White Paper | Manufacturing

Neural Ecosystems

Driving Next-Generation Aerospace Manufacturing

Abstract

The aerospace industry has been at the forefront of incorporating innovations to develop diverse and highly engineered new products, new manufacturing methods, and enhanced post-production aftermarket services. The aerospace manufacturing ecosystem is an integrated mix of industry players spread across airlines, aircraft manufacturers, airports, air traffic management, regulators, ground support, and an extended network of tiered suppliers. Legacy operational technologies were not designed to be connected, and therefore, work only in their own environment. As a result, information exchange and interoperability between this extended aerospace ecosystem have been slower and fragmented.

A neural aerospace enterprise leverages emerging technologies to build a resilient, adaptive, and intelligent value chain supported by purpose-driven and networked partners. This kind of extended aerospace value chain ecosystem underpinned by various digital technologies mimics the human neural network, enabling strong interoperability and information flow in all directions (Figure 1). This is what we refer to as Neural Manufacturing for Aerospace – a highly networked ecosystem that is connected, intelligent, resilient, automated, adaptive, personalized, and cognitive. This paper focuses on the key facets of a neural aerospace enterprise and the benefits neural ecosystems can bring to the aerospace industry.

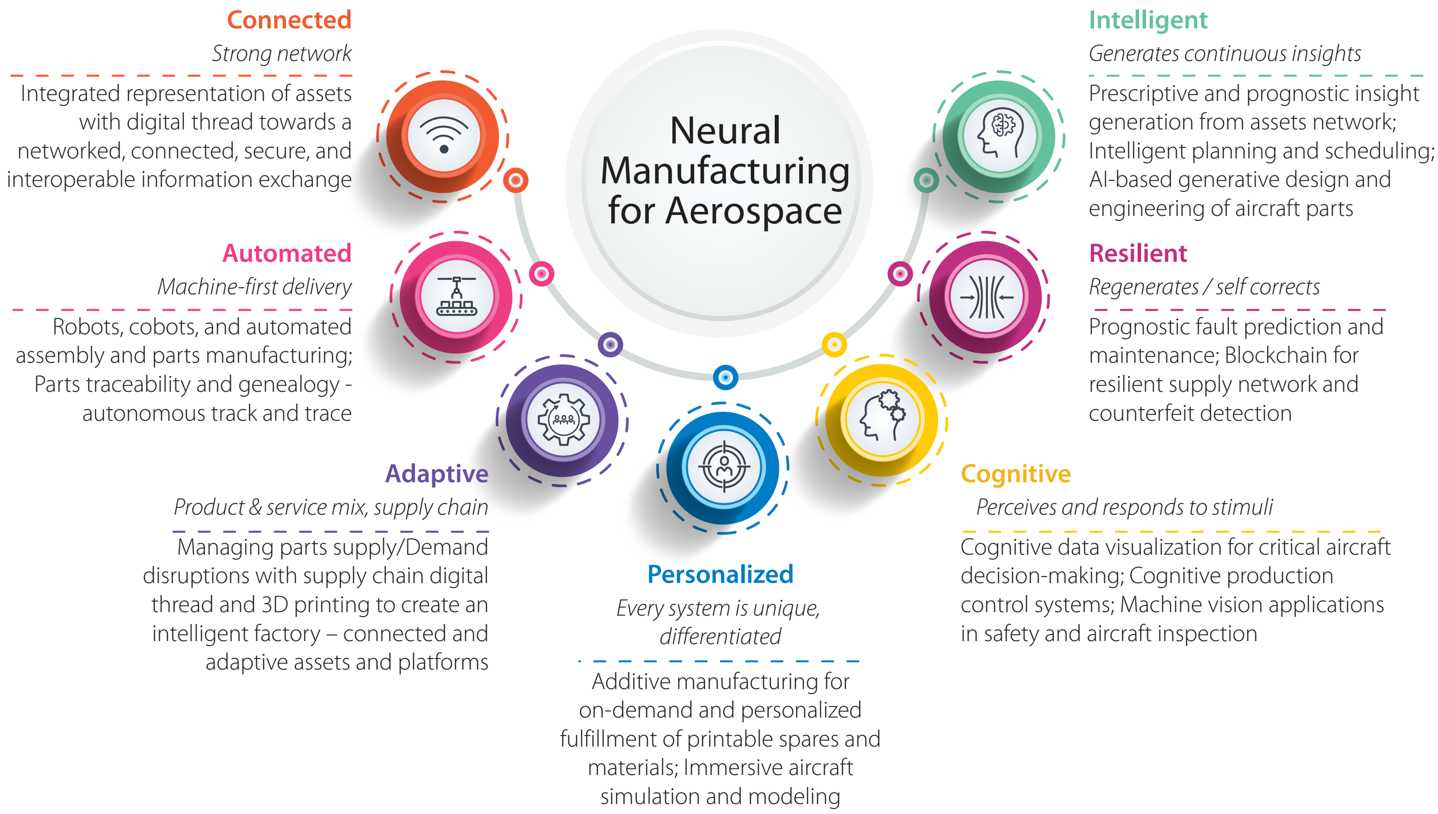

Figure 1: Key facets of a neural aerospace enterprise

Smart neural factory: Connected everything with secured interoperability

Aerospace manufacturing lead times often run into several quarters and years, resulting in less than agile response to supply/demand disruptions. A fully autonomous, always-on network architecture of systems enables information flow in multiple directions across factory cells and machines, and augments human decision making. Such a network can also autonomously predict production scenarios through self-health monitoring and real-time maintenance, thereby achieving efficiency, precision, and much-desired agility.

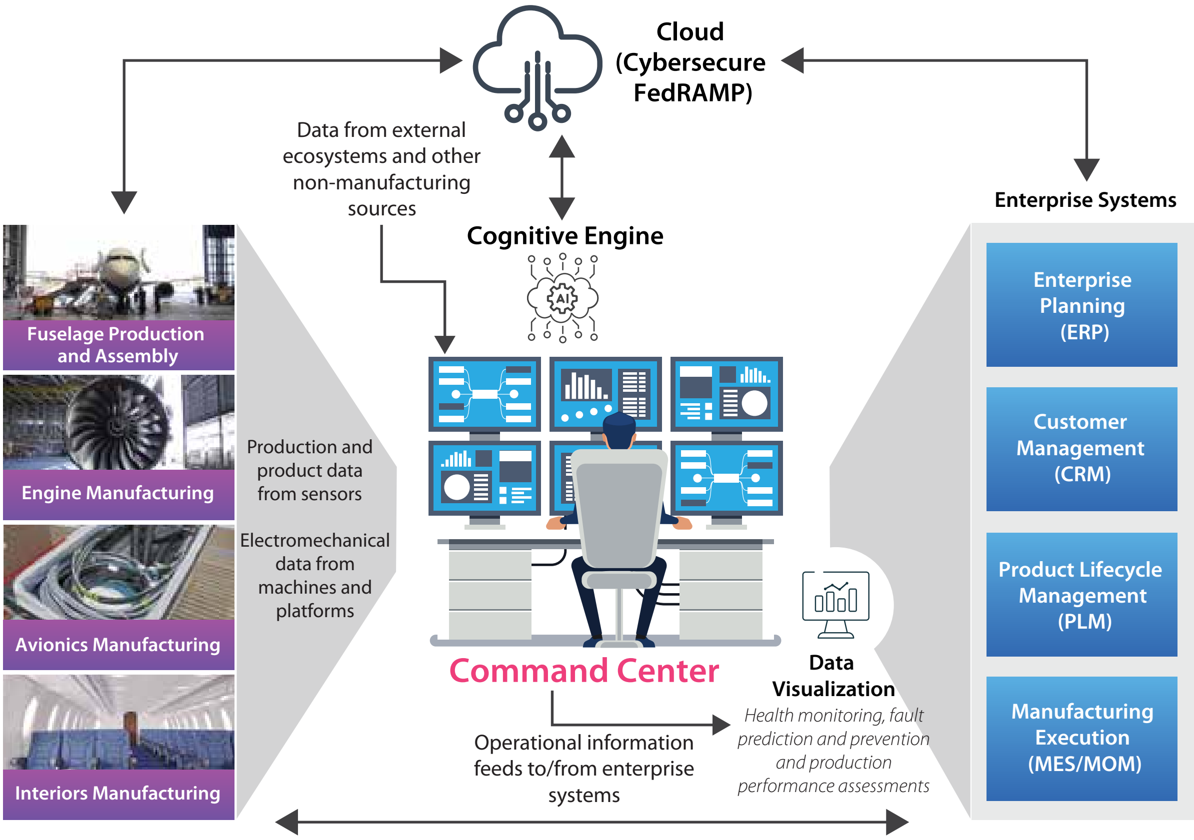

Figure 2: Smart neural factory of the future

A smart neural factory of the future (see Figure 2), drawing inspiration from biological neural systems, can better adapt to shocks and respond to external stimuli with resilience. The advanced analytics-based cognitive command center receives demand and supply data from external and internal factory sources. It then analyzes demand and supply signals from various enterprise systems like customer relationship management (CRM), enterprise resource planning (ERP), supply chain management (SCM), manufacturing execution systems (MES), product lifecycle management (PLM), and also from the factory floor. Such data analysis enhances machine health monitoring, enables fault prognostics, and improves overall equipment effectiveness (OEE). This paves the way for optimal manufacturing scheduling, production planning, and control.

In addition, the neural system extracts data from numerous internet of things (IoT) sensors installed in the products, assets, and platforms on the manufacturing floor. These sensors can capture production data from engine manufacturing, fuselage, wings, avionics, and other product sub-systems and their suppliers. Similarly, data can also be gathered from devices such as augmented and virtual reality (AR/VR) gears and mobile devices that scan the factory. The system can also connect workers and tools for specific tasks. It also connects industrial IoT platforms, enabling information flow across aircraft assembly and the extended supply chain network. All the big data is then aggregated into the central control system where it can be analyzed through advanced artificial intelligence (AI) and machine/deep learning (ML/DL) techniques 'on the edge' and presented via a data visualization system for human consumption and decision making. The core system then acts as a neural brain to provide analytical prescriptive decisions for health monitoring, fault prediction and prevention, and production performance. This in turn improves real-time decision making leading to enterprise and ecosystem-wide process and resource optimization.

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The evolution of technology across the aerospace value chain

As aerospace manufacturers become more agile, resilient, and intelligent, a neural aerospace innovation path is emerging, which is a purpose-driven ecosystem, that can support glocal, a combination of global and local, manufacturing with automated operations. Figure 3 below graphically depicts how aerospace transformation across the value chain is being driven by various digital technology advances.

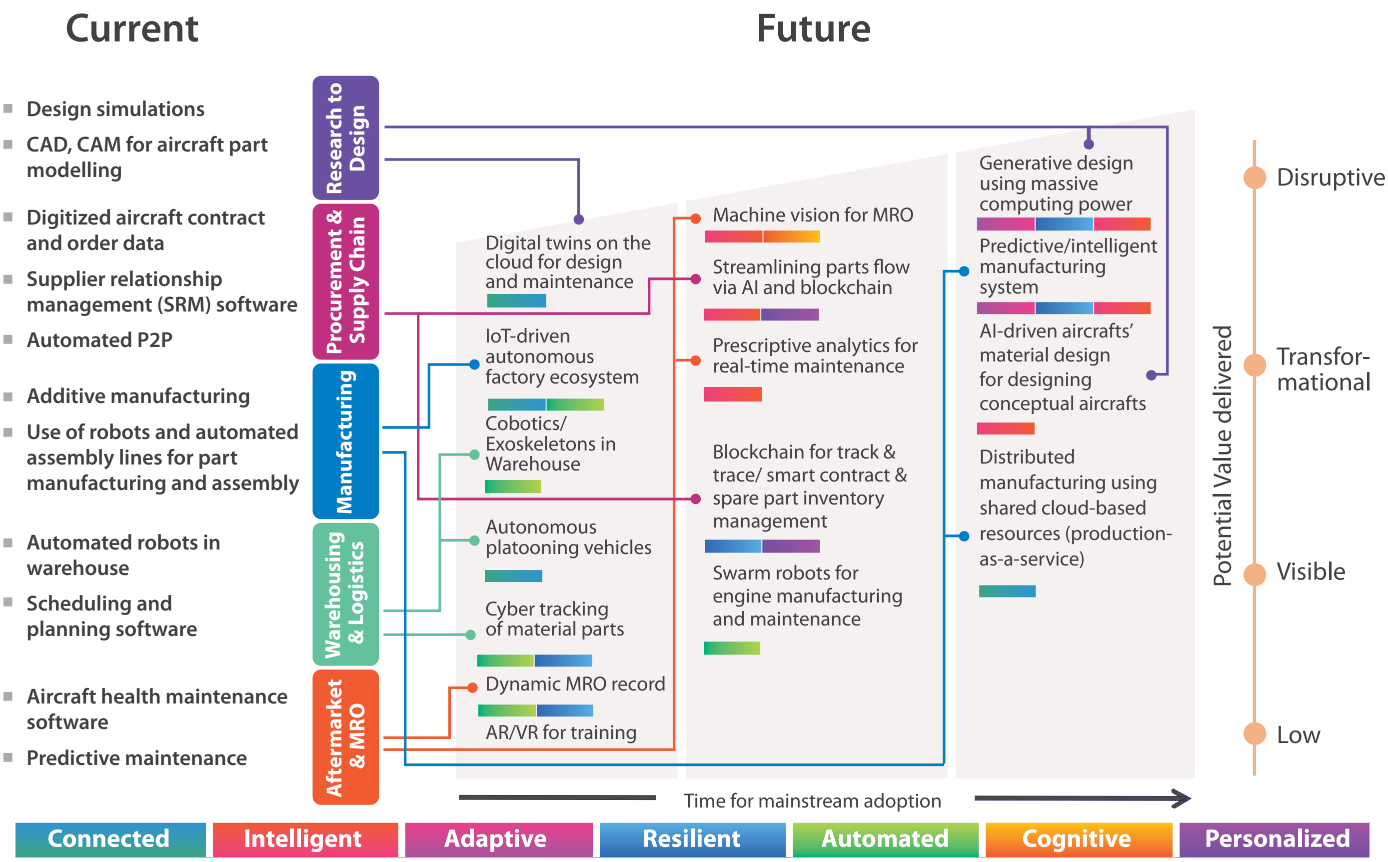

Figure 3: The future aerospace value chain driven by neural pillars

The increasing use of massive computing power and digital twins to develop radical new parts and aircraft designs will disrupt aircraft design, accelerating the evolution from computer-aided simulative design (CAD) towards generative design. The use of AI-driven materials design will create advanced smart materials that enable lightweight, agile, and intelligent aircraft designs for the future. In addition, blockchain can be used to track and trace parts across the supply chain and ensure optimal spare parts inventory management. Aerospace players are increasingly using cobots and bionic exoskeletons in the warehouse as well as autonomous platoons for logistics, and AI for streamlining parts flows. In fact, additive manufacturing and robots are being increasingly used for end-use parts fabrication and parts manufacturing. An increased influx of connected assets and platforms will present the opportunity to create a fully autonomous factory with IoT and distributed manufacturing through shared cloud-based resources, creating an asset-light environment (production-as-a-service). Digital twin and model-based outcome prediction for maintenance and aircraft health in the maintenance, repair, and overhaul (MRO) aftermarket have been dynamically augmenting matured technologies such as aircraft health maintenance software. Likewise, prescriptive analytics is supplementing predictive maintenance by enabling decision making in addition to predicting failure events.

Designing a neural aerospace enterprise

The aerospace value chain is rapidly changing from a traditionally linear structure to a highly layered network with multiple ecosystem partners. Here, each ecosystem participant may be viewed as a neuron interconnected by a web of nodes. The edges that connect the nodes form an information-sharing network. This biomimicry of a neural network consisting of three representational layers (see Figure 4) can pave the way for the neural aerospace enterprise.

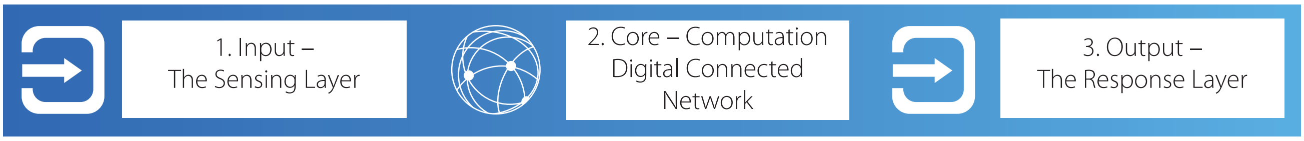

Figure 4: The three layers of the aerospace neural network

1. Input – The sensing layer: This system perceives stimuli and can learn and orchestrate complex sets of tasks. For instance, data coming from flying aircraft, real-time engine information, and data from the partner ecosystem can enable data monetization, assist in creating new services, and enhance customer and partner relationships.

2. Core – Computational digital connected network

a. The core neural system:

- Core systems are technologies underpinning the network. For instance, the aerospace industry has wide-scale use of technologies such as the cloud for infrastructure support; 5G for aircraft and satellite communication and data sharing; autonomous flying; and data lifecycle management and cybersecurity solutions for information sanitization and privacy.

- Interface systems are emerging technologies that can enhance networking and communication across each value chain function. For instance, additive manufacturing in the aerospace industry enables on-demand fulfillment of spares. Interface technologies such as blockchain, IoT, and immersive technologies can act as different enabling nodes of the network.

b. **The digital network:** Creating a network requires interaction and platform integration among all ecosystem players. With platform technologies—such as shared computing and on-demand service platforms, data harvesting systems and distributed B2B marketplaces—individual partners can offer dynamic and enhanced value to customers by leveraging their partner ecosystem.

3. Output – The response layer: With the input layers (sensing), middle layer (core neural system), and the connecting network nodes, the ecosystem creates a response which remains resilient and can better withstand disruptions. The response layer takes curated inputs from all the network partners and offers data-driven business insights via visualization platforms which aids in decision making.

Aerospace ecosystems of the future: Three neural dimensions

The evolving neural aerospace ecosystem of the future can be represented by three interconnected dimensions building on Industry 4.0 foundational technologies (see Figure 5).

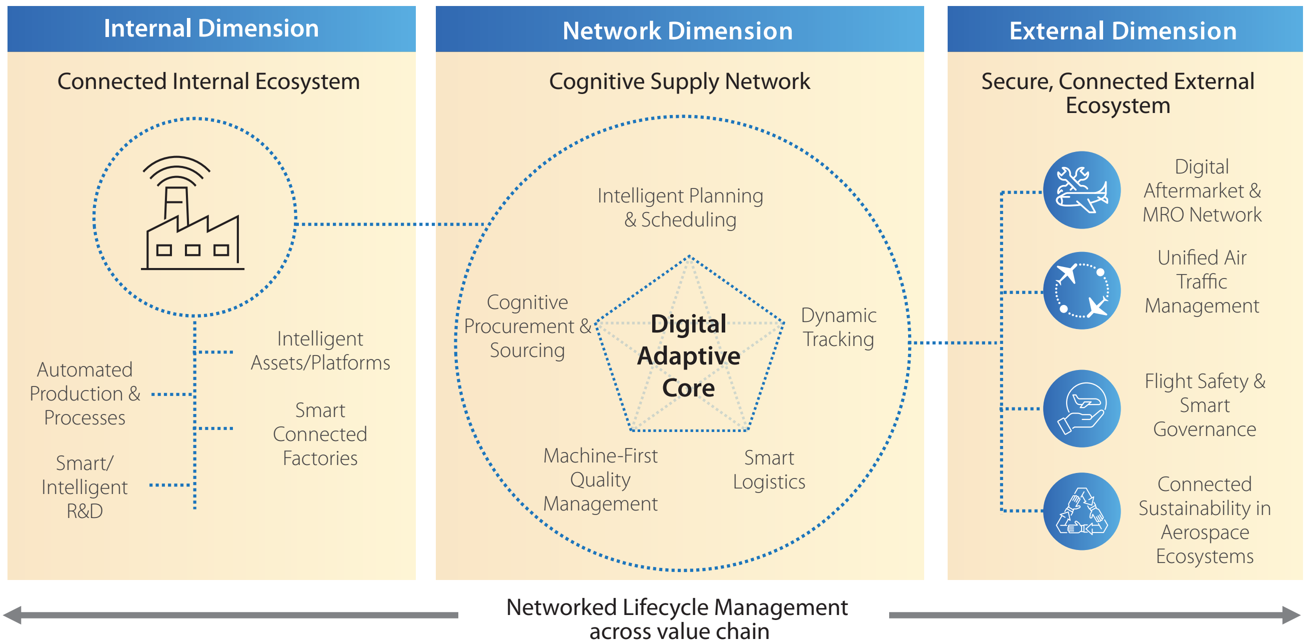

Figure 5: Three key dimensions of the neural aerospace ecosystem of the future

- **Internal dimension:** A connected internal ecosystem with cognitive computing architecture – This dimension intelligently connects internal smart assets and platforms powered by IoT and automated production and processes with human-machine interaction.
- **Network dimension:** A cognitive supply network (CSN) – The application of cognitive technologies such as AI, ML, natural language processing (NLP), computer vision, and robotics in supply chain allows the entire network to think and interact over the cloud. An end-to-end visibility of the supply network can be achieved by coupling connected networks with IoT for increased automated communication and digital twin technologies, which offer the ability to simulate multiple scenarios and predict failures and risks.
- **External dimension:** A connected external ecosystem – The successful neural ecosystem is efficient and seamlessly integrates the elements of the internal, network, and external dimensions, as described below:
  - **Digital aftermarket and MRO network:** With diverse and distributed aftermarket partners, it becomes a challenge for the industry to access a single source of truth (SSOT) throughout long lifecycles. A digital aftermarket network offers the benefit of remaining always on for stakeholders by offering access to real-time shared services and insights from across the network such as gaining real-time monitoring and repair instructions using immersive reality, IIoT, and wearables from all the equipment and parts across the entire ecosystem.
  - **Neural unified air traffic management:** Commercial aviation is rapidly evolving, where new aircrafts are emerging, including drones for various applications, air taxies, and sub-orbital and supersonic aircrafts. Traditional air traffic management (ATM) systems, which were designed for large commercial aircraft, will need to evolve to handle this complexity as well as allow for continued innovations to enable the emerging aviation sectors to shift to unmanned aircraft system traffic management (UTM). UTM is expected to offer digital-native and intelligent, automation capabilities which can pave the way for future services and new concepts of operation, while working in tandem with and converging with current ATM advancements. Significant work lies ahead in AI, cybersecurity, digitalization, cloud, and sustainability to integrate the emerging aviation sectors with the traditional aviation system, which will manifest into a neural unified UTM-ATM air traffic management vision.
  - **Flight safety and smart governance:** The industry is moving beyond the on-premise systems with high-information latency towards a shared and cloud-enabled on-demand resource with secure data transparency and accountability improving aerospace ecosystem safety and governance.

- **Connected sustainable environments:** Original equipment manufacturers (OEMs) today are rethinking aircraft design and engine technologies for sustainability with electric and hybrid-electric propulsion. AI and IoT data sources coupled with advanced analytics for real-time air navigation and continuous climb and descent operations are improving aircraft scheduling, route planning, safety practices, and conflict predictions, creating a sustainable ecosystem.

Building agility and resilience through a neural aerospace manufacturing ecosystem

The aerospace industry has traditionally been a cutting-edge user of scientific advances whether through government funded R&D or its own industrialization research. In recent years, the pace of technology absorption has been accelerating with several digital innovations coming to fruition. COVID-19 has further accelerated the move towards digitalization and the envisioned neural aerospace ecosystem of the future. The commercial space industry is also emerging as a new frontier with unprecedented possibilities leveraging digital technologies. Digitally mature and other early-adopter organizations are well-equipped to build a resilient ecosystem of value chain partners and suppliers, and in the process creating the neural aerospace ecosystem of the future.

Authors

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