles by:

- o Showing that current CFD methods are able to predict the static characteristics of these vehicles to within reasonable accuracy, even for highly non-linear flow fields.
- o Determining that dynamic motion simulations are predicted well, certainly to within engineering accuracy levels for predicting the stability derivatives for these vehicles.
- o Establishing the need for further improvements to turbulence models, especially for flows near leading edges of flight vehicles.
- o Initiating the prediction of dynamic motion using System Identification, which could lead to affordable and fast estimation of characteristics of vehicles without the need for numerous lengthy CFD simulations.
- o Starting the process of determining how well autonomous vehicles can be designed using CFD techniques to improve future NATO capabilities.

AVT-161 has built an incredible experimental knowledge base, including surface and off surface measurements, for maneuvering UCAVs, which will lead to greatly improved design of autonomous intelligent technologies.

3) Quality and degree of collaboration

The AVT-161 enabled Ph.D. thesis and academic accomplishments

- One Ph.D. dissertation and more than a dozen M.S.E. theses
- AIAA conference papers, collaborative across AVT-161
- Special sections in AIAA Journal of Aircraft, AST - Aerospace Science and Technology, collaborative across AVT-161
- Over 12 journal articles and 38 conference papers have been published on the sea domain side

Out of the AVT-161 Task Group the idea of AVT-183 was derived on "Reliable Prediction of Separated Flow Onset and Progression for Air and Sea Vehicles" to have a more detailed look at the basic physical problems on the progression and prediction of vortical flow around rounded leading edges on swept wing configurations with a focus on giving recommendations for changes or new development of algorithms for turbulence modeling. Furthermore, AVT-161 initiated a Specialists' Meeting AVT-189 on the Stability and Control prediction subject. One purpose of the

RSM was to get new ideas, participants and further contributions for the follow on Task Group AVT-201, which will extend the work on Stability and Control prediction methods. Some extensions will include looking at control devices and their effectiveness for blended wing body UCAVs, and to extrapolate the results to full scale applications and to investigate techniques for creating flight simulation models from CFD predictions.

On the naval side an Exploratory Team ET-118 was formed to identify appropriate test cases, applicable computational approaches, and available and required experimental data to provide recommendations for a technical team to achieve the expansion and benchmarking of prediction of ship performance in realistic operational conditions at sea and provide guidance for design analysis, including maneuvering in waves, shallow-water operations, and ship-ship interaction.

Annex A.

The following Annex gives an impressive list of publications generated by the cooperation of the members and contributors of AVT-161 and clearly underlines the role of each TG member.

The work of AVT-161 contributes significantly to the body of knowledge regarding the status of stability and control predictions methods for highly agile UAVs and ship maneuvering. The contributions achieved as a result of the participating nations working together far exceeded what would have been achieved by the individual countries working in isolation during the period of activity.

A.1. Dissertations

[1] Vallespin, D., “Computational Study of Vortical Flow Influence on Flight Mechanics of a Typical UCAV Configuration,” *PhD Thesis – University of Liverpool*, Liverpool, UK, 2011.

A.2. Journal Articles

[1] Cummings, R.M., Schütte, A., “An Integrated Computational/Experimental Approach to UCAV Stability & Control Estimation,” accepted and in final stages of publication in Special Issue of AIAA Journal of Aircraft.

[2] Vicroy, D.; Loeser, T.; Schütte, A., “Static and Forced Oscillation Tests of the SACCON Generic UCAV Model” accepted and in final stages of publication in Special Issue of AIAA Journal of Aircraft.

[3] Roosenboom, E.; Konrath, R.; Schroeder, A.; Pallek, D.; Otter, D.; Morgand, Stéphane; Gilliot, A.; Monnier, J.-C.; Le Roy, J.-F.; Geiler, C.; Pruvost, J., “Stereoscopic Particle Image Velocimetry Flowfield Investigation of an Unmanned Combat Air Vehicle” in final stages of publication in Special Issue of AIAA Journal of Aircraft.

[4] Tomac, M.; Rizzi, A.; Nangia, R.; Mendenhall, M.; Perkins, Jr., S., “Engineering Methods Applied to a UCAV Configuration - Some Aerodynamic Design Considerations” in final stages of publication in Special Issue of AIAA Journal of Aircraft.

[5] Rohlf, D.; Schmidt, S.; Irving, J. “Stability and Control Analysis for an Unmanned Aircraft Configuration Using System Identification Techniques “ in final stages of publication in Special Issue of AIAA Journal of Aircraft.

[6] Schütte, A.; Hummel, D.; Hitzel, S., “Numerical and experimental analyses of the vortical flow around the SACCON configuration,” accepted and in final stages of publication in Special Issue of AIAA Journal of Aircraft.

[7] Vallespin, D.; Boelens, O.; Da Ronch, A.; Badcock, K., “Validation of RANS Predictions for the Vortical Flow on a UCAV Model,” accepted and in final stages of publication in Special Issue of AIAA Journal of Aircraft.
[8] Frink, N.T., Tormalm, M.; Schmidt, S., “Overview of Three Unstructured CFD Studies on a Generic UCAV Configuration,” accepted and in final stages of publication in Special Issue of AIAA Journal of Aircraft.
[9] Schütte, A.; Cummings, R.M., Loeser, T., “An Integrated Computational/Experimental Approach to X-31 Stability & Control Estimation,” Aerospace Science and Technology (AST): http://dx.doi.org/10.1016/j.ast.2011.10.010, Nov. 2011.
[10] Tomac, M.; Rizzi, A.; Mendenhall, M.; Nangia, R, “Comparing and Benchmarking Engineering Methods for the Prediction of X-31 Aerodynamics “ in final stages of publication in special section of Aerospace Science and Technology (AST).
[11] Boelens, O., “CFD Analysis of the Flow Around the X-31 Aircraft at High Angle of Attack” in final stages of publication in special section of Aerospace Science and Technology (AST).
[12] Schütte, A.; Boelens, O.; Jirasek, A.; Loeser, T.; Oehlke, M., “Prediction of the flow around the X-31aircraft using three different CFD methods,” Aerospace Science and Technology (AST): http://dx.doi.org/10.1016/j.ast.2011.07.014, Nov. 2011.
[13] Jirasek, A.; Cummings, R., “Reduced order modeling of X-31 wind tunnel model aerodynamic loads” Aerospace Science and Technology (AST): http://dx.doi.org/10.1016/j.ast.2011.10.014, Nov. 2011.

A.3. Conference Papers

[1] Schütte, A., Cummings, R.M., Loeser, T., Vicroy, D.D., “Integrated Computational/Experimental Approach to UCAV and Delta-Canard Configurations Regarding Stability & Control,“ 4th Symposium on Integrating CFD and Experiments in Aerodynamics, 14-16 September 2009, von Karman Institute, Rhode-Saint-Genèse, Belgium.
[2] Boelens, O., “CFD Analysis of the Flow Around the X-31 Aircraft at High Angle of Attack,” AIAA Paper 2009-3628, 27th AIAA Applied Aerodyn. Conf., San Antonio, TX, June 22-25, 2009.
[3] Jirasek, A.; Cummings, R.M., “Application of Volterra Functions to X-31 Aircraft Model Motion,” AIAA Paper 2009-3629, 27th AIAA Applied Aerodyn. Conf., San Antonio, TX, June 22-25, 2009.
[4] Cummings, R.M.; A. Schuette, A., “An Integrated Computational/Experimental Approach to UCAV Stability & Control Estimation: Overview of NATO RTO AVT- 161,” AIAA Paper 2010-4392, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[5] Loeser, T.; Vicroy, D; Schuette, A., “SACCON Static Wind Tunnel Tests at DNW- NWB and 14´x22´ NASA LaRC,” AIAA Paper 2010-4393, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[6] Vicroy, D.; Loeser, T., “SACCON Dynamic Wind Tunnel Tests at DNW- NWB and 14´x22´ NASA LaRC,” AIAA Paper 2010-4394, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[7] Gilliot, A., “Static and Dynamic SACCON PIV Tests - Part I: Forward Flowfield,” AIAA Paper 2010-4395, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[8] Konrath, R.; Roosenboom, E.; Schröder, A.; Pallek, D.; Otter, D., “Static and Dynamic SACCON PIV Tests - Part II: Aft Flow Field,” AIAA Paper 2010-4396, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[9] Nangia, R.; Boelens, O.; Tormalm, M., “A Tale of Two UCAV Wing Designs,” AIAA Paper 2010-4397, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.

[10] Tomac, M.; Rizzi, A.; Nangia, R.; Mendenhall, M.; Perkins, S., "Engineering methods for SACCON configuration - Some Design Considerations," AIAA Paper 2010-4398, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[11] Rohlf, D.; Schmidt, S.; Irving, J., "SACCON Stability and Control Analyses Applying System Identification Techniques," AIAA Paper 2010-4399, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[12] Frink, N, "Strategy for Dynamic CFD Simulations on SACCON Configuration," AIAA Paper 2010-4559, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[13] Vallespin, D.; Ronch, A.; Badcock, K.; Boelens, O, "SACCON CFD Simulations Using Structured Grid Approaches," AIAA Paper 2010-4560, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[14] Tormalm, M.; Schmidt, S., "Computational Study of Static And Dynamic Vortical Flow over the Delta Wing SACCON Configuration Using the FOI Flow Solver Edge," AIAA Paper 2010-4561, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[15] Le Roy, J; Morgand, S., "SACCON CFD Static and Dynamic Derivatives Using elsA," AIAA Paper 2010-4562, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[16] Chakravarthy, S.; Chi, D.; Goldberg, U., "Flow Prediction around the SACCON Configuration Using CFD++," AIAA Paper 2010-4563, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
[17] Schütte, A.; Hummel, D.; Hitzel, S., "Numerical and experimental analyses of the vortical flow around the SACCON configuration," AIAA Paper 2010-4690, 28th AIAA Applied Aerodyn. Conf., Chicago, IL, June 28-July 1, 2010.
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