College of Engineering and Computer Science
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Announces the Ph.D. Dissertation Defense of

Wenqiang Xu

for the degree of Doctor of Philosophy (Ph.D.)

A Self-sustained Autonomous System for Long-term Arctic Monitoring

March 12th, 10:30 a.m.
Building EW, Room # 187
777 Glades Road
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DEPARTMENT:

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ABSTRACT OF DISSERTATION
The accelerated melting of Arctic sea ice poses critical challenges to global climate stability, marine ecosystems, and navigation safety. To address the need for continuous, high-resolution monitoring of the Arctic environment, this dissertation explores the development and feasibility of a Self-sustaining Autonomous System (SAS) for long-term Arctic observation. The proposed system is designed to overcome the limitations of traditional fixed or drifting buoys, as well as the range and endurance constraints of drones and Autonomous Underwater Vehicles, by utilizing a Small Waterplane Area Twin Hull (SWATH) Unmanned Surface Vehicle (USV) as a core observation platform. The wind-powered SWATH harnesses both wind energy through its sail and marine current energy via an underwater turbine to enable sustained, autonomous operation in remote Arctic regions. This hybrid energy-harvesting approach ensures the SAS can operate independently for extended durations, significantly improving the spatial and temporal resolution of Arctic data collection.

The SAS is designed as a multi-platform observation system, integrating Unmanned Aerial Vehicle and AUV to provide a comprehensive view of Arctic sea ice dynamics, oceanographic conditions, and ecological changes. The SWATH-based platform serves as a mobile docking and charging station for UAV and AUV, extending their operational range and enabling data acquisition from multiple domains—air,

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surface, and subsurface. The system architecture prioritizes autonomy, energy efficiency, and environmental adaptability, with a customized hull design that ensures enhanced stability, even in extreme Arctic conditions. A dimensionless formula is introduced to estimate the minimum sail area required for different SWATH sizes to sustain power generation under varying environmental conditions, ensuring optimal system performance in dynamic Arctic environments.

Additionally, the dissertation investigates the navigation performance of SWATH vessels in drifting ice fields, a key consideration for long-term Arctic operations. Through Finite Element Method (FEM) simulations using ANSYS LS-DYNA, this study analyzes hull-ice interactions, hydrodynamic resistance, and ice displacement mechanisms. The findings confirm that the SWATH hull design significantly reduces ice-induced forces, allowing for safer and more energy-efficient navigation compared to conventional single-hull vessels. The bow wave effect of SWATH effectively fragments and displaces ice, mitigating direct hull-ice collisions and reducing overall resistance, thereby extending the system's operational longevity in semi-ice-covered waters. Furthermore, Computational Fluid Dynamics (CFD) simulations are conducted to validate hydrodynamic performance parameters, including vessel resistance, drag forces, and sail efficiency, ensuring the accuracy and reliability of the proposed system design.

By integrating renewable energy harvesting, autonomous multi-vehicle coordination, and optimized hull design, this research advances the field of Arctic ocean monitoring. The proposed SAS represents a breakthrough in self-sustaining, long-term observation systems, offering a scalable and cost-effective alternative to traditional monitoring methods. The insights gained from this study will contribute to climate change research, Arctic policy development, and future autonomous maritime operations, ultimately supporting global efforts to understand and mitigate the impacts of Arctic sea ice loss.

BIOGRAPHICAL SKETCH
Born in China.

B.S., Tianjin University, Tianjin, China, 2016

M.S., Florida Atlantic University, Boca Raton, Florida, 2018

Ph.D., Florida Atlantic University, Boca Raton, Florida, 2025

CONCERNING PERIOD OF PREPARATION
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"Performance of SWATH in Drifting Ice Fields" (In press)

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