# COMPUTATIONAL MODELLING AND DATA-DRIVEN DESIGN OF MECHANICAL METAMATERIALS

**FRANCISCO J. MONTÁNS[*], JUAN GARCÍA-MARTÍNEZ[†], ÁLVARO GARCÍA JUÁREZ[‡] AND JOSÉ MARÍA BENÍTEZ BAENA[*]**

[*] E.T.S. de Ingeniería Aeronáutica y del Espacio, Universidad Politécnica de Madrid
Pza. Cardenal Cisneros 3, 28040 Madrid, Spain
fco.montans@upm.es josemaria.benitez@upm.es www.upm.es

[†] Instituto Nacional de Técnica Aeroespacial (INTA)
Carretera de Ajalvir km 4 28850 Torrejón de Ardoz, Madrid, Spain
jgarciam@inta.es www.inta.es

[‡] Universidad de Castilla La Mancha (UCLM), DYPAM, ETSII-INEI,
Avda. Camilo José Cela s/n, Ciudad Real, 13071, Spain
Alvaro.Garcia@uclm.es www.uclm.es

## ABSTRACT

Architected mechanical metamaterials and metastructures are attracting increasing attention due to their ability to achieve combinations of properties that are difficult or impossible to obtain using conventional materials. Their unique performance derives from the interaction between geometry, material behaviour and structural response across multiple length scales, creating new possibilities for lightweight, multifunctional and damage-tolerant systems in aerospace, defence, space and advanced engineering applications.

Recent advances in computational mechanics have significantly expanded the capability to analyse and design metamaterials exhibiting tailored mechanical behaviour, including controlled fracture and crack propagation, enhanced toughness, vibration attenuation through band-gap engineering, wave manipulation and functionally graded responses. Furthermore, the maturation of additive manufacturing technologies has played a key enabling role in the metamaterials field, providing unprecedented freedom to fabricate architected materials with complex geometries and spatially varying properties. Numerical methodologies such as finite element formulations, multiscale modelling, topology optimization, phase-field approaches and reduced-order models are enabling the efficient exploration of increasingly complex architectures.

In parallel, data-driven and physics-based artificial intelligence techniques are emerging as powerful tools to accelerate design processes while preserving physical consistency. Physics-informed machine learning, surrogate modelling, digital twins and hybrid computational frameworks are providing new opportunities for optimisation, uncertainty quantification and real-time prediction of metamaterial performance.

This Invited Session aims to bring together researchers working on the modelling, simulation, optimisation and experimental validation of architected metamaterials and metastructures. Contributions addressing computational methods for fracture control, nonlinear behaviour, multiscale analysis, vibration attenuation, wave propagation, topology optimisation, additive manufacturing-oriented design and physics-based AI are particularly welcome. The session seeks to foster interdisciplinary discussion between

Corresponding Organizer: Juan García-Martínez (garciamj@inta.es)

computational mechanics, materials science and artificial intelligence communities, highlighting emerging challenges and opportunities for next-generation engineering structures.

Corresponding Organizer: Juan García-Martínez (garciamj@inta.es)