**Title:** Design And Development of High Energy Absorbent Aircrew Helmet Using 3D Woven Structural Composites

**Abstract:** The protection of aircrew personnel against ballistic threats, blunt impacts, and high-velocity debris remains a critical challenge in aerospace safety systems. This research presents a multidisciplinary investigation into the development of lightweight, high-performance aircrew helmets incorporating advanced 3D woven structural composites. The study systematically addresses limitations in conventional helmet designs that predominantly rely on 2D laminates and traditional liner materials with suboptimal damage tolerance and energy dissipation properties. Through geometric modelling, optimisation techniques, and experimental validation, this work explores the integration of 3D woven solid composites for the helmet shell and 3D woven honeycomb composites for the helmet liner. Key parameters such as areal density, fibre volume fraction, and structural integrity are evaluated, and a predictive geometric model is developed and validated to optimise the preform architecture for balanced mechanical performance and lightweight characteristics.

Further, the research employs statistical design of experiments (Box Behnken Design) to optimise honeycomb geometries for enhanced energy absorption under impact loads. The study also investigates intralayer hybridisation using Kevlar, Glass, Dyneema, Sisal, Hemp, and Jute to improve damage tolerance and specific energy absorption. Additionally, the interface properties of composites are enhanced through ZnO nanorod surface treatments and matrix modification with graphene nanoplatelets, achieving notable improvements in mechanical and impact performance. Comparative evaluations against commercial liner materials like Nomex and Aluminium demonstrate the superior crashworthiness of the developed 3D woven honeycomb composite liners. Finite Element Analysis (FEA) and 3D X-ray Tomography are employed to assess back-face deformation, failure modes, and internal damage mechanisms under high-velocity impacts, with numerical results closely correlating with experimental findings. This research delivers a comprehensive framework for designing next-generation aircrew helmets that offer superior impact energy absorption, reduced back-face deformation, and enhanced operational safety for aerospace applications.