AEROSPACE ENGINEERING

DIMEAS - Critical monitoring for real-time diagnostic and prognostic capabilities in hostile environment

Funded By	Dipartimento DIMEAS
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Context of the research activity	Critical infrastructure monitoring in hostile environments represents one of the most significant challenges in modern industrial engineering. The DAO (Sviluppo Diagnostica avanzata in Ambienti Ostili) project is led by Newcleo S.p.a., a Torino-based pioneer in next-generation nuclear energy. DAO addresses the urgent need for advanced diagnostic systems capable of operating under extreme conditions: temperatures exceeding 500°C, intense ionizing radiation (gamma and neutron flux >1e+05 n·cm¿²·s¿¹), and highly corrosive environments. Currently, no commercial sensors exist that can withstand the combination of these harsh conditions while maintaining measurement accuracy and reliability. Founded in 2021, Newcleo is developing Generation IV Small Modular Reactors (SMRs), specifically Lead-cooled Fast Reactors (LFRs), designed to provide safe, clean, and sustainable energy while contributing to global decarbonization goals.
Objectives	This PhD research will contribute to the DAO project by focusing on the development and validation of advanced computational frameworks for real-time diagnostic and prognostic capabilities in hostile environments. The core work is centered on the WP 1.4 (Multi-Physics Modeling and Algorithm Development), with supporting activities in experimental validation and system integration to ensure the models' applicability to real-world conditions. The research aims to bridge the gap between discrete sensor measurements and continuous system-level understanding through innovative multi-fidelity modeling and machine learning approaches, ultimately enabling predictive maintenance strategies for critical infrastructure operating under extreme conditions. The objectives of the proposed research are: • Develop multi-fidelity numerical models (thermomechanical and fluid-dynamic) for digital twin implementation capable of representing the complex physics of LFR primary systems • Create Edge Virtual Sensing (EVS) algorithms using Machine Learning to generate continuous surrogate data from discrete sensor measurements, minimizing the number of physical sensors required while maintaining diagnostic accuracy

	• Implement sensor fusion frameworks that integrate physical laws with AI-driven real-time processing, enabling robust state estimation even under sensor failures or degraded conditions • Validate computational models against experimental data to ensure diagnostic and prognostic accuracy across the full range of operating conditions • Demonstrate prototype functionality in environment simulators before integration into the DAO demonstrator, ensuring readiness for industrial-scale testing • Support demonstrator testing campaigns and KPI validation activities, providing modeling expertise to interpret results and optimize system performance

Skills and competencies for the development of the activity	The ideal candidate must have a comprehensive understanding of FBG sensor principles, interrogation systems, and signal processing techniques essential for fiber optic diagnostic applications. Familiarity with Generation IV reactor concepts, particularly LFR technology, and knowledge of harsh environment instrumentation challenges. Technical proficiency spans CAD/FEA tools including SolidWorks and Calculix, CFD including OpenFoam, programming languages such as Python, MATLAB, and C++ for numerical simulations and data analysis, and statistical analysis for Design of Experiments and data interpretation. The candidate shall demonstrate strong analytical thinking and proven ability to work effectively in highly interdisciplinary environments, integrating concepts from photonics, materials science, nuclear engineering, and computational modeling. Collaborative and project management capabilities include experience in international research environments, and the ability to interface effectively with academic researchers, industrial partners, and regulatory bodies. English—both written and spoken—enables effective communication within the multinational DAO consortium and the broader scientific community, as demonstrated through international collaboration experience and technical publication preparation.