NATO Science & Technology Organization (STO)
Collaboration Support Office (CSO)
Applied Vehicle Technology Panel (AVT)

Preliminary Meeting Announcement and

**Call for Papers**

AVT-391 Specialists’ Meeting

on

**Advanced Wind Tunnel Boundary Simulation III**

organized by the Members of the

Applied Vehicle Technology Panel

AVT-391 Programme Committee

to be held in Washington DC, USA

X-Y May 2025 **tbc**

(in conjunction with the 55th AVT PBM, 19-23 May 2025)

Contributions and participation are invited from NATO Nations
plus Australia, Sweden and Japan

**Note: Final date for submission of abstracts is 08 April 2024**

**AVT-391 RSM on** **Advanced Wind Tunnel Boundary Simulation III**

**Framework of the Meeting**

The Applied Vehicle Technology (AVT) Panel of the NATO Science and Technology Organization (STO) is organizing, under its Performance, Stability & Control & Fluid Physics (TCPSF) Technical Committee (TCMSM), a Research Specialists’ Meeting (RSM) on the subject of “Advanced Wind Tunnel Boundary Simulation III”. The meeting is open to NATO Nations plus the three “Enhanced Opportunity Partner” nations Australia, Sweden, and Japan, and is classified as “NATO UNCLASSIFIED OPEN TO AUSTRALIA, SWEDEN and JAPAN”. The Meeting is to be held in Washington DC, USA, from X-Y May 2025, during the Spring AVT PBM week from 19 -23 May 2025.

A RSM is a medium-sized three-day event with up to 100 participants that aims at promoting exchange of state-of-the-art knowledge among an audience of experts and specialists on an important scientific or applied topic. The Programme Committee is responsible for selecting and inviting the Speakers. Observers, who present no paper, can also participate. RSMs result in a STO Report (Meeting Proceedings).

Selected papers from the RSM will be considered for publishing in the NATO STO Review Journal after an extensive technical peer review process. The authors of the subset of papers put forward for the peer review process and journal publication will be contacted after the RSM has taken place.

There will also be a Best Paper Award. The winner will be announced and awarded during the summary session of the RSM in Washington DC, USA.

**General Scope and Meeting Objectives**

One of the major goals of the STO is to monitor methods and technologies and to bring together experts to present and discuss the needs and ideas for these new technologies for application in their fields. As a follow-on of two previous successful RSM on this topic in 2018 and 2021, this RSM will provide an opportunity for technical experts to assess the state of the art in the use of high-fidelity computational fluid dynamics (CFD) simulation of wind tunnel flow and boundaries, including inflow, outflow, walls, and model support hardware. The Meeting Organizers highly encourage collaboration of computational and experimental experts to explore potential opportunities for improved integrated prediction capability and physical understanding.

The following objectives are to be addressed:

* Discuss activities to physically characterize wind and water tunnel and measurement processes for CFD (e.g. boundary/initial conditions and sensitivities of both test section and article, mass flow at diffuser);
* Presentation of work on high-fidelity CFD (Reynolds Averaged Navier-Stokes, Scale Resolving Simulation, Lattice Boltzmann, etc.) simulation of measured wind/water tunnel flow (to include matched post processing to the extent possible);
* Discuss results from coordinated activities involving facility simulations, for example:
	+ Discuss first results from AVT-387 “Common Research Wind Tunnels for CFD Verification and Validation” activities;
	+ Discuss results from NASA (high-lift) Common Research Model eco-system
* Develop recommendations for (1) the use of high-fidelity simulation of wind/water tunnel flows (geometries, boundaries, model support, etc.) and/or (2) experimental characterization for CFD comparison;
* Identify educational aspects (link to AVT-ET 235), with a view to establish a course on the requirements for and methods to predict wind tunnel interference effects, including blockage, buoyancy, slotted and perforated wall effects for transonic testing etc.
* Continue to identify key areas requiring further research and development, possibly resulting in support of mid to long term simulation and testing plans;
* Mature a longer-term Community of Interest for wind tunnel corrections and CFD validation in research, academia and industry.

**Background**

Understanding and modelling the flow physics in the wind/water tunnel is fundamental for at least two key objectives:

* Formulating a correction methodology to wall and support interference effects in order to estimate the free-air, interference-free characteristics of a test article;
* Properly simulating the boundary conditions imposed by the test environment for the validation of high-fidelity CFD tools.

The first objective was addressed from the 1930’s using potential flow modelling, and idealized boundary conditions. With advances in computing power, potential flow panel methods were introduced, therefore improving the shape and flow physics modelling of the boundary conditions. For example, the ventilated walls typically used in transonic wind tunnel testing could be modelled with first order cross flow physics or alternating open-jet/closed-wall boundary conditions, with varying degrees of success. These boundary conditions generally still rely on experimental data to calibrate the wall boundary model used for each specific facility over a range of operating conditions. Moreover, the underlying differential equation solved is still the linearized flow potential that is increasingly inappropriate when getting higher in the transonic regime or with larger test articles or with models at high angle of incidence.

Several AGARD publications by the Fluid Dynamics Panel summarized the past state-of-the-art for assessment and correction of wind tunnel interference: AGARDograph AG-109 published in 1966, CP-535 in 1993 and AG-336 in 1998. In these documents, CFD was identified as an evolving capability that would mature to provide improved corrections for cases that classical methods are not capable of addressing.

While this high-fidelity approach will not be required for all cases, some elements may command an increase in modelling fidelity beyond classical linear aerodynamic theory: growth in test article size, higher test Mach numbers, increased required accuracy, complex boundary conditions. Accommodation of these more recent demands on testing combined with the continued maturation of high-fidelity CFD necessitates an extension to the state-of-the-art in wall and support correction methodology.

The second objective emerged more recently for the validation of high-fidelity CFD. In performing such a validation, it is desirable that the simulation encompasses the entire wind tunnel experimental environment including the actual inflow, support hardware and the test section boundaries as opposed to the isolated test article. In that case, the wall boundaries and support hardware are no longer regarded as an interference effect but are considered to be fully part of the test situation. There is then no longer the need to formulate corrections to a free-air case. In doing so, it is expected that any difference between the experiment and the simulation is entirely connected to modelling and/or instrumentation issues and not to an incomplete representation of the test environment.

In both cases, it is critical to set up the boundary conditions of the in-tunnel simulations in such a way that the obtained solution closely replicates the state of the flow during the experiment. This is not a trivial problem. The test environment needs to be fully characterized, for example with a sufficient number of measurements to represent the upstream flow, the behavior of ventilated walls and the details of the tunnel geometry. Additionally, the test article and support system may also contain numerous complex geometric details.

The experimental workflow between raw sensor measurements and calculated quantities usually involves a number of data processing steps such as: calibration, filtering, averaging and combining information. This workflow may need to be replicated in the simulations.

Recommended practice developed by the AVT-387 “Common Research Wind Tunnel” will be discussed.

A carefully formulated set of recommended practices could greatly assist other researchers attempting similar validation problems and wind tunnel engineers developing wall interference assessments or predictions. Therefore, it is desirable to determine how these simulations are accomplished in practice and chart a path toward a consensus approach.

The first “Advanced Wind Tunnel Boundary Simulation Research Workshop” held in Torino, Italy in May 2018 (https://tinyurl.com/AdvWTSimI) and the second “Advanced Wind Tunnel Boundary Simulation Research Workshop II” held virtually in May 2021 (https://tinyurl.com/AdvWTSimII), gathered researchers to address these topics. There was consensus that a third meeting was needed to further extend the knowledge that was presented.

This RSM directly supports the AVT mission on “Improve performance, affordability, and safety of vehicle, platform, propulsion and power systems operating in all environments for new and ageing systems through advancement of appropriate technologies”.

 It will also facilitate exchange of state-of-the-art knowledge in high-fidelity computational simulations of wind tunnels including boundary effects and installation effects and it will develop a community of interest for wind tunnel boundary simulation topic to address key issues identified during the event. It will make progress toward establishment of a best practice for wind tunnel boundary simulation with high-fidelity simulations.

**AVT-391 Technical Programme Committee**

**Co-Chairs**

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**Deadlines and Preliminary Schedule**

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| **19 Dec 2023** | **Distribution of Call for Abstracts**To solicit abstracts from NATO nations and all other included NationsAfter: authors to send their abstracts to the Programme Committee |
| **08 Apr 2024** | **Abstract Submission Deadline** After: Programme Committee to select abstracts and to create the Meeting Programme from selected abstracts |
| **Jun 2024** | **Authors Informed of Selection Decision**Programme Committee to inform selected as well as rejected authorsAVT to dispatch authors’ information package to selected authorsAfter: selected authors to prepare their papers, presentation and clearances |
| **Dec 2024** | **Final Agenda Approved by the Programme Committee**Programme Committee to finalize the ProgrammeAfter: AVT to prepare and publish the official Meeting Announcement |
| **tbc Feb 2025** | **Submission of Advance Copy of US Presentations/Papers to US National Coordinator**Deadline for US authors to submit a copy of their advance paper to the US National Coordinator (special instructions to be issued with authors’ information package) |
| **tbc Mar 2025** | **Electronic Advance Copy of Presentations/Paper due at AVT**Deadline for all other authors to send an advance copy of their full scientificPaper to AVTAfter: Technical Evaluator to review all submitted papers |
| **tbc Apr 2025** | **Submission of Final Version of all Presentations/Papers to AVT**Deadline for all authors to send final cleared papers to AVTAfter: AVT to pre-release all papers on the STO website making them accessible to all registered participants of the Specialists‘ Meeting |
| **tbc May 2025** | **Specialists’ Meeting to be held in Washington DC, USA** |
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| **tbc Jun 2025** | **Submission of Corrected Manuscripts**Deadline for all presentations/papers to be included in the Meeting ProceedingsAfter: AVT to edit, prepare, produce Meeting Proceedings, which will be made accessible through the STO website. Selection of paper for peer-reviewed aeronautical journal. |

**Procedures**

**Invitation and Abstract Submission**

Authors are encouraged to submit a two (2) page abstract describing advances in integration of experimental analysis and computational simulation of wind tunnel flows. This includes advancements in accuracy or capability, challenges encountered, and recommendations for further improvement of computation simulation and experimental methods.

**Paper Requirements for Consideration**

The work presented in selected papers must report on:

1. A high-fidelity simulation (Reynolds Averaged Navier-Stokes, Scale Resolving Simulations, Lattice Boltzmann, etc.) of a measured wind/water tunnel flow (to include matched post processing to the extent possible), and should contain some of the following details:
	* A description of the experimental techniques and assumptions used in measurement of facility boundary conditions (for example facility geometry (with or without a test article), inflow and outflow boundary conditions, inflow turbulence, inflow angularity, mass flow, leakage, etc.).
	* The method of determination of experimental reference quantities and their sensitivity to those used in the high-fidelity simulation (typically Mach number, angle of attack, total pressure, dynamic pressure, etc.).
	* A description of the modelling techniques and assumptions used, including initial conditions and boundary conditions, and the extent of the test section modelled.
	* An uncertainty analysis on experimental and simulation results (modelling assumptions and approximations, input data, etc.)
	* Comparison of high-fidelity CFD with experimental data with uncertainty, using published uncertainty quantification techniques.
	* Recommendation(s) for (1) the use of high-fidelity simulation of wind tunnel flow, (2) experimental characterization required for CFD comparison, and (3) key areas requiring further research and development.

or:

1. Physical measurement needs for rigorous validation of CFD models. Specifically details of what physical geometry and instrumentation details are needed for the comprehensive validation of numerical models, including new methods and technologies. This should include impacts of facility geometry (model, supports and boundaries) and its proximity to test articles on measurements.

 or:

1. Requirements to disseminate the understanding and experience of rigorous wind tunnel testing within stake holder communities in universities and professional organizations. This includes understanding of the important issues affecting one or more of these metrics, i) metrology, ii) installation of instrumentation and hardware, iii) data reduction and corrections and iv) basic underlying assumptions of test setup.

**Additional Recommended Topics**

Authors might consider addressing the following topics in their papers:

* Comparison of characteristics and state of flow at the boundaries of the test section or in other pertinent parts of the facility.
* Variations in the modelling assumptions, with their corresponding effects (e.g. change in the extent of the test facility modelled, build-up with the support system (dynamic movement of support?), representation of explicit plenum flow vs. a ventilated boundary model).
* Needs/interest in digitalization of wind tunnels, incl. wall perforation
* Common Research Wind Tunnel activities (e. g. AVT-387).
* Knowledge capture, lectures that addresses numerical/experimental testing
* Identification of improvements in wind tunnel instrumentation, and flow measurements.
* Aspects of Uncertainty Quantification and propagation
* Discuss synergies of numerical simulations and wind tunnel experiments, exploration/synergy of data
* Data/AI re-enforced modelling for CFD
* Unsteady flow effects, incl. propeller flows, gust effects, buffet effects
* Aerodynamic dynamic derivatives
* Certification by analysis aspects
* Identification and appropriate justifications of improvements over established methods permitted by the high-fidelity modelling.
	+ A comparison of the applied methods to a reference work. Reference works may include classical wall interference techniques, experimental data, or another trusted work. The intent of the reference is to provide context for the work and/or justification for improvements upon classical techniques.
* A discussion of the “cost” and “risk” of the high-fidelity modelling compared with the benefit it provides, e.g.:
	+ Discuss the practicality of the possible use of the high-fidelity modelling in daily wind tunnel operation (is it intended to be applied for every run/data point in a wind tunnel test matrix or would it be limited to a few “check” cases or research type work?)
	+ Discuss the effort required (e.g., human expertise, CPU time, grid generation)
	+ Discuss the reliability of and the risk associated with the use of high-fidelity modelling (e.g., possible misinterpretation of results)

Authors’ names, complete email addresses and other pertinent information must be included with the abstracts. For this purpose, please use the Abstract Submittal Form (Annex 1).

**Please submit your abstract along with the Abstract Submittal Form by no later than 08 April 2024 via email to the Programme Committee Co-Chairs (contact data on page 6).** The program committee will select the abstracts. The full scientific paper (recommended limit of 12 pages) will be requested once the Programme Committee has selected the authors and developed the final agenda for the Meeting.

**Meeting Format**

* A 3-day meeting is planned, approx. 20 papers.
* The Programme Committee plans to have open topical discussions after groups of presentations, with 40-50% of the time in guided technical discussions.
* Full Meeting Proceedings will be published on the STO website: [www.sto.nato.int](http://www.sto.nato.int).
* Additionally, the Programme Committee will arrange for selected authors to publish papers in a special edition of a peer-reviewed journal. Authors should consider the quality of their initial submission to minimize subsequent corrections.

**Security Level, Clearance and Paper Preparation**

This Specialists’ Meeting is classified as NATO UNCLASSIFIED OPEN TO AUSTRALIA, SWEDEN and JAPAN. For details please consult the attached section on NATO and Partner Nations Overview (Annex 2). It is the responsibility of each contributor to fulfil the publication release and clearance requirements of his/her organization/company/affiliation and country to obtain clearance of abstracts and papers as needed. **An official clearance is mandatory in the US (see Annex 3)** and there may also be a requirement in other countries. If in doubt, authors should contact a Programme Committee Member.

Authors of papers selected for presentation and publication will be notified by the Programme Committee by no later than June 2024. The AVT Executive Office will then send an Authors’ Information Package containing templates, detailed instructions concerning the preparation of manuscripts, as well as, information about the clearance process to each lead author.

**Travel and Logistics**

Authors of contributions selected for presentation will not be financially supported by NATO. Authors are responsible for their own hotel and travel reservations based on suggestions given in the General Information Package which will be provided typically 4 months ahead of time. Expenses for travel and per diem costs are the responsibility of each author’s organisation and nation.

**Contact Information**

Any questions about the technical aspects of the scientific programme or the contents of papers should be addressed to the Programme Committee Co-Chairs listed above.

Questions on the administrative aspects of this Specialists’ Meeting or requests for further information about STO activities should be addressed to:

Ms. Isavela Kontolaimaki

AVT Panel Assistant

AVT Executive Office

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BP 25 - F-92201 Neuilly-sur-Seine, Cedex 01 - France

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***Thank you for your contributions
which are very much appreciated by the NATO community.***

**The NATO Science & Technology Organization**

The NATO Science & Technology Organization promotes and conducts co-operative scientific research and exchange of technical information amongst NATO nations and NATO partners. Being the largest such collaborative body in the world, the STO encompasses over 5000 scientists and engineers addressing the complete scope of defence technologies and operational domains. This effort is supported by the Collaboration Support Office, which facilitates the collaboration by organising a wide range of studies, workshops, symposia, and other fora in which researchers can meet and exchange knowledge.

For further information, please consult the STO web site: [www.sto.nato.int](file:///C%3A%5CUsers%5Cvelterop%5CDownloads%5Cwww.sto.nato.int)

The STO website provides a wide variety of information and on-line services ranging from overview information on the organization’s mission to news regarding upcoming events. You will find on-line access to more than 1800 scientific publications, as well as, information about current activities.

**Applied Vehicle Technology**

The Applied Vehicle Technology Panel, comprising more than 1000 scientists and engineers, strives to improve the performance, reliability, affordability, and safety of vehicles through advancement of appropriate technologies. The Panel addresses platform technologies for vehicles operating in all domains (land, sea, air, and space), for both new and ageing systems.

The members of the AVT community exploit and focus their joint expertise in the following fields:

* Mechanical Systems, Structures, and Materials
* Performance, Stability and Control, Fluid Physics
* Propulsion and Power Systems

For further information please consult the [AVT web site](https://www.sto.nato.int/Pages/technical-team.aspx?k=(*)&s=Search%20AVT%20Activities&View=%7b2C52FF39-CB1C-4A13-8129-6976E923EDEC%7d&FilterField1=ACTIVITY%5FPANEL&FilterValue1=AVT).

**Annex 1**

**Abstract Submittal Form**

**AVT-391 Specialists’ Meeting on**

 **“Advanced Wind Tunnel Boundary Simulation III”**

***Please attach a copy of this form to each abstract.***

**TITLE OF PAPER:**

**1. Author Title Name Nationality**

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***Please copy as required – recommended not more than 5 authors.***

**Note bene:***Authors should be listed in the order they will appear on the programme and in the final manuscript. Unless specified otherwise, the first listed author is presumed to be the lead author**having the major responsibility regarding content of the paper.*

**Annex 2**

**NATO and Partner Nations Overview
 with Geographical Abbreviations**

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| --- |
| **NATO NATIONS** |
| ALBANIA | ALB | LITHUANIA | LTU |
| BELGIUM | BEL | LUXEMBOURG | LUX |
| BULGARIA | BGR | MONTENEGRO | MNE |
| CANADA | CAN | NORTH MACEDONIA | MKD |
| CROATIA | HRV | NORWAY | NOR |
| CZECH REPUBLIC | CZE | POLAND | POL |
| DENMARK | DNK | PORTUGAL | PRT |
| ESTONIA | EST | ROMANIA | ROU |
| FINLAND | FIN | SLOVAKIA | SVK |
| FRANCE | FRA | SLOVENIA | SVN |
| GERMANY | DEU | SPAIN | ESP |
| GREECE | GRC | THE NETHERLANDS | NLD |
| HUNGARY | HUN | TURKEY | TUR |
| ICELAND | ISL | UNITED KINGDOM | GBR |
| ITALY | ITA | UNITED STATES | USA |
| LATVIA | LVA |  |  |
|  |
| **EAPC/PARTNERSHIP for PEACE NATION (PfP)** |
| ARMENIA | ARM | MALTA | MLT |
| AUSTRIA | AUT | MOLDOVA | MDA |
| AZERBAIJAN | AZE | SERBIA | SRB |
| BELARUS | BLR | SWEDEN\* | SWE |
| BOSNIA & HERZEGOVINA | BIH | SWITZERLAND | CHE |
| MACEDONIA | MKD | TAJIKISTAN | TJK |
| GEORGIA | GEO | TURKMENISTAN | TKM |
| IRELAND | IRL | UKRAINE | UKR |
| KAZAKHSTAN | KAZ | UZBEKISTAN | UZB |
| KYRGYZSTAN | KGZ |  |  |
|  |
| **MEDITERRANEAN DIALOGUE NATION (MD)** |
| ALGERIA | DZA | MAURITANIA | MRT |
| EGYPT | EGY | MOROCCO | MAR |
| ISRAEL | ISR | TUNISIA | TUN |
| JORDAN | JOR |  |  |
| **ISTANBUL COOPERATION INITIATIVE (ICI) NATION LIST** |
| BAHRAIN | BHR | SAUDI ARABIA | SAU |
| KUWAIT | KWT | UNITED ARAB EMIRATES | ARE |
| QATAR | QAT |  |  |
|  |
| **GLOBAL PARTNERS (GP)** |
| AFGHANISTAN | AFG | KOREA (Republic Of) | KOR |
| AUSTRALIA\* | AUS | NEW ZEALAND | NZL |
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| JAPAN | JPN |  |  |
|  |
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**\* Australia, Sweden and Japan are usually referred to as “Enhanced Opportunity Partner” (EOP)**.

**Annex 3**

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