INTEGRATED AIR AND MISSILE DEFENCE
CENTRE OF EXCELLENCE

IFB FINCON 25-05

Review study paper-report

"Comparative study of Computational Flow Dynamics methodologies, with respect to their effectiveness and accuracy in predicting hypersonic flows. How can this study assist the alliance in creating appropriate methods of modelling and simulation to address Hypersonic effectors".

PART III

SPECIAL PROVISIONS & TECHNICAL SPECIFICATIONS (STATEMENT OF WORK)

November 2025

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PART III

NATO UNCLASSIFIED
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1. **Statement of Work (SOW)**

1.1 The current Statement of Work (SOW) covers the special provisions and technical specifications that shall be covered by the Contractor for the services requested.

2. **General Specifications**

2.1 The requested services include the creation and launch of four (4) deliverable products – services, as described below in a specific and defined timeframe.

2.1.1 Writing and delivery of a Study Paper under the subject: “Comparative study of Computational Flow Dynamics methodologies, with respect to their effectiveness and accuracy in predicting hypersonic flows. How can this study assist the alliance in creating appropriate methods of modelling and simulation to address Hypersonic effectors”.

2.1.2 Writing and delivery of an extended abstract of the abovementioned study/report and creation of the geometry models of the vehicles to be used for the comparative simulation studies (test-cases).

2.1.3 Writing and delivery of an extended abstract of the abovementioned study/report and delivery of the produced comparative simulation data of the two CFD solvers, for the pre-specified test-cases at hypersonic speeds.

2.1.4 Publishing of the abovementioned paper-report into a scientific journal or magazine.

3. **Technical Specifications - Description of Deliverables**

3.1 Deliverable “1”: Extended abstract of Review study paper-report

3.1.1 It concerns an extended abstract of the Study Paper of par 2.1.1 with additional information on the geometrical models of the vehicles to be used for the simulation test-cases and the selected flow conditions that will be used in the corresponding CFD simulations.

3.1.2 Structure: Typical

3.1.3 Length of paper: Not less than 3.000 words.

3.1.4 Language: English Language.

3.1.5 Delivery Date: NLT 31 March 2026.

3.1.6 Authors: From the side of IAMD CoE two co-authors will be mentioned in the paper. These persons will cooperate with the scientific staff of the Turbomachines & Fluid Dynamics Laboratory (Technical University of Crete) in order to prepare the extended abstract.

3.2 **Deliverable "2" Interim Report:**

It concerns an interim report of the Study Paper of par. 2.1.1, with additional information on the produced comparative simulation data of the computational methodologies, for the pre-specified test-cases at hypersonic speeds.

3.2.1 Structure: Typical

3.2.3 Length of paper: Not less than 8.000 words.

3.2.4 Language: English Language.

3.2.5 Delivery Date: NLT 31 July 2026.

3.2.6 Authors: From the side of IAMD CoE two co-authors will be mentioned in the paper. These persons will cooperate with the scientific staff of the Turbomachines & Fluid Dynamics Laboratory (Technical University of Crete) to prepare the interim report of the Study Paper.

3.3 **Deliverable "3" Study/Report:**

3.3.1 Subject:

"Comparative study of Computational Flow Dynamics methodologies, with respect to their effectiveness and accuracy in predicting hypersonic flows. How can this study assist the alliance in creating appropriate methods of modelling and simulation to address Hypersonic effectors".

3.3.2 Pillars:

The Study/Report should be divided into three (3) stages/chapters, which will provide:

(a) The development of digital geometrical models of two (2) hypersonic vehicles, corresponding to the **BOLT** and the **HIFiRE-5** experiments, or alternative, using CAD (Computer-Aided Design) software.

(b) The performance of flow simulations around the corresponding geometrical models in relevant flow conditions (using different Computational Fluid Dynamics methodologies - different solvers, different turbulence models, different computational procedures), and the subsequent analysis of the simulated physical phenomena, the accuracy, convergence, easiness of use, efficiency and effectiveness of the corresponding methodologies, with respect to hypersonic flow simulations.

(c) Propose Best Practices for the flow simulation of hypersonic flight using CFD solvers in general, and how those best practices can assist the alliance in creating appropriate methods of modelling and simulation to address Hypersonic effectors.

3.3.2.1 **Stage/Chapter 1**

At this stage, a reference should be made to the development of the digital geometrical models to be used for the hypersonic flow simulations. It is proposed that 2 different geometrical models will be developed for CFD simulations, corresponding to 2 well-known experiments: the first one should be based on the BOLT experiment, while the second one should be based on the HIFiRE experiment. Similar experiments will be also considered as alternatives to the aforementioned ones, according to the availability of data. For the experiments, proper flight conditions will be selected, to be compatible with the capabilities of the CFD methodologies under comparison, which will be determined during the initial phase of this study.

3.3.2.2 **Stage/Chapter 2**

At this stage, reference should be made to the performance of flow simulations around the corresponding geometrical models, in the predetermined flow conditions, using different Computational Fluid Dynamics methodologies, such as different flow solvers, different turbulence models, and different computational procedures. Two open-source CFD software, OpenFOAM and SU2, respectively, will be used as a starting point. However, alternative software may be used, according to the results of this study. In the subsequent analysis of the simulated physical phenomena, the accuracy, convergence, easiness of use, efficiency and effectiveness of the alternative computational methodologies, with respect to hypersonic flow simulations, will be studied. This report should analyze and provide data, as far as possible, for the comparative performance of the alternative computational methodologies and their effectiveness in predicting the phenomena observed in flight at hypersonic speeds.

3.3.2.3 **Stage/Chapter 3**

At this stage, a summary of the above, and a reference will be made to the Best Practices for the flow simulation of hypersonic flight using CFD solvers in general, and especially for the methodologies under comparison, and how those best practices can assist the alliance in creating appropriate methods of modelling and simulation to address Hypersonic effectors. Extensive discussion, concerning the CFD simulation of hypersonic flight, and the accuracy in predicting the relevant thermo-aerodynamic phenomena, will be included.

3.3.3 Structure: Typical scientific paper.

3.3.4 Length of paper: Not less than 15.000 words.

3.3.5 Language: English Language.

3.3.6 Delivery Date: NLT 30 November 2026.

3.3.7 Authors: From the side of Integrated Air & Missile Defence Centre of Excellence (IAMD CoE) two co-authors will be mentioned in the paper. These persons will cooperate with the scientific staff of the Turbomachines & Fluid Dynamics Laboratory (Technical University of Crete) to prepare the publication (paper).

3.3.8 “This study was funded by the Integrated Air and Missile Defence Centre of Excellence (IAMD COE) and any intellectual property resulting from the work covered by this will be property of the IAMD COE. This paper reflects only the IAMD COE policies and its author(s)’ positions and it is not intended to create any legal obligations nor does it reflect NATO’s policies or positions, or engage NATO in anyway”.

3.4 **Deliverable “4”**

3.4.1 The report of par. 3.3 (Deliverable “3”) (properly prepared in scientific publication format) will be submitted for publication into a scientific journal or magazine.

3.4.2 The selection of the scientific journal or magazine will be under the choice of Professor’s Ioannis Nikolos, competent/responsible professor of the Turbomachines & Fluid Dynamics Laboratory (TurboLab-TUC) of the School of Production Engineering & Management of the Technical University of Crete (TUC) (hereinafter “responsible professor”), following the respective approval by the IAMD COE (see below par. 4.5.2).

3.4.3 Delivery Date: NLT 30 June 2027.

3.4.4 Any extra cost regarding the Publishing will be covered by TUC.

3.5 All the required documentation (report, documents for compliance, etc.) shall be written - submitted in English and should be signed by the Contractor.

3.6 On the last Friday of each month, Prof. Nikolos and his team will provide the IAMD CoE with a presentation/update on the progress of the study and findings so far. These presentations/updates may be used by the IAMD CoE for internal purposes. Additionally, a presentation/update of a similar level can be requested from Prof. Nikolos at any time, with five (5) working days' notice.

3.7 Any details required for the above requirements will be provided by the IAMD CoE competent official (Concept Development & Experimentation BH) in written.

4. **Project Management**

4.1 The research project will be undertaken and managed by Prof. I.K. Nikolos, Director of the Turbomachines & Fluid Dynamics Laboratory, Technical University of Crete.

4.2 The responsible professor shall:

4.2.1. Ensure that all associates, who will be working with him on this project, understand, respect, and will abide by all conditions of this agreement and all related agreements.

4.2.2 Devote his best endeavors to achieve the technical goals described in paragraph “3” and meet the reporting schedule described in paragraph “6”.

4.2.3 Not assign, discuss, or sub-contract any part of the technical study outside of the scientific personnel of the Turbomachines & Fluid Dynamics Laboratory without the prior written consent of IAMD CoE.

4.3 Non-Disclosure

4.3.1 In the context of the Contract, the IAMD CoE may disclose verbally or in writing, information about IAMD CoE’s own intellectual property, pending or filed patents or research intensions and directions. This may be necessary to allow Prof. Nikolos to fulfil this contract. Prof. Nikolos agrees not to disclose any of this information to any third party.

4.3.2 The responsible professor agrees not to make any commercial gains, by the sale of products or information related to any aspects of the current contract.

4.3.3 The responsible professor will ensure that all project members will respect the commercial confidentiality of information supplied by IAMD CoE in relation to the work described in this agreement. Prof. Nikolos will obtain all project member’s agreement that they will not disclose to any third party any information or results related to this work.

4.4 Intellectual Property

4.4.1 Any intellectual property resulting from the work covered by this agreement will be the property of IAMD CoE. This includes reports, calculations, inventions, discoveries, or otherwise patentable material. Should Prof. Nikolos make, during the execution of this project, or at any time thereafter, an invention or inventive step based on or derived from IAMD CoE’s disclosures, or work carried out within this project, Prof. Nikolos agrees to disclose and assign any such inventions to IAMD CoE.

4.4.2 The responsible professor shall:

4.4.2.1 Disclose promptly to IAMD CoE full details of all inventions, discoveries, improvements, or other novel material whether patentable or not, arising from the work covered by this agreement.

4.4.2.2 Assist IAMD CoE and make available to IAMD CoE all information required to make and pursue applications for patents arising from the work or related to this agreement.

4.4.3 IAMD CoE will investigate each disclosure submitted by Prof. Nikolos and, if it elects to file patent application thereon, agrees to pay all expenses in connection with the preparation and pursuance of such patent application or applications which it may decide to file as deemed appropriate. The appropriate research

members of Prof. Nikolos team will be acknowledged as the inventors or co-inventors (as appropriate) for their intellectual contribution in any patent application or publication.

4.4.4 If the responsible professor petitions IAMD CoE in writing to release any of the rights to any inventions, discoveries, novel information or any patent granted thereon, which by this Agreement are assigned to IAMD CoE, the latter will consider and act on such petition, but it is not obliged to release any of its rights to the responsible professor.

4.4.5 Any inventions, discoveries, or novel information, within the scope of this agreement and held by the responsible professor prior to the date of signing of this Agreement and not included in this or any earlier Agreement will not be covered by this Agreement.

4.4.6 IAMD CoE will:

4.4.6.1 Perpetually indemnify the responsible professor against any costs, losses, and expenses arising from the pursuance or future servicing of any patent arising from the work covered by this agreement or from any future commercial exploitation of any information or inventions arising from the work covered by this agreement howsoever those costs, losses, or expenses may arise.

4.4.6.2 Recognize the responsible professor‘s ownership of any invention or patentable idea, which is outside the scope of the current project. In such cases IAMD CoE will be open to negotiation on patent ownership, royalties etc. as part of a separate agreement. Patentable ideas within the scope of the project remain the property of IAMD CoE with the responsible professor (and the involved members of his team) receiving due acknowledgement.

4.5 Publication and Publicity

4.5.1 Neither party shall use the other parties name in any publication or publicity material unless mutually agreed in advance in writing.

4.5.2 The IAMD CoE:

4.5.2.1 Has the sole right to grant permission for publication and such permission must be obtained in writing prior to submission for publication of any information related to the matters covered by this agreement. The manuscript should be submitted to IAMD CoE for consideration, at least 20 days prior to the date of submission for publication.

4.5.2.2 Actively encourages and seeks publication but reserves the right to withhold permission if confidentiality is required for security reasons.

4.5.2.3 Agrees not to unduly, willfully or unnecessarily withhold permission for publication.

5. **Guarantee**

No special guarantee is required by the Contractor.

6. **Delivery - Shipping costs**

6.1 All services requested, and deliverables shall be completed, provided and delivered to the IAMD CoE as below:

6.1.1 Deliverable “1”: Delivery NLT 31 March 2026.

6.1.2 Deliverable “2” Delivery NLT 31 July 2026.

6.1.3 Deliverable “3” Delivery NLT 30 November 2026.

6.1.4 Deliverable “4” (Publishing of Deliverable 3): NLT 30 June 2027.

6.2 Any delivery or shipping costs (e.g. for the publication, etc.) will be borne by the Contractor.

7. **Contractor’s Standards**

7.1 The Contractor shall establish, document and implement a Quality Management System with procedures that satisfy the ISO 9001 standards.