Evolved Structures: Using AI and robots to build lightweight spaceflight structures

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ABSTRACT

Digital Engineering technologies are transforming long-stagnant development processes by applying the tremendous advancements in Information Technology (IT) to classical engineering tasks such as design, analysis, and fabrication of space-flight structures. Generative Design leverages developments in Artificial Intelligence (AI) and Cloud computing to enable a paradigm shift in the design process, allowing the engineer to focus on defining the requirements and objectives of the design while AI generates optimized designs which comply with the input requirements. Digital Manufacturing allows these complex lightweight designs to be efficiently manufactured by directly fabricating from the resulting 3D models. The development of these two Digital Engineering technologies realizes significant mass savings while simultaneously reducing structure development time from months to days. This presentation will describe the Evolved Structures process applying these technologies to spaceflight structures including an example demonstrating greater than 10x reduction in development time/cost and greater than 3x improvement in structural performance.

Evolved structures are currently planned for planetary missions including Dragonfly and Mars Sample Return, but are not yet widely known outside of the NASA Goddard community. Applied early in development, this technology can dramatically increased science return by reducing structure cost and mass, resources that can instead be applied to improved instrumentation. Landers, probes, and sample return missions are particularly promising applications.

Related public media

- SPIE presentation: https://www.spiedigitallibrary.org/conference-proceedings-of-spie/12217/122170O/Generative-design-and-digital-manufacturing--using-AI-and-robots/10.1117/12.2646476.full
- ASME Webinar: https://hubs.ly/Q01kwvRb0 (register to watch recording)
- Small Steps, Giant Leaps Podcast: https://appel.nasa.gov/podcast/episode-92-evolved-structures/#content
- Digital Engineering 24/7 article: https://www.digitalengineering247.com/article/meet-your-new-design-consultant-generative-design/

Application Examples

Applications of the Evolved Structures process include the EXCITE radiator bracket (top left), the EXCITE cryostat mount (top center), the ALICE Optical Bench (top right), the STAR-X detector mount (bottom left), the CCRS diode bracket (bottom center), and the NGXO mirror mount (bottom right).

Performance improvement example

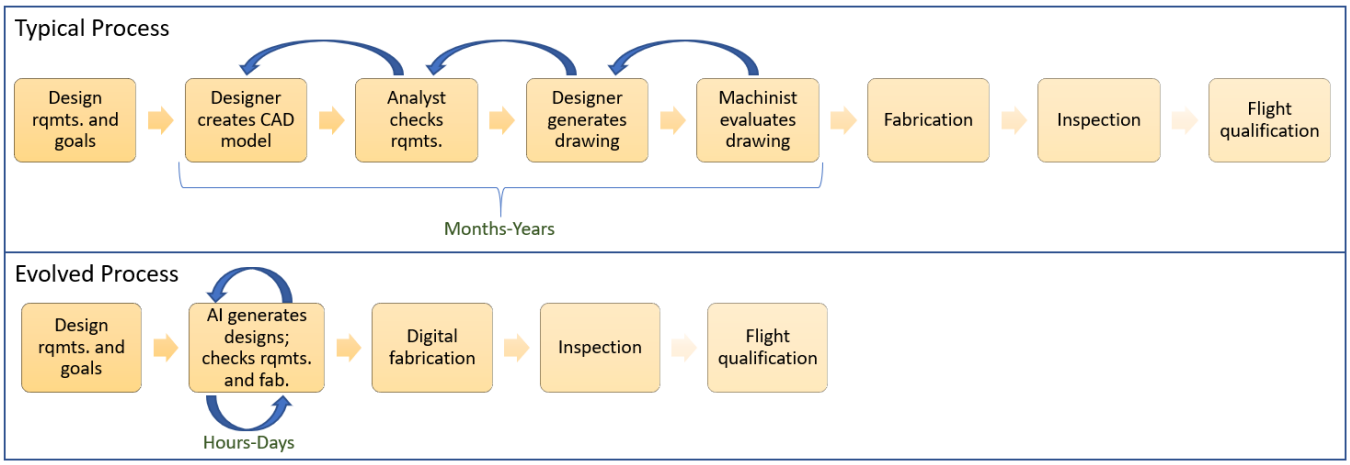
Designer	Expert Humans	Expert Humans	Expert Humans	Expert Humans	AI	AI
Design						
Iterations	1	2	3	4	31	31
Mass (kg)	0.59	0.18	0.27	0.18	0.2	0.2
1st Mode (Hz)	137	37	65	108	147	177
Max Stress (MPa)	26.3	189	103	60.7	14.8	11.2
Manufacturing	CNC $1700, 3 weeks	CNC No quotes	CNC No quotes	CNC/AM No quotes	CNC $1000, 3 days	AM $2000, 3 weeks

Expert human vs. AI designs of the EXCITE Tip/Tilt Bracket. The human designs were developed over two days by two expert humans (designer and analyst). Both AI designs were completed in about 1 hr. The AI designs are stiffer, stronger, and easier to manufacture.

Evolved Structures Process

Evolved Structures process has been developed at NASA GSFC. This process has three primary steps:

1. Digitally encode structure requirements into software
2. Use Generative Design AI to evolve optimal designs
3. Fabricate parts directly from CAD models using Digital Manufacturing processes (CNC Milling or 3D printing)



Comparison of a typical development process for spaceflight structures, and the Evolved Structures process. Iterations between multiple people/organizations are automated into a single process, yielding optimal designs faster and with fewer errors.