Engineers weigh in on the design freedom of GenAI in aerospace

Rocket propulsion and other next-gen aerospace systems increasingly depend on GenAI models – a force for democratising design

By Greg Zacharias, Aerospace R&D Domain Lead and Executive Producer, AIAA SciTech Forum.

From nuclear-thermal rockets to hypersonic aircraft, today's aerospace systems are increasingly complex, relying on lighter-weight 3D-printed materials, as well as advanced structures, which can include a mix of different materials and thermal-management technologies.

The control over form offered by 3D printing means that these components are exceptionally complex, requiring aerospace engineers to develop innovative design approaches.

Not surprisingly, some of the most promising approaches tap into generative artificial intelligence, or GenAI, which will be featured at the upcoming 2025 AIAA SciTech Forum in January in Orlando, Florida.

"GenAI is more than just ChatGPT; it has applications in engineering design and it's going to be used in critical engineering components in the not-so-distant future," says Zachary Cordero, the Esther and Harold E. Edgerton Associate Professor in MIT's Department of Aeronautics and Astronautics, who will present in two sessions at the forum.

GenAI systems leverage vast datasets to autonomously generate novel solutions and designs, enhancing innovation and applications in diverse fields.

"GenAI is extremely powerful if you have a lot of data," notes Faez Ahmed, Assistant Professor of Mechanical Engineering, who leads the MIT Design Computation & Digital Engineering (DeCoDE) Lab in the MIT Center for Computational Science and Engineering (CCSE), an interdisciplinary research and education center focused on innovative methods and applications of computation.

The lack of data for learning models – the oxygen that fuels GenAI training – is the biggest bottleneck, Ahmed adds. "Whenever someone says GenAI doesn't work, a lot of times it's not the model; it's the lack of data."

The DeCoDE Lab bridges this gap by creating design datasets, often by performing a lot of high-fidelity engineering simulations, including recent work for the automobile industry. The Lab created one of the largest and most comprehensive multimodal datasets for aerodynamic car design named DrivAerNet++, which comprises 8,000 diverse car designs modelled with high-fidelity computational fluid dynamics simulations.

Image above courtesy of ASME. From: Heyrani Nobari, Amin, Justin Rey, Suhas Kodali, Matthew Jones, and Faez Ahmed. 2023. "AutoSurf: Automated Expert-Guided Meshing With Graph Neural Networks and Conformal Predictions." Proceedings of ASME 2023 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Volume 3A: 49th Design Automation Conference (DAC). https://doi.org/10.1115/DETC2023-115065.

Ahmed emphasises that his MIT team doesn't always use data from good designs but also develops methods to leverage negative data, since bad designs "are cheap and much easier to get."

Cordero's Aerospace Materials and Structures Lab at MIT is pushing the boundaries of additive manufacturing for spaceflight through developing new processes and materials. Cordero is collaborating with Ahmed and MIT Research Scientist Cyril Picard on a US Department of Defense-funded research project on the design of next-generation reusable rocket engines.

According to Picard, the team is using GenAI to assess mechanical and thermal properties of materials to inform the design of 3D-printed multi-material parts, with the "long-term goal of making the engines more high-performing, efficient and lighter."

Looking across the aerospace sector, GenAI offers many benefits, from optimising materials to reducing costly late-stage design changes when scaling production to enabling rapid validation and qualification, say the researchers.

To Ahmed, the biggest benefit of GenAI goes beyond making better products faster: it affords the time for people to explore new designs while also opening up design to innovators outside of traditional aerospace fields.

"I'm personally really excited about this idea of democratisation of design. Historically, design has been limited to the headquarters of major industries. But with tools, like GenAI, we can tap into the creative potential of people with good ideas, but who aren't necessarily experts."