TATA CONSULTANCY SERVICES

Building on belief

The Future of Aerospace Design and Development is Neural

Prioritizing connectivity, efficiency, and design safety

Abstract

The latest technologies in the aerospace industry are paving the way for aircrafts that are more efficient, automated, and autonomous but also ultimately safer than ever before. The exponential increase in software content and the associated systems complexities associated with technological advancements are testing the limits of the design and certification processes for traditional aircraft systems of the past. Meanwhile, advances in information technologies are bringing new possibilities to the product development discipline, where we see the future of design, simulation, and testing of aerospace tools is neural. The TCS Neural Manufacturing™ framework provides a vision of cognitive technologies incorporated into product development and associated manufacturing. By applying neural principles to interconnected design tools, aircraft designers, regulators, and operators can prioritize both the safety and efficiency of developing significantly complex aerospace products.

Aircraft Design Stakeholders and Their Challenges

As market forces continue to incentivize advanced functionalities in the latest aircraft designs, the impact of these new systems must be thoroughly explored. This paper explores how these trends affect some of the key stakeholders within the new product development process, starting with their most pressing needs.

At the forefront of this advanced technology is the software developer. Over the past two decades, software developers have been tasked with building cutting-edge functionality into the aircraft systems. Yet with systems complexity increasing exponentially, it is not feasible for individual software engineers to be in full command of the many intricacies at play. Rather, the burden must be shared by advanced design tools and techniques.

Another key stakeholder is the gatekeeper, the persona represented by the designated engineering representative (DER) and regulators. This group is tasked with ensuring the safety and reliability of these complex designs, which are the collaborative result of many designers, departments, and disciplines. Individual gatekeepers must have visibility into cross-functional information to ensure meaningful oversight without encumbering the product development processes.

The third key persona here is the pilot. The interplay between pilots and aircrafts continues to evolve in areas such as automation and control authority. Cognitive technology can play a significant role in the development of these systems, as well as pilot training and systems certification while ensuring overall safety of flight.

An Era of New Challenges

Historically, the practice of aerospace engineering has been driven by the steady evolution in disciplines like aerodynamics, structures, mechanical and electrical systems, and hydraulics. As a result, many of the currently practiced design and certification processes were developed for the traditional aircraft systems of the past. The complex software systems of the present and future are testing the limits of these tools and processes.

Challenge #1: System as Hierarchy versus System as Network

The first challenge to the new aircraft development status quo is the nature of the modern, software-focused aircraft system. While legacy systems are well-suited to a hierarchical approach, this no longer supports their modernized counterparts. Further, a more agile product development cycle is a competitive advantage that all aircraft designers would like to have.

Systems designed and organized according to a hierarchy, with each part contributing directly to the next higher assembly, conveys a top-down approach to the design and validation processes. Even organizations are arranged with subsystems, such as engineering teams, project managers, DERs, and Federal Aviation Administration (FAA) committees, as building blocks.

Modern software systems redefine each of these organizational elements. Software is developed and behaves more like a network of modules than a functional hierarchy. Systems may interact at different levels, with multiple data streams and consumers. For example, data from a single sensor may be consumed by multiple systems with various levels of safety criticality and design assurance level (DAL). This is enabled by a lack of physical constraints, giving designers more flexibility while removing the long-established functional boundaries of legacy aircraft.

While this paradigm shift is clearly a positive advancement in aerospace technology and design, it has demonstrated a gap in the contemporary tools and processes. Traditional product lifecycle management (PLM) still treats software content as embedded and contained within individual components. Development teams and departments no longer need to be constrained by systems or function. Design requirements need buy-in and contribution from many different stakeholders. Tools and processes conforming to the old paradigm need to catch up.

Challenge #2: Coverage Gaps for Developers and Gatekeepers

In terms of team organization, software development has a higher tolerance for disconnected, siloed development over their physical designer counterparts. Legacy designers might be regularly exposed to the upstream and downstream impacts of their designs in the traditional hierarchy, whereas software developers may not have the same contextual reference.

These challenges of contextual knowledge can extend to the DERs and regulators as well who are the gatekeepers for systems certification (see Figure 1). While the traditional regulatory subject matter expert (SME) had a finite functional system to provide oversight coverage, those gatekeepers of software systems do not enjoy the same structure. System architecture as a network of modules does not provide clear boundaries for oversight.

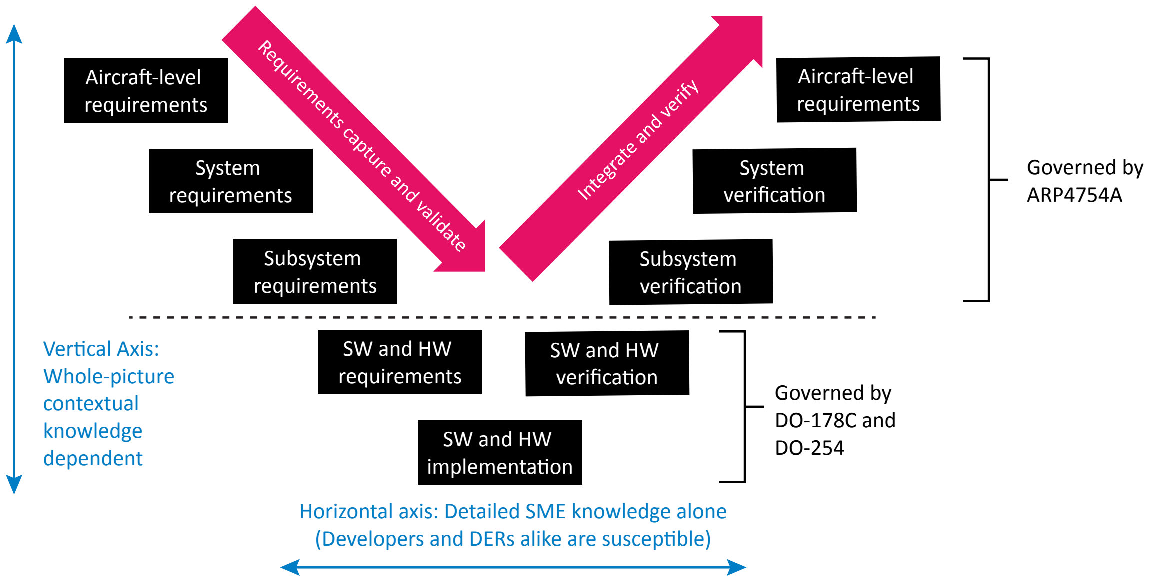


Figure 1: FAA-accepted model for development and certification of complex systems

Challenge #3: Pilot Interface and the Cognitive Flight Deck of the Future

Beyond the difficulties of designing systems-of-systems lies the complication of how best to integrate the pilot into the mix. As the computing power of machines has scaled exponentially, it is increasingly at odds with the human who is meant to be in command.

For instance, adding more sensors to systems and instruments to the flight deck is intended to help the pilot in abnormal flight situations. But multiple systems might consume and interpret the same data, or a single system may combine multiple data sources with complex calculations. In such cases, providing more information may actually hinder the pilot in a stressed situation. Furthermore, it is impractical to train pilots for every permutation of system failure modes and cascading effects.

Furthermore, a significant complication to the pilot-aircraft interface is the propagation of automated flight deck functionality. Advances in artificial intelligence (AI) will continue to automate discrete functionality, which was previously performed by the pilot. In the AI field of study, this is known as human-in-the-loop (HITL) automation (see Figure 2).

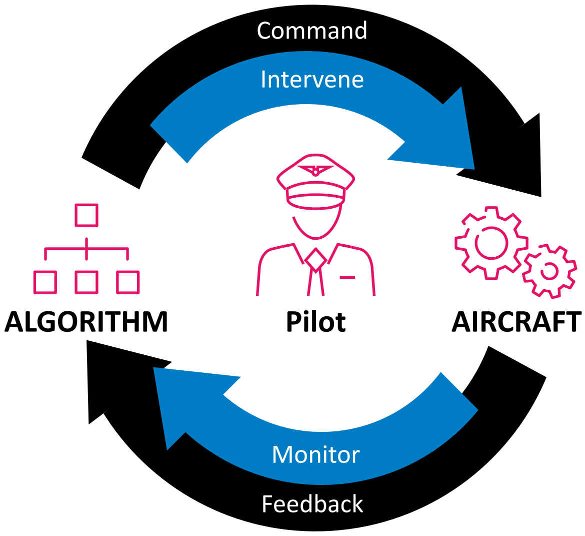


Figure 2: Human-in-the-loop automation in the flight deck

This presents new regulatory challenges to aircraft development, certification, and operation. For example, systems that provide autonomous functionality must display a clear line of command with the human pilot and make its intentions clear. Additionally, at any given time, the pilot must be given the ability to revoke an autonomous system's authority. A recent study suggests that pilots are often unaware of why some automated functions behave as they do, and that they are already concerned about keeping up with the future of cognitive automation. The scrutiny of cognitive automation in the flight deck is sure to increase, with added pressure on the regulatory oversight of the design of these systems.

Challenge #4: Full Autonomy as the New Paradigm

As cognitive automation assumes more control over flight management, the fully autonomous flight deck, manned or un-manned, is emerging as a realistic design. While the individual systems may not change dramatically, the level of human authority over those systems will have a fundamental shift, from a human pilot with granular control to a human operator providing oversight alone. This has been referred to as the human-governing-the-loop (HGTL) (see Figure 3).

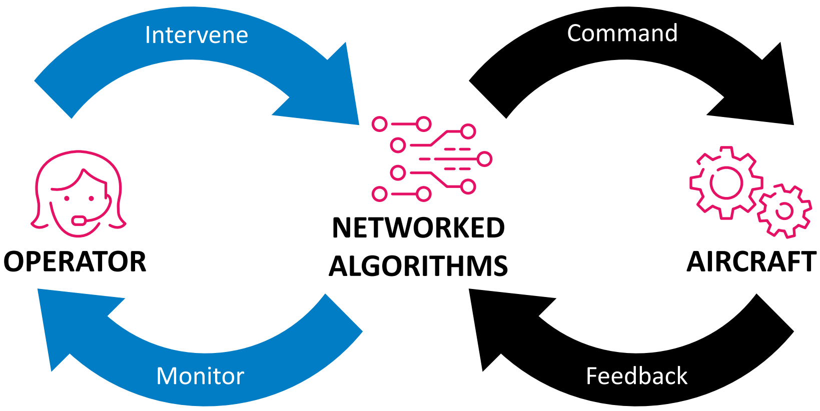


Figure 3: Human-governing-the-loop autonomy

Contemporary development processes and tools are built with the traditional arrangement of the human pilot. To support the new paradigm of the aircraft operator, these tools must also evolve. For example, designers must demonstrate that these systems take the correct action under every foreseeable circumstance.

As for oversight, the regulatory challenges will likely mature more slowly than the technology itself. While this delay is expected, manufacturers must be proactive. Regulatory agencies will need industry support and performance data to define the governing code for this new paradigm. Industry-first adopters will have a competitive advantage in this process, as early input can shape policy and bolster company reputation along with ultimate customer confidence.

Opportunities in the Pilot-Aircraft Interface

Improvements to the HITL arrangement are an immediate opportunity area. Recent developments in neural networks allow simulation of the human mind and behavior, including logic and processing. Applying these advances to a simulated pilot would be a powerful development tool for avionics design and certification. This could be used as a real-time testing tool, to validate design decisions and identify problematic interactions much earlier in the design process. Instead of discovering issues at the flight test phase of certification, they could be preempted by an iterative design process before the software is ever committed to the aircraft.

Sourcing the data for such a pilot model would involve capturing and aggregating data which is already being measured. Flight simulators, mobile app assessments, and actual flight deck data can provide both the statistical foundation for the model, as well as training data for AI enhancement.

Opportunities in Systems Modeling, Simulation, and Definition

Another area of development which is primed for reform is the tools and processes used in the systems design effort itself. The discipline of model-based systems engineering (MBSE) has provided a framework for functional and logical design and promotes the importance of systems thinking in general. The next major improvement in this space will be to formalize this framework into machine-testable models to simulate complex systems, and then use those simulations to validate development code in real time.

Machine learning will enable automated testing of all interactions and edge-cases of various aircraft systems, without requiring the systems designers to define endless lists of test points. Such testing will unburden designers from legacy systems requirements, while ensuring all possible scenarios are probed and evaluated.

Beyond automated testing is the potential for supporting DER and other regulators' analyses and reviews. Since these stakeholders are tasked with being the gatekeepers for safety and reliability, they too would greatly benefit from robust modeling and the ability to validate any number of complex interactions. Such a model represents a technology-enabled augmentation of regulators' reviewing capacity. Combined with the previously discussed modeling of human pilot capabilities, the aircraft safety reviews would no longer be constrained by the limits of individual expertise but would rather be driven by AI/ML techniques to isolate any problematic combination of events and low probability edge-cases.

Opportunities for AI-Augmented Designers and Reviewers

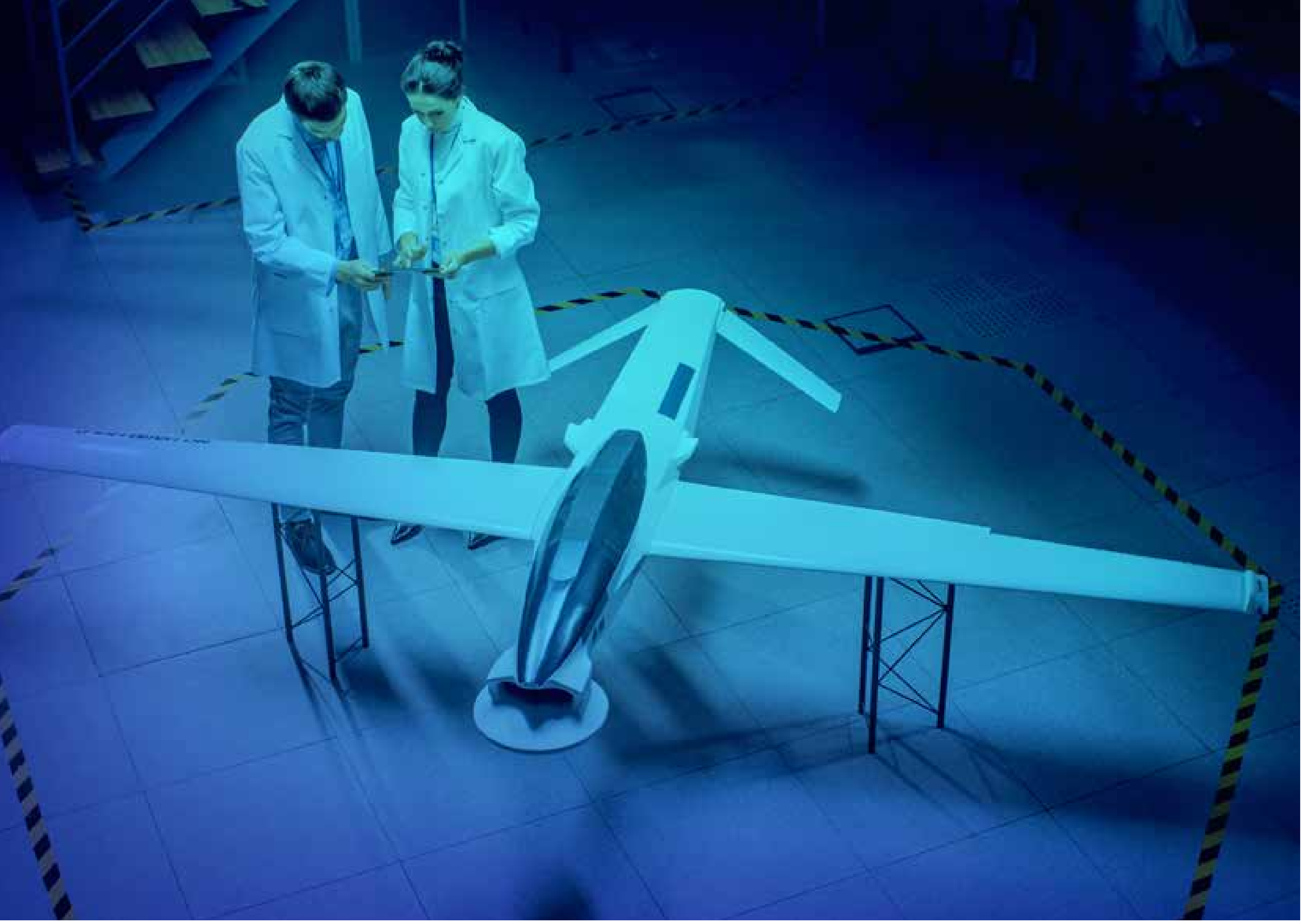
Design aids powered by AI are poised to become the third groundbreaking engineering discipline. Once the foundation of integrated software management and robust systems modeling is laid, machine-learning toolkits then have the source material from which to provide meaningful guidance.

First, training content on industry best practices and company standards can be identified by AI/ML algorithms. Imagine a developer, creating code to govern a system with which they don't have direct experience. The code is housed in the application and product lifecycle management platforms (ALM-PLM), as is the system model used to validate that code, as well as historical codebase for similar applications and aircraft. The AI/ML toolkit can mine all metadata and suggest a company-specific training video or an example of a similar application to assist the developer and promote design integrity. The same process can be applied to the regulator analyzing the system or the engineers and pilots tasked with the flight test program. Not only does this address a discrete moment in the design process, but it also promotes contextual knowledge for all parties, which is crucial over the longer-term.

In addition to serving contextual knowledge, such an AI/ML toolkit can provide direct reviews of analysis documentation. This follows precedent in the legal field, where AI contract reviews are both streamlining the human review process and identifying red-flag language or structure which may otherwise be missed. For example, DERs and regulators are responsible for reviewing thousands of pages of dense technical documentation. The use of an AI/ML-based application to parse that documentation and search for inconsistencies or other flaws would be a groundbreaking approach. It would provide greater visibility to regulators and promote consistency in the review process, thus not only speeding-up the review process but also potentially enhancing safety.

A Neural Approach to Aircraft Design

In the future, the pilot interface will leverage massive data sources, used to drive pilot-friendly design and improve pilot proficiency and situational awareness. This can bridge the gap between pilot and machine with neural AI/ML simulations to address both sides at once. The future of MBSE is a fully integrated modeling environment, where a user can seamlessly evaluate design elements, both software and hardware, to ensure proper systems operation in any scenario. This vision augments the capabilities of designers, reviewers, and regulators at each stage of new aircraft development. This reiterates the fact that the future of contextual knowledge depends on AI-augmented developers and regulators and a neural ecosystem for product developers and regulators. The emerging technology can create linked networks of relevant information, isolate key concepts needing review, and raise red flags for inconsistencies in product designs. These smart tools are poised to improve the efficiency, safety, and reliability of new aircraft designs.



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