N0001424SBC02
Special Program Announcement for Office of Naval Research Opportunity: Fundamental Research Towards Expeditionary Air Warfare & Weapons
Amendment 03

The purpose of this amendment is to extend the Full Proposal submission date to 08 March 2024. All changes have been highlighted in yellow.

BAA Call N0001424SBC02
Special Program Announcement for Office of Naval Research
Research Opportunity:

Fundamental Research Towards Expeditionary Air Warfare & Weapons

I. INTRODUCTION

This announcement describes a technology area, entitled "Fundamental Research Towards Expeditionary Warfare & Weapons," under the N0001424SB001, Long Range Broad Agency Announcement for Navy and Marine Corps Science and Technology which can be found at https://www.nre.navy.mil/work-with-us/funding-opportunities/announcements. The submission of proposals, their evaluation and the placement of research grants and contracts will be carried out as described in the above Long Range Broad Agency Announcement.

The purpose of this announcement is to focus attention of the scientific community on (1) the three topic areas to be studied, (2) associated informational workshops for dialogue amongst those interested in these topics, and (3) the planned timetable for the submission of white papers and full proposals.

II. TOPIC DESCRIPTION

The ONR Naval Air Warfare and Weapons (Code 35) department supports the Navy and U.S. Marine Corps' needs by fostering the technology development of naval aviation platforms, kinetic weapons, directed energy and electric weapons. This BAA Call will pursue innovative fundamental research in three (3) topic areas relevant to Expeditionary Forces and provide them an enduring unfair technological advantage into the future.

<u>Topic 1: Enabling Magnetics for Ultra-Wide Bandgap (UWBG) Power Electronics</u>

Background: Currently, no Commercial Off-the-Shelf (COTS) inductor materials, nor air core, can satisfactorily address the needs of future Navy Power and Energy systems in terms of power handling, efficiency, volumetric efficiency, and thermal rise. This undeniable conclusion calls for not only new materials but a new design paradigm for ultra-high frequency materials that capture 250 MHz or more of bandwidth. Focusing on the development of novel magnetic materials for inductors, with an eye towards extending the application to high frequency transformers, are needed to provide high SWAP+C2 (size, weight, and power plus cost and cooling) and reliable inductors for ultra-high frequency applications. Additionally, the cut-off frequency and permeability/magnetization (inductor saturation current) experience an inverse relationship, consistent with the well-known trends observed in spinel ferrites and alloys (i.e., the Snoek's Relationship). Wider bandwidth (i.e., higher cut-off frequency), however, comes at the cost of lower permeability and magnetization, which translates to lower power handling capacity, higher loss factors and a compromise to SWAP+C2. However, samples with higher permeability have lower cut-off frequencies that curtail higher frequency power harmonics. Temperature rise is presented as the uncompensated temperature increase of the inductor components. In some cases, the uncompensated temperature rise exceeds the degaussing temperature of the magnetic inductor core material indicating that it would obtain a permeability of unity. The uncompensated temperature rise is merely a prediction of the generated heat by the inductor component that must be compensated with appropriate cooling techniques. It's important to consider the cooling expenses and associated impact of size and weight of such systems. Investigating and delivering novel magnetic technologies must be pursued to ensure that ultra-wide bandgap (UWBG) semiconductors can be employed in Power and Energy circuits. In addition to miniaturization, improved efficiency and high performance improvements for power systems employing UWBG based power systems containing passive components, such as inductors. Additionally, contained in the LRUs are high frequency transformers which are necessary to provide galvanic isolation and voltage step-up/down requirements. Existing State of the Art (SOA) magnetic materials (i.e., ferrites, amorphous, and nano-crystalline materials) in are being pushed to their performance limits. No novel materials for inductors currently exist to enable UWBG LRU applications. While investments are being made in UWBG semiconductor development, without a concerted investment in revolutionary magnetic materials for inductors and ultimately, high frequency transformers, UWBG LRU converters will be inoperable in the future. In addition to meeting SWaP+2C requirements, innovative magnetic materials must be able to perform reliably in their intended environments consisting of high humidity, wide temperature ranges, shock and vibration, and noise.

Research Objective: The objective of the proposed research effort is to discover novel magnetic materials and scalable synthesis methods to effectively meet emerging needs for UWBG based LRU converters, and to fully leverage these new technologies in the context of optimized magnetic components capable of ultrahigh frequency and medium voltage operation in extreme environments (i.e., high humidity, and subject to shock and vibration.) Examples of relevant research areas include but are not limited to: (1) Computational materials science methods and techniques to understand and optimize new magnetic materials, including their thermal performance; (2) Advanced, scalable synthesis techniques (e.g., 3D Printing/Additive Manufacturing) (3) New optimization methods and algorithms to tailor magnetic components for specific applications; (4) Modeling and experimental validation of ultrahigh frequency component and converter level performance criteria which include parasitics, (e.g., loss mechanisms such as eddy current losses, hysteresis), resistivity, permeability, leakage flux, saturation properties, proximity effects, and component performance under application relevant excitation conditions.

Anticipated Resources: It is anticipated that awards under this topic will be $333K for the "start-up" year in FY24 and $910K per year for years 2-5, supporting a team of up to 4 US research institutions, for up to 4 Principal Investigators and 8 students. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of the solicitation.

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References:

1. Chapter 3 - Power Inductor Cores for MHz Applications," Parisa Andalib and Vincent G. Harris, *Modern Applications of Novel Ferrites*, edt. V.G. Harris, Wiley, 202
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3. P Andalib and V Harris, "Grain boundary engineering of power inductor cores for MHz applications," Journal of Alloys and Compounds, 60th Jubilee Edition, 832, 153131, 2020. (By editorial invitation)
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5. P. Andalib, Y. Chen, V. Harris, "Concurrent Core Loss Suppression and High Permeability by Introduction of Highly Insulating Intergranular Magnetic Inclusions to MnZn Ferrite," IEEE Magnetics Letters 9 5 (2018)

Topic 2: Theoretical Foundations and Limitations of Predicting, Deceiving, and Disrupting Artificial Intelligence Algorithms in Perception/Action Loops

Background: The future will likely see an increasing number and diversity of physical systems in the world with Artificial Intelligence (AI) components, organic sensors, and the ability to take observable, physical actions in the world. Future marine units may operate in environments in which there may be a range of systems including highly sophisticated intelligent systems, rapidly evolving "garage built" systems that exploit open source elements, and civilian/commercial systems that might be repurposed for military uses. As the AI of these systems becomes more complex, it may become susceptible to new forms of prediction, deception, and disruptions that are focused on the underlying algorithms and not other aspects of the system such as the hardware, infrastructure, or command and control. Thus, it becomes important to develop a general theory and methods to understand under what conditions it would be possible to create and exploit useful models or partial models of artificial intelligence components embedded within a closed loop, partially observable system. Also important will be the development of appropriate "lightweight," easily configurable fundamental research experimental testbeds to address this problem. Consider one example of a motivating problem: (1) an arbitrary set of perceptive adversarial systems or civilian/commercial systems that could be exploited by an adversary is disbursed in an operational environment with unknown or only partly known AI in their perception/action loops, (2) there is a friendly force that can actively move sensors to observe the adversarial entities, but in which the exact state and prior history of individual adversarial entities is at best only partially observable (3) the friendly force can stimulate and manipulate the adversarial systems at a meaningful level to make behavioral and modal shifts observable and to its advantage.

Research Objectives: The goal of this effort would be to develop generalized theoretical foundations and limitations for deceiving, shaping, and manipulating AI systems in perception/action loops that are black box (unknown) or grey box (partly known) elements of intelligent systems with the ability to take physical actions (embodied and situated) and that are only partially observable.

Key research questions are:

- What is the simplest model of the adversarial system theoretically sufficient to predict, deceive, manipulate, or disrupt performance or action? Would some form of partial model be sufficient and at what level of abstraction?
- Under what circumstances would particular adversarial system properties be theoretically observable in some formalizable sense to identify and model characteristics of a system within timeframes of value? How does this change if we have some degree of *a priori* knowledge or can stimulate the system so as to improve our ability to reason about it?
- What is the best way to actively control sensing and stimulation of the adversarial system to enable identification, modeling, and characterization of the system? Is there a formal relationship between stimulation and manipulation so as to allow us to jointly characterize the system while shaping its perceptual understanding, learning, and/or behaviors at the same time?
- What are appropriate "lightweight" and easily configurable testbeds, challenge problems, and metrics for experimental fundamental research, including assessing progress under some degree of realistic assumptions and incorporating a "red teaming" perspective in which the designers of the new methods do not have full control or knowledge over the experimental scenario, apparatus, and/or test conditions?

Anticipated Resources: It is anticipated that awards under this topic will be $330K for the "start-up" year in FY24, $910K per year for years 2-3, and $1M per year for years 3-4, supporting a team of up to 4 US research institutions, for up to 4 Principal Investigators and 8 students. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of the solicitation. The grants should be structured as a 3 year base for FY24-26 and a 2 year option for years FY27-FY28. The two year option will emphasize a greater amount of experimental testing of the theories and methods developed under the base against unexpected, adversarial scenarios including increased use of red teaming elements. The goal will be enable a feedback and learning process that tests the explicit and implicit assumptions underlying the main theory and methods development, while also driving forward the science of how to develop effective experiments for these classes of problems.

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Topic 3: Lifting body dynamics under influence of 2- & 3-D unsteady ground effect

Background: Lifting bodies operating in-ground effect (IGE) offer an attractive option as a technology for high-speed, resilient multi-domain craft. They leverage the cushioning effect generated by trapped air between the wing and the surface, leading to increased lift and lower induced drag – both of which amount to significant efficiencies relative to similarly sized aircraft operating at altitude. Though fixed-wing IGE aerodynamics have been explored extensively in the past, numerous challenges persist in enabling IGE craft operation in foul weather and high sea states – both conditions that are prevalent throughout the year in operational theaters of interest.

The most critical of these challenges is stability and control (S&C) of IGE vehicles, which has hampered their widespread use [1]. S&C challenges are exacerbated in high sea-state conditions due to the tightly coupled nature of vehicle aerodynamics and the unsteady conditions induced by operating within a relatively small surface effect zone (SEZ). Such challenges have been slowly ameliorated by the development of active stability controls for longitudinal and transverse dynamic stability [2] [3]. However, their development is intimately tied to specific platforms with limited understanding of how to maximally take advantage of fundamental unsteady aerodynamic phenomena.

A lifting body operating in the presence of a wavy, potentially three-dimensional, surface representative of the water interface experiences an unsteady lift component that changes periodically. Not only does the surface wave motion affect the evolution of the wing tip vortices, lift distribution, and aerodynamic center position on the lifting body, but other secondary environmental effects could prove to be first-order contributors to overall performance. For example, strong winds are ubiquitous in high sea-states. In such environments, wavy surface motions contribute to the development of strong vertical gusts within the SEZ that could severely impact the lifting body, potentially forcing it to operate within an unstable regime. Lack of understanding and the severity of such coupled effects have resulted in open ocean operations of IGE craft to be limited to larger configurations [4]. More importantly, no IGE craft have been successful in transitioning to full-scale operations. Basic research into the coupling of the relevant fundamental aerodynamic phenomena in these environments will greatly enhance our ability to develop high-speed, resilient multi-domain craft.

Capturing the relevant physical phenomena described above has been a significant challenge, both from an M&S and experimental techniques perspective. The main reason is the need to capture the multi-scale/-physics/-phase of importance to capture the effects of such stochastic environments. An example of the complexity is the highly-coupled nature of the surface dynamics and the resulting aerodynamics of lifting bodies within the SEZ, which becomes exceedingly challenging to represent in an M&S environment. Recent progress in computational and experimental techniques and diagnostics afford a path towards gaining significant insight in such complex environments while maintaining focus on fundamental mechanisms generally applicable to IGE dynamics.

Towards this end, this topic seeks innovative, tightly-coupled experimental and computational research into fundamental phenomena of unsteady ground effect. Limited examples exist in the literature of such investigations, and most focus on specific configurations (*e.g.* [5]) versus canonical insight. Modern modeling and simulation (M&S), experimental techniques/facilities, and diagnostics offer a unique opportunity to contribute to the IGE body of work – including the development of mitigation strategies to navigate the highly unsteady environment – to enable revolutionary capabilities for the future expeditionary warfighter.

Research Objectives: The primary objective of this proposed work is to conduct fundamental studies to better understand the underlying physics of canonical IGE lifting bodies (IGE-LB) of differing aspect ratio, chord, etc., in several key multi-disciplinary areas. First, systematic investigation into the dynamic coupling between IGE-LBs and an unsteady surface representative of a highly-dynamic sea-state will be executed via coupled experimental &

computational campaigns. This study will help elucidate: (1) fundamental scaling parameters governing IGE-LB unsteady aerodynamics; (2) response dynamics of IGE-LBs to highly-unsteady, asymmetric ground conditions (e.g. wave-height-to-wing-chord effects, influence/relationship/interplay between wave height, altitude, and efficiency in 2D and 3D ground effect, etc.); (3) approaches to detect and predict unsteady ground-induced loading; (4) mechanisms influencing aerodynamic 'suckdown' (loss of lift); (5) critical coupling between angle-of-attack and altitude for adequate stability; (6) and other relevant phenomena.

Said knowledge will be foundational towards developing approaches to mitigate the unsteady loading caused by such a complex, dynamic environment. Active flow control (AFC) techniques – such as fluidic actuators, chemical impulse actuation, distributed bleed, morphing structures, etc. – offer potential means of pushing the boundary on the stability of IGE-LBs. Thus, a second thrust area of the proposed work is the exploration of the coupling between various AFC modalities, IGE-LBs, and dynamic surfaces to gain better understanding of: (1) requirements for gust detection/prediction; (2) phase-lag response of IGE-LBs to actuation; (3) effectiveness of AFC modalities in mitigating unsteady loading induced by dynamic surface; (4) other critical performance phenomena.

A third element of the proposed research is the investigation of AFC approaches capable of generating high-impulse effects to provide maximum control effectiveness. Novel energetics formulations and/or morphing structures resilient to the maritime environment offer elegant potential solutions that could/should be explored in a comprehensive manner to maximize AFC effectiveness when coupled to IGE-LBs.

Finally, the fundamental knowledge gained by these systematic investigations can be transitioned towards the development of novel flight dynamics and control methodologies to enable advanced active control of IGE-LBs.

Anticipated Resources: It is anticipated that awards under this topic will be $333K for the "start-up" year in FY24 and $910K per year for years 2-5, supporting a team of up to 4 US research institutions, for up to 4 Principal Investigators and 8 students. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of the solicitation.

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References:

[1] K. V. Rozhdestvensky, "Wing-in-ground effect vehicles," *Progress in Aerospace Sciences*, vol. 42, pp. 211-283, 2006.

[2] A. V. Nebylov and V. A. Nebylov, "Controlled WIG Flight Concept," in *The International Federation of Automatic Control*, Cape Town, South Africa, 2014.

[3] A. Nebylov, V. Nebylov and S. Sharan, "Development of New-Generation Automatic Control Systems for Wing-In Ground Effect Crafts & Amphibious Seaplanes," in *Third International Conference on Advances in Control and Optimization of Dynamical Systems*, Kanpur, India, 2014.

[4] M. Halloran and S. O'Meara, "Wing in Ground Effect Craft Review," DSTO Aeronautical and Maritime Research Laboratory, Melbourne, Australia, 1999.
[5] L. Wang, K. Yang, T. Yue and H. Liu, "Wing-in-ground craft longitudinal modeling and simulation based on a moving wavy ground test," *Aerospace Science and Technology*, vol. 126, p. 107605, 2022.

III. WHITE PAPER SUBMISSION

The due date for white papers has passed. To ensure full, timely consideration for funding, white papers should have been submitted no later than 15 December 2023. However, any white paper received after 15 December 2023 will be considered as time and availability of funding permit and in a more cursory manner than those submitted before the initial deadline. A white paper submitted less than two weeks before the full proposal deadline may not be reviewed before the full proposal deadline.

Each white paper that was submitted by 15 December 2023 will be evaluated by the Government to determine whether the technology advancement proposed appears to be of particular value to the Department of the Navy. Initial Government evaluations and feedback will be issued via e-mail notification from the Technical Point of Contact. The initial white paper appraisal is intended to give entities a sense of whether their concepts are likely to be funded.

Detailed Full Proposal (Technical and Cost volumes) will be subsequently encouraged from those Offerors whose proposed technologies have been identified through the above referenced e-mail as being of “particular value” to the Government. However, any such encouragement does not assure a subsequent award. Full Proposals may also be submitted by any offeror whose white paper was not identified **as being of particular value to the Government or any offeror who did not submit a white paper.**

For white papers that propose efforts that are considered of particular value to the Navy but either exceed available budgets or contain certain tasks or applications that are not desired by the Navy, ONR may suggest a full proposal with reduced effort to fit within expected available budgets or an effort that refocuses the tasks or application of the technology to maximize the benefit to the Navy.

White papers should not exceed 5 single-sided pages, exclusive of cover page, references, and resume of principal investigator, and should be in 12-point Times New Roman font with margins not less than one inch. White papers shall be in Adobe PDF format (preferred) or in Microsoft Word format compatible with at least Microsoft Word 2016.

The Cover Page can be found at https://www.nre.navy.mil/work-with-us/how-to-apply/submit-contract-proposal for contract submissions and at https://www.nre.navy.mil/work-with-us/how-to-apply/submit-grant- application for grant submissions. The 5-page body of the white paper should include the following information:

- Technical Concept: A description of the technology innovation and technical risk areas.

- Future Naval Relevance (where applicable) – A description of potential Naval relevance and contributions of the effort to the agency’s specific mission.

- Operational Naval Concept (where applicable) – A description of the project objectives, the concept of operation for the new capabilities to be delivered, and the expected operational performance improvements.

- Operational Utility Assessment Plan (where applicable) – A plan for demonstrating and evaluating the operational effectiveness of the Offeror's proposed products or processes in field experiments and/or tests in a simulated environment.

- Rough Order of Magnitude (ROM) cost estimate

A resume of the principal investigator, not to exceed 1 page, should also be included after the 5- page body of the white paper.

White papers must be submitted through Fedconnect at www.fedconnect.net in accordance with Section D. Application and Submission Information, Section 2. Content and Form of Application Submission, paragraph d. White Paper Requirements, ii. White Paper Submission in N0001424S B001. Interested parties are also strongly recommended to provide a courtesy copy of their white papers to the respective topic chair(s) via electronic mail.

The planned date for completing the review of white papers is **26 January 2024**.

IV. FULL PROPOSAL SUBMISSION AND AWARD INFORMATION

Full proposals should be submitted under N0001424SB001 by **08 March 2024**. Full Proposals received after that date will be considered as time and availability of funding permit.

ONR anticipates that both grants and contracts will be issued for this effort.

Full proposals for contracts should be submitted in accordance with the Appendix 2 of the N0001424SB001. Full proposals for grants should be submitted via Grants.gov in accordance with Appendix 1 of N0001424B0001.

The period of performance for projects may be from 3 to 5 years.

Although ONR expects the above described program plan to be executed, ONR reserve the right to make changes.

Funding decisions should be made by 19 April 2024. Selected projects will have an estimated award date of 24 May 2024.

V. SIGNIFICANT DATES AND TIMES

Event	Date*	Time
BAA Call Publication	23 October 2023	11:59 PM Eastern Standard Time (ES)
Recommended White Paper Submission Date Passed	15 December 2023	11:59 PM Eastern Standard Time (ES)
Notification of White Paper Valuation	26 January 2024	11:59 PM Eastern Standard Time (ES)
Recommended Full Proposal Submission	08 March 2024	11:59 PM Eastern Standard Time (ES)
Notification of Selection: Full Proposals	19 April 2024*	
Awards	24 May 2024*	

Note: * These are approximate dates**.**

VI. Small Business Subcontracting

As indicated in ONR Broad Agency Announcements large businesses and non-profit organizations must submit a subcontracting plan along with their research proposal. While large businesses and non-profits are responsible for making these subcontracting arrangements, ONR will help facilitate prime contractor/small business contracting connections by posting to the ONR external website contact information of small businesses that have indicated their subcontracting interests and technological niche for prime contractor consideration for this program. This is not an endorsement, but an effort by ONR to help bring these parties together to provide superior solutions.

If you are a small business, and your company is interested in subcontracting activities with large businesses and/or non-profits considering your technology for this program, please provide the following information by email, to the ONR Small Business Director at ellen.simonoff.civ@us.navy.mil with the subject line, "BC N0001424SBC02". Provide this information:

1) Company Name and Website
2) Individual (POC) name and POC email address
3) Business Size and socio-economic category
4) Brief Technology Description (no more than 3 sentences)
5) Technology Key Words (no more than 10 words)

Note: Do not include ANY proprietary information. This information will be posted on the ONR website under this BAA call and will available to the public.

VII. POINTS OF CONTACT

In addition to the points of contact listed in N001424SB001the specific technical points of contact for each topic within this announcement are listed in Section II. The business point of contact is listed below:

Business Point of Contact/Contracting Officer:

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VIII. SUBMISSION OF QUESTIONS

Any questions regarding this announcement must be provided to the Technical Points of Contact and/or the Business Point of Contact listed above. All questions shall be submitted in writing by electronic mail.

Answers to questions submitted in response to this BAA Call will be addressed in the form of an Amendment and will be posted to the following web pages:

- Beta.sam.gov Webpage –Contract Opportunities – https://beta.sam.gov/
- Grants.gov Webpage – http://www.grants.gov/
- ONR BAAs, FOAs and Special Program Announcements Webpage - https://www.nre.navy.mil/work-with-us/funding-opportunities/announcements

Questions regarding **White Papers or Full Proposals** should be submitted NLT two weeks before the dates recommended for receipt of White Papers and/or Full Proposals. Questions after this date may not be answered.