RCloud Tasking Form – Part B: Statement of Requirement (SoR)

Title of Requirement	**Bio Inspired propulsors phase II**
Requisition No.	**RQ0000005919**
SoR Version	**1.0**

1.	**Statement of Requirements**
1.1	**Summary and Background Information**
	A feasibility needs to be conducted to investigate the scaling of bio-inspired propulsion methods to assess their suitability for use on large maritime platforms and at high Reynolds numbers. Bio-inspired propulsion methods are receiving increased attention in open source literature. The applications of such propulsion methods is largely limited to small scale objects such as robotic fish and much of their study aims at understanding the efficiency of the animals that they are mimicking. Little attention has been paid to the feasibility of using these methods at large scales. In order to carry out a feasibility, new numerical tools need to be developed which are capable of simulating complex dynamic motion at high Reynolds numbers. Complex dynamic motions can be simulated using the Immersed Boundary Methods (IBM) code developed by Dr [Redacted] at the University of Southampton but further developments are required to allow the simulation of high Reynolds number systems. This project is aimed at developing the IBM code to allow efficient computation of large complex systems. A short term contract was awarded due to the financial constraint the current research mandate ending at the end of the current financial year. DST has now approved funding for another year to continue the work, prior to the release of the next research mandate. There is a lack of information on bio-inspired propulsion system for high Reynolds number applications. The original intention was to award a multi-year contract to develop an accurate simulation tool to study the hydrodynamic and hydroacoustic performances of a flapping foil. The constraint of the end of the current research mandate means any contract must finish by the end of the current year. Prof [Redacted] at the University of Southampton is an expert in bio-inspired propulsion systems and has developed the Immersed Boundary Method (IBM) Computational Fluid Dynamics (CFD) code suitable for flapping foil simulations. A short contract was awarded to the University of Southampton to conduct preliminary investigation on the limitations of the current Raynolds-Averaged Navier-Stokes (RANS) simulations of flapping foils when applying to high Reynolds numbers.

The key requirement for maritime platform development is to operate at a minimal signature to be detected by other threat platforms. These signatures can be in the form of radiated acoustic noise (RAN) typically produced by numerous rotational and reciprocating machinery components, such as the engine and propellers. Several studies have been conducted to reduce the noise to improve current designs, such as efficient design inspired by nature. Animals have been known for their efficient propulsion underwater associated with the less perturbed flow and less noise compared with underwater vehicles, suitable for long-distance travel.

In the previous study, reasonable flapping foil sizes for large underwater platform systems have been predicted based on chord-length Reynolds numbers to be around ten million. Any experiment at that high Reynolds number needs complex setups making the fluid flow simulation a preferable tool. However, high Reynolds number simulations are expensive as the grid size is required to solve smaller structures for the accuracy of turbulent flow solutions. Immersed Boundary Method (IBM) is known for its speed because of the Cartesian grid and accurate solver using Large-eddy Simulation (LES). The IBM code developed by Dr [Redacted] has been tested and improved for the flow over moving bodies for various kinematics, shapes, and multibody setups. The current challenge is finding a robust wall model for LES suitable for IBM as a denser grid required at a high Reynolds number. IBM requires a different wall model setup than CFD codes with body-fitted mesh. Flapping foil simulations require a particular wall model to handle dynamic pressure gradients.

In addition, there is also a need to develop IBM that can simulate resolved flow using highly parallelized cores to maintain accuracy for turbulent flow conditions for very high Reynolds numbers. Increasing scalability of IBM at high-performance computing facilities can be used as a benchmark to the IBM with wall model. In the future, increased scalability will allow running fully resolved simulations at high Reynolds numbers.

1.2 Requirement

General requirement:

The requirement is to build on previous work with University of Southampton to produce a wall model which can be used with a highly parallized immersed boundary method CFD code to enable efficient simulation of complex, dynamic systems at large Reynolds numbers.

The approach:

	The approach will be to use machine learning (ML) methods to train a turbulence model which can be used in the near wall region, where the grid resolution has the highest requirements, in order to increase the maximum Reynolds number which can be simulated for a given grid size or computational cost. This step is essential to simulate large scale propulsion devices such as tandem flapping foils, in a practical time frame. The ML wall model will be tested for different geometries and Reynolds regimes aiming to properly generalise on the highest Reynolds regime limiting case. In parallel, the efficiency of the current IBM code at the University of Southampton will be improved by improving its parallel core scalability and maintaining its accuracy. *The objectives:* • Improving current wall model for immersed boundary method code at the University of Southampton, with the possibility of using a learning algorithm. • Testing the wall model solver on the dynamic aspect of flapping foil at several high Reynolds numbers cases. • Improving parallel core scalability for current CFD code. • Provide benchmark on dense grid simulations for the wall modelled code. • Provide insights for future studies of flapping foils at increasing Reynolds number to a larger extent.
1.3	**Options or follow on work**
	The current work is limited to one year due to the funding constraint. There is a possibility to continue this line of research with a further PDRA. Once the wall model has been established then feasibility studies can begin at large scales. The validation of the large scale simulations will not be trivial as experiments at high Reynolds numbers have not yet been carried out in the literature, and so experimental studies may also be required.
1.4	**Contract Management Activities**
	Monthly reports and quarterly meetings
1.5	**Health & Safety, Environmental, Social, Ethical, Regulatory or Legislative aspects of the requirement**
	N/A

1.6	Deliverables & Intellectual Property Rights (IPR)					
Ref.	**Title**	**Due by**	**Format**	**Expected classification** (subject to change)	**What information is required in the deliverable**	**IPR Condition**
D - 1	Report on progress	T0+1 Month and repeat every month	Email report	[Redacted]	Monthly update on technical progress, progress compared with project schedule, any foreseeable risks or issues.	Default RCloud Agreement Terms and Conditions shall apply
D - 2	Quarterly progress meetings	T0+3 months and repeat every 3 months	Presentation	[Redacted]	Presentation to include but not limited to: • Update on technical progress • Progress report against project schedule. • Review of risk management plan. • Commercial aspects. • Review of deliverables. • Risks/issues. • GFA and supplier performance	Default RCloud Agreement Terms and Conditions shall apply
D - 3	Final report	T0+12 months	Final report	[Redacted]	Final report detailing the full extent of the work done throughout the project including but not limited to: • Literature review of other similar works	Default RCloud Agreement Terms and Conditions shall apply

					• Overall explanation of the virtues of the CFD method being used and its limitations • The specific need for the generation of a new wall function • Details pf the work carried out including ML methodology and outputs • Detailed description of the final wall model • Commercial applications of the work generated Recommendations for future work	

1.7	**Deliverable Acceptance Criteria**
	All Reports included as Deliverables under the Contract e.g. Progress and/or Final Reports etc. must comply with the Defence Research Reports Specification (DRRS) which defines the requirements for the presentation, format and production of scientific and technical reports prepared for MoD. • Interim or Progress Reports: The report should detail, document, and summarise the results of work done during the period covered and shall be in sufficient detail to comprehensively explain the results achieved; substantive performance; a description of current substantive performance and any problems encountered and/or which may exist along with proposed corrective action. An explanation of any difference between planned progress and actual progress, why the differences have occurred, and if behind planned progress what corrective steps are planned. • Final Reports: shall describe the entire work performed under the Contract in sufficient detail to explain comprehensively the work undertaken and results achieved including all relevant technical details of any hardware, software, process or system developed there under. The technical detail shall be sufficient to permit independent reproduction of any such process or system. All Reports shall be free from spelling and grammatical errors and shall be set out in accordance with the Statement Of Requirement (1) herein. Failure to comply with the above may result in the Authority rejecting the deliverables and requesting re-work before final acceptance

2	**Evaluation Criteria**
2.1	Method Explanation
	The proposal shall demonstrate sufficient understanding of the requirement in order to provide confidence that the outputs are achievable. The proposal must be affordable.
2.2	Technical Evaluation Criteria
	The proposal will need to demonstrate the following elements in order to be successful: • Expertise in the use of numerical methods with complex moving geometries • Demonstrable knowledge of the state of the art for biomimetic marine propulsion • Availability of SQEP • A clear work proposal which demonstrates an understanding of the aim of the work, and a suitable method to provide a robust approach which can deliver the data in a timely fashion.

2.3	Commercial Evaluation Criteria
	Please submit your full firm price breakdown for all costs to be incurred to fulfil this requirement, including: • What rates are being used for what role • Quantity of manpower hours per role • Any Materials costs • Any Facility costs • Any sub-contractor costs • Any travel and subsistence costs Any other costs. Please note the MOD operates a policy of No Acceptable Price No Contract (NAPNOC). The placing of any contract will depend upon consideration of the proposal received and the Authority reserves the right, at its sole discretion, not to proceed to contract for any part or all of a contractors proposal. And if necessary, not to place any contract as a result.