



PhD in MODELLI E METODI MATEMATICI PER L'INGEGNERIA / MATHEMATICAL MODELS AND METHODS IN ENGINEERING - 41st cycle

**BORSE TEF Research Field: MODELING AND OPTIMIZATION OF ADAPTIVE VERTICAL
FARMING SYSTEMS FOR SPACE MISSIONS**

Monthly net income of PhDscholarship (max 36 months)
1800.0
In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	The development of Adaptive Vertical Farming (AVF) by Space V (https://www.spacev.bio/) represents a breakthrough in efficient food production for space missions. By enabling dynamic adjustment of shelf spacing, local microclimate control, a precise planning of the growth stages of crops, AVF significantly enhances productivity and reduces energy consumption compared to standard VF cells. This PhD project aims to develop a virtual prototype to monitor the fluid dynamics (FD) within the AVF cell by integrating advanced modeling and innovative numerical methods. This will enable the optimization of environmental control and enhance system robustness in resource-constrained environments such as extraterrestrial settings, also advancing AVF technology through the introduction of groundbreaking solutions, such as the use of innovative substrates for hydroponic cultivation.
Methods and techniques that will be developed and used to carry out the research	Creating a virtual prototype for modeling the FD within the AVF cell is an ambitious task, since dealing with a multiphysics problem where heterogeneous phenomena interact (air circulation, LED lighting, plant growth, leaf transpiration, plant interactions and competition). Particular focus will be given to reproducing air and heat circulation within and between crop compartments; modeling localized climate control for optimal crop growth;



	simulating plant-environment interaction under varying spatial and temporal conditions; investigating energy efficiency improvements through geometry and control strategy variations; replacing current substrates for hydroponic cultivation with innovative 3D-printed growing media; enhancing resource sustainability through water, energy, and nutrient recycling. The core framework of the project will rely on advanced numerical methods for the approximation of partial differential equations, including model order reduction (MOR) techniques, adapted computational meshes (ACM) customized to the specific application, high-performance computing for multi-scale simulations, physics- or data-informed algorithms, possibly integrated with control and optimization techniques.
Educational objectives	This PhD project offers the candidate a comprehensive and multidisciplinary educational experience that spans the full research pipeline, from advanced theoretical development to practical implementation in real-world and extreme environments. Key educational benefits include: •Integrated understanding of multiphysics modeling: the candidate will address a highly complex and interdisciplinary problem, combining fluid dynamics, heat transfer, plant physiology, and materials science. Through the development of a virtual prototype of an AVF system, they will gain a deep understanding of the theoretical principles underlying the involved physical processes and their practical applications in constrained environments such as space. •Hands-on experience with cutting-edge technologies: the candidate will engage directly with high-performance computing tools, model order reduction techniques, adaptive computational meshes, and possibly physics- or data-informed algorithms, building robust skills in scientific computing, numerical modeling, and simulation-based optimization. •Exposure to innovative engineering practices: thanks to the collaboration with Space V, a pioneering spin-off of the University of Genova, the candidate will contribute to



	groundbreaking solutions such as the design of innovative 3D-printed substrates for hydroponic cultivation, energy-efficient control strategies, and the recycling of key resources (water, energy, nutrients). • Interdisciplinary and inter-institutional collaboration: the project fosters strong connections across disciplines and institutions, involving experts from applied mathematics, mechanical and environmental engineering. The collaboration with the University of Genova (Prof. Patrizia Bagnerini) and with the Space V team, led by Franco Malerba, offers a unique opportunity to work at the interface of scientific modeling and technological innovation, guided by the experience of Italy's first astronaut and an international leader in space-based agriculture. • Alignment with societal and sustainability goals: aligned with the United Nations Sustainable Development Goals (SDGs 2 – Zero Hunger, 9 – Industry, Innovation and Infrastructure, 12 – Responsible Consumption and Production), this project emphasizes sustainability, resource efficiency, and the development of scalable agricultural solutions with both terrestrial and extraterrestrial applications. • Entrepreneurial potential: thanks to the strong innovation component and the involvement of an academic spin-off, the project opens up concrete opportunities for technology transfer and entrepreneurship. The candidate will be exposed to the process of turning research into commercial applications, with the potential to contribute to or launch new start-ups in agri-tech or space-tech.
Job opportunities	This PhD project aims to equip the candidate with a future-oriented and versatile skill set that combines rigorous scientific training with practical, hands-on experience. The interdisciplinary nature of the research fosters strong problem-solving abilities and cultivates a mindset well-suited to industrial settings. Upon completion, the candidate will be prepared for high-impact



	careers in academia, industry, or entrepreneurship, particularly in emerging sectors such as sustainability, space research, and precision agriculture.
Composition of the research group	1 Full Professors 1 Associated Professors 1 Assistant Professors 2 PhD Students
Name of the research directors	Prof.ssa Simona Perotto

Contacts
simona.perotto@polimi.it Tel. 02-23994512

Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents	--

Scholarship Increase for a period abroad	
Amount monthly	900.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
Educational activities (purchase of study books and material, funding for participation to courses, summer schools, workshops and conferences): financial aid per PhD student per year 1st year: max 2.446,00 euros 2nd year: max 2.446,00 euros 3rd year: max 2.446,00 euros The PhD students are encouraged to take part in activities related to teaching, within the limits allowed by the regulations. 1 individual PC per student +several shared PC. Access to one cluster with 32 processors and 384 GB RAM, and to several multi-processor servers.