



# WHAT KEEPS PLANES SAFE: AN INTRODUCTION TO AIRCRAFT MAINTENANCE IN THE DIGITAL AGE

## Abstract

Aircraft maintenance is the foundation of aviation safety, ensuring that complex aircraft systems remain airworthy throughout their operational life. This article provides an introduction to aircraft maintenance, explaining how maintenance checks are structured over time and why disciplined inspection regimes are essential to managing risk at scale. From Augmented Reality (AR) maintenance checklists for airlines to data-driven systems, this article explores how emerging technologies are changing how maintenance is performed. It also explores the growing role of artificial intelligence, connected aircraft systems, digital twins, robotics, and secure digital records in strengthening maintenance governance.

More than 40 million commercial flights operate each year globally, and while serious accidents remain rare, industry data shows a slight rise in the global accident rate to one per 1.11 million flights in 2024. This confirms a critical

reality: aviation remains highly safe, but safety performance cannot be taken for granted. It is sustained through rigorously structured aircraft maintenance systems that identify, correct, and document risk long before an aircraft ever leaves the

ground. While aircraft design and pilot skill are critical, it is maintenance executed daily, governed meticulously, and verified through inspection regimes that quietly keep aviation safe at scale.

## What is aircraft maintenance: the basics and why it exists



At its core, aircraft maintenance is the structured set of activities that ensure an aircraft remains safe, serviceable, and compliant throughout its operational life. These activities include scheduled inspections, defect rectification, component replacement, mandatory service bulletins, and compliance with airworthiness directives.

Maintenance exists because aircraft are complex, safety-critical systems operating under constant mechanical stress and environmental exposure. Components wear, materials fatigue, and systems degrade over time. Effective maintenance involves applying repeatable inspection regimes, approved repair methods, and documented certification processes.

To manage this complexity consistently across fleets and geographies, maintenance is not performed ad hoc. It is organised into clearly defined inspection programmes that specify what must be checked, when, and to what standard, forming the backbone of airline maintenance planning.

## Aircraft maintenance checks: how inspections are structured over time

Maintenance work is commonly organised into recurring “checks” of escalating scope. The convention used by airlines and Maintenance, Repair, and Overhaul (MRO) organisations is helpful for planning resources and minimising downtime:

### A check

Lightweight, frequent inspections (done every few hundred flight hours or a few weeks, depending on the operator). These are line-level activities that keep aircraft in daily service.

### B check

Historically an intermediate check (6–8 months), now largely folded into A-check cycles or phase checks in modern MSG-3-based programs.

### C check

Comprehensive inspection performed every 18–24 months (or after a defined number of hours/cycles); it can put aircraft out of service for days or weeks.

### D check (heavy maintenance)

The most extensive teardown and overhaul; occurs every several years and can take aircraft out of service for weeks.

These checks follow approved intervals and demand advance planning for facilities, labour, and supply chains. This check-based framework anchors aircraft maintenance planning. However, the way these inspections are prepared for, executed, and documented is rapidly evolving.

## Technology transforming aircraft maintenance

From AI and connected aircraft systems to augmented reality and digital twins, emerging technologies are redefining how aircraft maintenance is planned, executed, and governed at scale.



### Artificial intelligence and predictive analytics

Artificial intelligence is transforming aircraft maintenance by shifting it from a reactive function to a predictive and decision-driven discipline. AI systems analyse large volumes of historical maintenance records, sensor data, and operational information to identify patterns that indicate potential component failures. Instead of waiting for faults to occur or relying solely on fixed maintenance intervals, airlines can anticipate issues earlier and plan interventions more efficiently. This reduces unscheduled maintenance events, improves aircraft availability, and helps maintenance teams focus effort where it delivers the greatest safety and operational impact.



### Internet of Things (IoT) and connected aircraft systems

The IoT plays a foundational role in modern maintenance strategies by enabling continuous data collection from aircraft systems and components. Sensors embedded across engines, avionics, landing gear, and environmental systems generate real-time performance data during flight and on the ground. This connectivity allows maintenance teams to monitor asset health remotely, detect anomalies sooner, and correlate operating conditions with wear and tear. As aircraft become increasingly connected, IoT data provides the raw intelligence required to support predictive maintenance models and more informed maintenance planning.



### Augmented reality in maintenance execution

AR is improving how maintenance work is carried out by helping technicians work faster and more accurately. AR maintenance checklists that airlines deploy provide visual, step-by-step guidance, interactive schematics, and real-time data through tablets or smart glasses. Technicians and line engineers show reduced task time, fewer errors, and faster onboarding. AR is particularly effective for complex, low-frequency tasks where visual guidance helps prevent mistakes and rework.



### Digital twins and simulation models

Digital twin technology creates a virtual model of an aircraft, system, or component that reflects its real-world condition over time. By combining design data, operational inputs, and maintenance history, digital twins enable performance simulation, wear analysis, and “what-if” maintenance scenarios. This supports more accurate life-cycle forecasting, better planning, and informed decisions on repairs and replacements, while giving operators clearer visibility into asset health.



### Robotics and drone-based inspections

Robotics and unmanned aerial vehicles are increasingly used to support inspection activities that are time-consuming or difficult for humans to perform. Drones equipped with high-resolution cameras and sensors can inspect fuselages, wings, and tail sections quickly and safely, reducing aircraft downtime and eliminating the need for extensive scaffolding or elevated platforms. Robotic systems can also assist with repetitive or precision tasks in controlled environments. These technologies improve inspection speed and consistency while enhancing safety for maintenance personnel.



### Data integration and secure maintenance records

As maintenance operations become more digital, integrating data across systems is essential. Advanced data platforms consolidate information from aircraft sensors, maintenance logs, supply chains, and regulatory records into a single, traceable environment. Strong data governance ensures that maintenance actions are accurately recorded, easily retrievable, and compliant with regulatory requirements, supporting both operational efficiency and airworthiness oversight.



## Blockchain for secure aircraft maintenance records

Blockchain is being explored in aircraft maintenance to improve the reliability and traceability of maintenance records. Using distributed ledgers, records can be securely shared across operators, MROs, and regulators, with time-stamped updates protected from unauthorised changes. This supports regulatory compliance and asset integrity, while simplifying documentation workflows, improving data availability, and enhancing transparency, security, and efficiency across the aircraft maintenance lifecycle.

### Why this matters

Individually, these technologies deliver incremental gains. Together, they enable more intelligent and scalable maintenance, requiring aligned people, processes, and governance to protect safety and compliance. At the centre of this system is the human expertise that turns insight into action.

## The aircraft maintenance technician: people behind airworthiness



Aircraft maintenance is ultimately a human responsibility. The aircraft maintenance technician inspects, repairs, tests, and certifies aircraft systems, and their sign-off legally confirms that an aircraft is fit to fly.

Technicians are trained, examined, and certified under strict regulatory regimes. Their authority is personal and explicit; maintenance actions are not considered complete until a qualified technician certifies them. This makes workforce competence, experience, and availability critical safety variables.

Maintenance staffing is both a safety and capacity issue. Training pipelines, certification throughput, and retention of experienced technicians directly affect an airline's ability to meet maintenance schedules and avoid operational disruption. Even with strong processes in place, safety outcomes depend on how effectively people execute them.

## Where services and technology create the most value

Technology and outsourcing decisions in aircraft maintenance can be viewed across three layers:

### Data and sensors (foundational):

High-quality telemetry (engine health monitoring, component sensors, avionics logs, and event-based records) is the raw material for analytics. Data standardisation and centralised storage are prerequisites.

### Decision platforms (predictive + decision intelligence):

Algorithms predict failures and decision intelligence layers translate predictions into prioritised actions based on operational context (flight schedules, spare availability, passenger impact).

### Execution tools (AR checklists, mobile workpacks, digital logbooks):

These make maintenance execution faster, more accurate, and auditable. AR maintenance checklists, digital manuals, and mobile job cards reduce human error and drive technician throughput.

Services-led models such as outsourced MRO, managed analytics, or co-sourced digital engineering can accelerate adoption while letting airlines focus on operational core competencies. But success depends on governance: data sharing, security, IP ownership, and cross-functional leadership alignment.

## Implementation pitfalls

Many early predictive or digital maintenance initiatives fail not from poor technology but from organisational friction:



**Data fragmentation**

Siloed maintenance records, non-standard formats, and poor traceability limit effective analytics, making neutral data governance essential for consolidating and standardising information across systems.



**Lack of executive sponsorship**

Successful projects often have COO-level sponsorship because maintenance impacts operations broadly (network reliability, passenger experience, crew scheduling).



**Ignoring the human factor**

Tools must be designed for technicians, not engineers alone. AR maintenance checklists and mobile workpacks must reduce, not add cognitive workload.

When these organisational barriers are addressed, the benefits of digital maintenance become far more tangible. Digitally mature organisations report over 5% revenue growth, 10% productivity gains, and 10% to 20% maintenance cost reductions.

## Governance, regulation, and safety assurance



Technology adoption must remain within the airworthiness framework. Regulatory guidance from organisations such as the Federal Aviation Administration (FAA), European Union Aviation Safety Agency (EASA), and International Civil Aviation Organisation (ICAO) requires that any new process, tool, or method used for maintenance be acceptable to

the regulator or be part of an approved maintenance program. This includes how digital records, human approvals, and novel inspection techniques (like drone or AR-enabled inspections) are documented and audited. Organisations must engage regulators early, especially for practices that change inspection regimes or data ownership principles.

## Turn aircraft maintenance into a scalable safety advantage

Aircraft maintenance remains the foundation of aviation safety, built on certified expertise, disciplined processes, and rigorous oversight. As fleets grow more complex, digital technologies are helping organisations execute these fundamentals more consistently and at scale. The real advantage lies not in adopting individual tools but in **integrating technology, people, and governance** into a cohesive maintenance ecosystem. Done well, this approach strengthens safety, resilience, and operational reliability over the long term.

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