

The future of FPGA technology in the aerospace and defense industry



Author: Dean Rosales, Solution Architect, Quest Defense



FPGA evolution and its role in aerospace & defense

Field Programmable Gate Arrays (FPGA) have transformed the landscape of electronic design and application, especially within the aerospace and defense (A&D) industry. Originating in the 1980s, FPGA technology has undergone significant evolution, transitioning from simple glue logic devices to complex, highly configurable systems capable of performing a wide array of digital functions. This technological progression has positioned FPGAs as indispensable tools in the A&D sector, thanks to their flexibility, high performance, and the ability to be reprogrammed post-production, which is crucial for long-term, adaptable missions and applications.

In the A&D industry, the role of FPGAs extends beyond traditional uses, enabling advanced communication systems, radar and signal processing, and flight control systems, among other applications. Their ability to be updated or reconfigured in the field allows for extended lifecycles of critical defense and aerospace equipment, ensuring these systems remain at the cutting edge of technology without the need for complete overhauls. Additionally, FPGAs play a pivotal role in prototyping and validating new systems, providing a versatile platform for testing before committing to mass production.

In this article, we can explore how they can also become the cornerstone of future innovations enhancing performance, efficiency, and sustainability in the aerospace and defense industries.



The criticality of FPGA in modern A&D applications

In the aerospace and defense industries, the demand for high-reliability systems cannot be overstated. FPGAs address this need effectively due to their unique ability to be reprogrammed and updated in the field, unlike traditional fixed-function chips. This flexibility allows for quick adaptations to new technologies and standards without the need to redesign the hardware, ensuring that critical systems can evolve over time and maintain stringent reliability standards. FPGAs are also renowned for their robustness against environmental challenges such as radiation and extreme temperatures, which are common in aerospace and defense scenarios. For example, FPGAs are employed in flight control systems,

where their ability to process complex algorithms in real time can enhance the precision and safety of aircraft operations.

Additionally, in satellite communications, FPGAs provide the processing power required for high-speed data transmission and encryption, which are crucial for both military and commercial satellites. The adaptability of FPGAs allows aerospace engineers to continuously improve and update systems, which is essential for maintaining the safety and efficiency of missions.

In defense systems, FPGAs' versatility is invaluable, supporting a wide range of applications from signal intelligence to weapon system management. FPGAs also play a crucial role in electronic warfare systems, wherein they process vast amounts of data in real time to identify threats and support defensive measures. Their ability to rapidly reconfigure provides a tactical advantage by allowing military hardware to adapt to new threats or operational requirements immediately. This adaptability is critical in modern warfare, where electronic and cyber capabilities are constantly evolving, requiring defense systems that can keep pace with new-age conventional warfare and urban conflicts.



Common challenges in FPGA deployment

Integrating Field-Programmable Gate Arrays (FPGAs) into aerospace and defense (A&D) systems comes with several challenges. One significant challenge is the complexity of FPGA programming and the expertise required to design and implement these systems effectively. Unlike traditional software development, FPGA programming requires a deep understanding of hardware design and parallel processing, which can limit the number of engineers qualified to work on FPGA projects.

Another challenge is related to the integration of FPGAs with legacy systems. Many aerospace and defense platforms have long lifecycles and incorporate technologies from different generations. Ensuring compatibility between these older systems and modern FPGA solutions requires extensive customization and can complicate maintenance and updates.

Additionally, FPGAs must meet extremely high reliability and safety standards due to the critical nature of A&D applications. Achieving this level of reliability often demands rigorous testing and validation, which can extend development timelines and increase costs.



Opportunities for aerospace and defense industries through FPGA advancements

Recent advancements in FPGA technology have significantly enhanced their capabilities, making them more indispensable in various industries, particularly in aerospace and defense. One notable development is the integration of System on Chip (SoC) designs that combine FPGA fabric with dedicated processor cores. This integration allows for greater system-level functionality within a single device, streamlining operations and reducing latency, which is crucial for real-time applications. The SoC FPGA devices, for instance, are ideal for space applications where both high processing power and minimal power consumption are needed. They support complex, multiple functionalities in satellites such as payload processing, telemetry, and command handling, all while adhering to the stringent power and space constraints typical of space missions.

Another advancement is the improvement in FPGA programming languages and tools, which has made FPGA development more accessible and reduced the time to market for custom FPGA-based solutions. Enhanced high-level synthesis (HLS) tools now allow engineers to write their FPGA algorithms in higher-level programming languages, such as C++, which are then compiled down to the hardware level, simplifying the design process, and opening up FPGA programming to a wider group of developers.

Newer FPGAs are now featuring more robust security features, such as integrated cryptographic blocks, secure boot, and physical unclonable functions (PUF). These features are critical for military and aerospace applications, where security against cyber threats is a critical concern. With threats evolving rapidly, the ability of FPGAs to integrate secure data handling capabilities directly into the hardware provides an additional layer of security to sensitive military communications and control systems.



FPGA in the push for green technology within A&D

FPGAs are pivotal in advancing energy efficiency within aerospace systems. One primary way they contribute is through their ability to optimize system operations by handling multiple functionalities simultaneously without the need for separate processors. This not only reduces the

physical hardware required but also cuts down on energy consumption.

FPGAs are crucial in the development of smart, adaptive power management systems within spacecraft and aircraft. These systems dynamically adjust power allocation based on the current operational demands, ensuring optimal efficiency, and reducing wastage. For example, in satellite systems, FPGAs manage power distribution to various subsystems like sensors and communication equipment, adjusting the power flow based on activity levels and power availability, which is often limited in space environments.

Additionally, the reprogrammability of FPGAs allows aerospace engineers to update systems with the latest power-saving algorithms without the need for hardware changes. This ability to adapt and upgrade hardware functionality through software updates ensures that aerospace systems can maintain peak energy efficiency over their operational lifespans.



FPGA and its influence on battery-driven vehicles and alternate fuels

In the context of battery-driven vehicles and alternate fuels, FPGAs facilitate significant advancements in the management and optimization of energy storage and consumption. In electric aircraft, FPGAs are employed to precisely control battery management systems, which are critical for the performance and longevity of battery packs. These systems utilize complex algorithms to monitor battery health, manage charging cycles, and optimize energy distribution based on real-time data, all processed by FPGAs.

FPGAs also enhance the functionality of vehicles powered by alternative fuels, such as hydrogen or hybrid systems. They are integral in managing the complex control systems that regulate fuel usage, engine performance, and emissions control. The flexibility of FPGA programming allows for precise tuning of these parameters to ensure optimal fuel efficiency and reduced environmental impact.

FPGAs also enable the integration of renewable energy sources into aerospace applications, such as solar-powered unmanned aerial vehicles (UAVs). FPGAs manage the energy harvested from solar panels, optimizing its storage and distribution throughout the vehicle's systems, thus maximizing the utility of renewable energy sources.



Predictions for FPGAs evolving role in sustainable aerospace and defense technologies.

The future of FPGAs in the Aerospace and DoD arenas will continue to grow. As AI proliferates and becomes more ubiquitous, AI-driven modules will help safeguard the operation of subsystems. Whether monitoring for faulted system conditions or part of the avionics evasive decision-making process, FPGAs will support compute-intensive AI algorithms. The net effect will be safer and more reliable aerospace, space, and DoD equipment.

Edge computing will be enhanced, enabling more sensor data processing, and consequently enabling more sensors to be deployed in a system. The result will be a feature-rich product with enhanced safety measures.

The ability to increase cyber vigilance will reduce the risks associated with bad actors. FPGAs will continue to expand the areas for data encryption, including communications and control data, which influence the security of the daily execution of the equipment's duties, the operators, and the occupants.

The per unit cost of computation, space, and power will continue to decline as it has historically.

Lastly, the reprogrammability of FPGAs will enable products to evolve with increased functionality, reduce deployment costs, and expedite upgrades in the field.



Ensuring a sustainable future with FPGA technology

The use of FPGAs in Aerospace and DoD products will continue its historical path of increasing features and reducing costs, weight, and power. The increase in embedded functionality in the areas of microprocessors, interfaces, communication protocols, cyber security, encryption, AI, and edge computing with high computation and low latency will enhance the end product with rich new features and increased safety and security.

Quest Global engineering projects span the full spectrum of FPGA-related challenges. Anything from simple designs that collect status and inventory and maintenance data to the computing of computationally intensive DSP algorithms, our teams have been involved. Making use of FPGA features such as a microprocessor of SoC designs as well as the circuitry intended to detect errors induced by radiation particles. We have designed them, simulated them, tested them, and integrated them with software. We have seen them come alive in the lab as well as witnessed them endure environmental testing through actual field deployments.



For further information or queries, please reach out to us at info@quest-defense.com