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# Digital Transformation in Aircraft Maintenance: International Practices and Development of a Maturity Assessment Tool for Implementation

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ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ  
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Ψηφιακός Μετασχηματισμός στη Συντήρηση  
Αεροσκαφών: Διεθνείς Πρακτικές και Ανάπτυξη  
Εργαλείου Αποτίμησης της Ωριμότητας  
Υλοποίησης

ΓΕΩΡΓΙΟΣ ΜΠΑΛΛΑΣ

ΕΠΙΒΛΕΠΩΝ: ΔΗΜΗΤΡΙΟΣ ΕΜΙΡΗΣ

ΑΘΗΝΑ, 2026



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## ABSTRACT

The aviation network is a critical national and international infrastructure, central to global economic and geographic connectivity, as well as the efficiency of humanitarian response mechanisms. The aviation mission involves numerous, diverse stakeholders, at various levels, as well as technical infrastructure and equipment. To fulfill this mission, the operational readiness of an aircraft is viewed not merely as a technical issue but rather as a contribution to a safer, more stable and more peaceful world.

Aviation maintenance projects are essential to support and safeguard aircraft operations; they are challenging by nature, as they deal with complex systems and must conform to the highest quality and safety standards. Recently, these projects have faced a huge transition from conventional practices to predictive, data-driven ones, within the frame of Digital Transformation of the maintenance ecosystem. As a result, specialized frameworks that can: (i) assess an organization's maturity to perform aviation maintenance projects efficiently, (ii) deal with unique regulatory and operational complexities, and (iii) measure the organization's readiness of transition to a digital ecosystem, became of essence.

This work addresses this need by proposing a framework that integrates digital readiness and project management maturity into a unified assessment model, designed for organizations involved in aircraft maintenance projects. The implemented tool combines digital dimensions with maintenance domains and produces a two-dimensional assessment grid; moreover, it employs a properly designed questionnaire, to generate detailed maturity indices at different levels and uses these results to generate a crisp and feasible maturity improvement roadmap.

International best practices, regulations, and principles were also incorporated into the framework; an initial validation was performed using data from an actual aviation maintenance organization. The analysis of this case study amplified the ability of the model to identify specific operational gaps and demonstrated its suitability for broader use.

### KEYWORDS:

Aircraft maintenance, digital transformation, project management maturity model, digital readiness.

## ΠΕΡΙΛΗΨΗ

Το δίκτυο των αερομεταφορών συνιστά μια κρίσιμη εθνική και διεθνή υποδομή, με κομβικό ρόλο τόσο στην παγκόσμια οικονομική και γεωγραφική διασύνδεση, όσο και στην αποτελεσματικότητα των μηχανισμών ανθρωπιστικής ανταπόκρισης. Η αποστολή της πολιτικής αεροπορίας εμπλέκει πολυάριθμους και ποικίλους ενδιαφερόμενους φορείς, σε διάφορα επίπεδα, καθώς και τεχνικές υποδομές και εξοπλισμό. Για την εκπλήρωση αυτής της αποστολής, η επιχειρησιακή ετοιμότητα ενός αεροσκάφους δεν θεωρείται απλώς ένα τεχνικό ζήτημα, αλλά μάλλον μια συνεισφορά σε έναν ασφαλέστερο, πιο σταθερό και πιο ειρηνικό κόσμο.

Οι εργασίες συντήρησης αεροπορικού υλικού είναι απαραίτητες για την υποστήριξη και τη διασφάλιση των αεροπορικών επιχειρήσεων· είναι από τη φύση τους απαιτητικές, καθώς περιλαμβάνουν πολύπλοκα συστήματα και πρέπει να συμμορφώνονται με τα υψηλότερα πρότυπα ποιότητας και ασφάλειας. Πρόσφατα, οι εν λόγω εργασίες αντιμετώπισαν μια τεράστια μετάβαση από τις συμβατικές πρακτικές σε προγνωστικές (predictive) πρακτικές βασισμένες σε δεδομένα, στο πλαίσιο του Ψηφιακού Μετασχηματισμού του οικοσυστήματος συντήρησης. Ως αποτέλεσμα, κατέστησαν ουσιαστικής σημασίας τα εξειδικευμένα πλαίσια που μπορούν να: (i) αξιολογούν την ωριμότητα ενός οργανισμού να εκτελεί αποτελεσματικά έργα αεροπορικής συντήρησης, (ii) να διαχειρίζονται το κανονιστικό και επιχειρησιακό πλαίσιο, και (iii) να αποτιμούν την ετοιμότητα του οργανισμού για μετάβαση σε ένα ψηφιακό οικοσύστημα.

Η παρούσα εργασία αντιμετωπίζει αυτήν την ανάγκη προτείνοντας ένα πλαίσιο που ενσωματώνει την ψηφιακή ετοιμότητα και την ωριμότητα στη διαχείριση έργων σε ένα ενοποιημένο μοντέλο αξιολόγησης, σχεδιασμένο για οργανισμούς που εμπλέκονται σε έργα συντήρησης αεροσκαφών. Το εργαλείο που υλοποιήθηκε συνδυάζει τις ψηφιακές διαστάσεις με τους τομείς συντήρησης και παράγει ένα δισδιάστατο πλέγμα αξιολόγησης· επιπλέον, χρησιμοποιεί ένα κατάλληλα σχεδιασμένο ερωτηματολόγιο για τη δημιουργία λεπτομερών δεικτών ωριμότητας σε διάφορα επίπεδα και αξιοποιεί αυτά τα αποτελέσματα για τη δημιουργία ενός σαφούς και εφικτού οδικού χάρτη βελτίωσης της ωριμότητας.

Ενσωματώθηκαν επίσης διεθνείς βέλτιστες πρακτικές, κανονισμοί και αρχές και πραγματοποιήθηκε μια αρχική επικύρωση με τη χρήση δεδομένων από έναν πραγματικό οργανισμό συντήρησης αεροσκαφών. Η ανάλυση αυτής της μελέτης περίπτωσης ενίσχυσε την ικανότητα του μοντέλου να εντοπίζει συγκεκριμένα επιχειρησιακά κενά και απέδειξε την καταλληλότητά του για ευρύτερη χρήση.

ΛΕΞΕΙΣ ΚΛΕΙΔΙΑ:

Συντήρηση Αεροσκαφών, Ψηφιακός Μετασχηματισμός, Μοντέλο Ωριμότητας, Ψηφιακή Ετοιμότητα.

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Dedicated to the memory of my best friend, whose faith in me remains a constant source of strength and inspiration.

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## List of Acronyms and Abbreviations

|        |                                                                                                     |
|--------|-----------------------------------------------------------------------------------------------------|
| ADDS   | Automated Damage Detection Software (Λογισμικό Αυτοματοποιημένης Ανίχνευσης Ζημιών)                 |
| AFMAN  | Air Force Manual (Εγχειρίδιο Πολεμικής Αεροπορίας)                                                  |
| AI     | Artificial Intelligence (Τεχνητή Νοημοσύνη)                                                         |
| ALIS   | Autonomic Logistics Information System (Ενοποιημένο Δίκτυο Λειτουργικών Δεδομένων)                  |
| AOG    | Aircraft On Ground (Καθελωμένο Αεροσκάφος)                                                          |
| API    | Application Programming Interface (Διεπαφή Προγραμματισμού Εφαρμογών)                               |
| AR     | Augmented Reality (Επαυξημένη Πραγματικότητα)                                                       |
| ATARS  | Advanced Tactical Augmented Reality System (Προηγμένο Σύστημα Τακτικής Επαυξημένης Πραγματικότητας) |
| CAMO   | Continuing Airworthiness Management Organizations (Οργανισμοί Διαχείρισης Διαρκούς Αξιοπλοΐας)      |
| CASK   | Cost per Available Seat – Kilometer (Κόστος ανά Διαθέσιμη Θέση ανά Χιλιόμετρο)                      |
| CI     | Continuous Improvement (Συνεχής Βελτίωση)                                                           |
| CMMI   | Capability Maturity Model Integration (Μοντέλο Ωριμότητας Δυνατότητας Ενσωμάτωσης)                  |
| CMMS   | Computerized Maintenance Management System (Μηχανογραφημένο Σύστημα Διαχείρισης Συντήρησης)         |
| DBRA   | Digital Backbone Reference Architecture (Αρχιτεκτονική Αναφοράς Βασικού Ψηφιακού Κορμού)            |
| DCMA   | Defense Contract Management Agency (Οργανισμός Διαχείρισης Συμβάσεων Άμυνας)                        |
| DMAM   | Digital Maturity Assessment Model (Μοντέλο Αξιολόγησης Ψηφιακής Ωριμότητας)                         |
| DOD    | Department Of Defense (Τμήμα Άμυνας)                                                                |
| DREAMY | Digital Readiness Assessment Maturity (Αξιολόγηση Ψηφιακής Ετοιμότητας Ωριμότητας)                  |
| DT     | Digital Transformation (Ψηφιακός Μετασχηματισμός)                                                   |
| DTMM   | Digital Transformation Maturity Model (Μοντέλο Ωριμότητας Ψηφιακού Μετασχηματισμού)                 |
| EASA   | European Aviation Safety Agency (Οργανισμός της Ευρωπαϊκής Ένωσης για την Ασφάλεια της Αεροπορίας)  |
| ERP    | Enterprise Resource Planning (Σύστημα Ενδο-Επιχειρησιακού Σχεδιασμού)                               |
| FAA    | Federal Aviation Administration (Ομοσπονδιακή Υπηρεσία Αεροπορίας των ΗΠΑ)                          |
| FH     | Flight Hours (Ωρες Πτήσης)                                                                          |

|       |                                                                                                          |
|-------|----------------------------------------------------------------------------------------------------------|
| GR&A  | Ground Rules and Assumptions (Βασικοί Κανόνες και Υποθέσεις)                                             |
| HAF   | Hellenic Air Force (Ελληνική Πολεμική Αεροπορία)                                                         |
| IFTC  | International Flight Training Center (Διεθνές Εκπαιδευτικό Κέντρο Πτήσεων)                               |
| ILS   | Integrated Logistics System (Ενσωματωμένο Σύστημα Λογιστικής Επιμελητείας)                               |
| IT    | Information Technology (Τεχνολογία Πληροφοριών)                                                          |
| IOT   | Internet Of Things (Δίκτυο των Πραγμάτων)                                                                |
| JIT   | Just In Time (Ακριβώς στην Ώρα)                                                                          |
| KPI   | Key Performance Indicator (Βασικός Δείκτης Απόδοσης)                                                     |
| LM    | Lockheed Martin                                                                                          |
| MIT   | Massachusetts Institute of Technology (Ινστιτούτο Τεχνολογίας της Μασαχουσέτης)                          |
| ML    | Machine Learning (Μηχανική Μάθηση)                                                                       |
| MM    | Maturity Model (Μοντέλο Ωριμότητας)                                                                      |
| MRO   | Maintenance, Repair and Overhaul (Συντήρηση, Επισκευή και Γενική Επισκευή)                               |
| MTBF  | Mean Time Between Failures (Μέσος Χρόνος Μεταξύ Βλαβών)                                                  |
| MTBUR | Mean Time Between Unscheduled Repair (Μέσος Χρόνος Μεταξύ Μη-Προγραμματισμένων Επισκευών)                |
| MTTR  | Mean Time to Repair (Μέσος Χρόνος Επισκευής)                                                             |
| NATO  | North Atlantic Treaty Organization (Οργανισμός Βόρειο-Ατλαντικού Συμφώνου)                               |
| NDBB  | NATO Digital Backbone (Ψηφιακός Βασικός Κορμός του NATO)                                                 |
| NDI   | Non-Destructive Inspection (Μη Καταστροφική Επιθεώρηση)                                                  |
| NFF   | No Fault Found (Μη- Εύρεση Σφάλματος)                                                                    |
| OBK   | ODIN Base Kit (Βασική Συλλογή του ODIN)                                                                  |
| ODIN  | Operations Data Integration Network (Δίκτυο Ενσωμάτωσης Δεδομένων Επιχειρήσεων)                          |
| OEM   | Original Equipment Manufacturer (Κατασκευαστής Πρωτότυπου Εξοπλισμού)                                    |
| OMI   | Overall Maturity Index (Συνολικός Δείκτης Ωριμότητας)                                                    |
| PDCA  | Plan-Do-Check-Act (Σχεδίασε – Εκτέλεσε – Έλεγξε – Δράσε)                                                 |
| PCI   | Pavement Condition Index (Δείκτης Κατάστασης Οδοστρώματος)                                               |
| PdM   | Predictive Maintenance (Προβλεπτική Συντήρηση)                                                           |
| PHM   | Prognostic and Health Management (Προγνωστική Διαχείριση και Παρακολούθηση Κατάστασης/Υγείας Συστημάτων) |
| PM    | Project Management (Διαχείριση Έργων)                                                                    |
| PMO   | Project Management Office (Γραφείο Διαχείρισης Έργων)                                                    |
| QA    | Quality Assurance (Διασφάλιση Ποιότητας)                                                                 |
| QC    | Quality Control (Έλεγχος Ποιότητας)                                                                      |
| QMS   | Quality Management System (Σύστημα Διαχείρισης Ποιότητας)                                                |
| RACI  | Responsible - Accountable - Consulted - Informed (Υπεύθυνος – Υπόλογος – Σύμβουλος – Ενημερωμένος)       |
| RFID  | Radio Frequency Identification (Αναγνώριση Ραδιοσυχνοτήτων)                                              |

|      |                                                                                              |
|------|----------------------------------------------------------------------------------------------|
| RUL  | Remaining Useful Life (Εναπομένουσα Λειτουργική Ζωή Εξαρτήματος/Συστήματος)                  |
| SEI  | Software Engineering Institute (Ινστιτούτο Μηχανικής Λογισμικού)                             |
| SIRI | Smart Industry Readiness Index (Δείκτης Ετοιμότητας Έξυπνης Βιομηχανίας)                     |
| SLA  | Service Level Agreement (Συμφωνία Επιπέδου Υπηρεσιών)                                        |
| SME  | Subject Matter Expert (Εμπειρογνώμων)                                                        |
| SUP  | Suspected Unapproved Parts (Υποπτα Μη Εγκεκριμένα Εξαρτήματα (ή υλικά / ανταλλακτικά)        |
| SWOT | Strengths, Weaknesses, Opportunities, Threats (Δυνατά Σημεία, Αδυναμίες, Ευκαιρίες, Απειλές) |
| TAT  | Turn Around Time (Χρόνος Διεκπεραίωσης)                                                      |
| TDR  | Technical Dispatch Reliability (Τεχνική Αξιοπιστία Αποστολής)                                |
| UAS  | Unmanned Aerial System (Μη-επανδρωμένο Εναέριο Σύστημα)                                      |
| UAV  | Unmanned Air Vehicle (Μη-επανδρωμένο Αεροσκάφος)                                             |
| USAF | United States Air Force (Πολεμική Αεροπορία των Ηνωμένων Πολιτειών)                          |
| VR   | Virtual Reality (Εικονική Πραγματικότητα)                                                    |

## **Chapter 1.**      **Introduction**

Aircraft Maintenance, Repair and Overhaul (MRO) is a moving target. In the past, aircraft maintenance depended on routine inspections, paper records and addressing issues as they came up. Although this method was functional, it resulted in extended downtimes, high cost and occasional flight delays. Today, rapid advancements in digital technology are revolutionizing the industry, forcing companies to rethink the way they make maintenance processes in terms of managing, planning and executing maintenance tasks.

Here, Digital Transformation (DT) has more to do than adding a new software or a shift of paper to a tablet. It's a mindset change, from responding to problems to anticipating and stopping issues by applying data. Modern aircraft are equipped with extensive sensor systems that continuously monitor a wide range of onboard functions, including engines, avionics, and structural health. Through real-time analysis, companies can predict when parts in an aircraft will fail and when systems will need to be replaced or troubleshooted and continue to make maintenance easier by optimizing all systems in terms of safety and efficiency, at all times. This switch to condition-based maintenance is already driving costs down, saving time and increasing safety.

Technologies such as Augmented Reality (AR) and Virtual Reality (VR) are used practically every day. Instead of relying solely on manuals and printed documentation, technicians can use smart glasses to access step-by-step instructions or be trained in virtual environments for rare or complex tasks. Similarly, robotics is being introduced for difficult and repetitive tasks, including tight space inspection or automatic drilling.

Nevertheless, these shifts don't happen immediately. This is where each organization will need to understand its current state of digital maturity. Some maintenance service providers or air forces have already installed sophisticated data systems – and others still work by hand. Organizations cannot develop a useful strategy without an awareness of their point of start. DT means investing in people, new skills, changing how work is done, and not just applying technology innovations.

This shift impacts more than efficiency. Safety is a top priority in aviation, and identifying problems in advance can literally save lives. For airlines, faster maintenance also cuts delays and costs. Military air forces, in turn, will have better fleet readiness and,



consequently, greater mission success. Across the board, adapting digital transformation techniques, is critical to a rapidly evolving market.

In short: the nature of aviation maintenance is moving from manual schedule-based methods to computerized systems using data, automation and smart tools. Organizations that move quickly will reduce costs, increase safety and reliability and remain relevant and essential in the future of aviation.

## 1.1. Purpose and Objectives

This thesis aims to explore the impact of DT on the aircraft maintenance industry and what such changes will mean for the broader aviation industry.

The study aims at three main objectives. The first involves exploring globally best practices and case studies where digital tools have been successfully leveraged. Some examples are predictive maintenance (PdM), digital twins, AR/VR-based training, robotics and paperless maintenance. By being analytical of these cases, we have a better idea of the pros of these technologies, and the challenges an organization faces that arise with their implementation.

The second goal would be to have a tool of assessment for digital maturity of organizations on aircraft maintenance. This tool will facilitate leadership and decision-makers to determine their readiness, assess the opportunity in order to address the digital infrastructure gap, and select the process to achieve this.

Finally, the third objective focuses on developing an aircraft maintenance DT roadmap, that is relevant to the issues faced around DT and the requirements of the organization (aviation maintenance companies, airlines, industries and military Air Forces). The project will outline feasible next steps and priorities to the transition away from traditional maintenance-based approaches, towards complete digital infrastructure that delivers improved safety, reduced operating costs and greater efficiency.

This thesis seeks to be a contribution both in the academic and operational sense, based on combination of international experience, testing and structured roadmap. The long-term objective is to present a realistic view of how DT could feasibly be transformed to operationalize the maintenance of an aircraft as a safe and effective and future-proof process.

## 1.2. Methodology and Structure

This thesis utilizes systematic methodology to demonstrate DT in aircraft maintenance and develop a feasible framework to implement that process. This approach integrates a review of the literature, scientific databases (from Google Scholar and other academic sources), specialized journals in the aviation industry and maintenance, research of international cases and also a maturity measure tool relevant for aviation maintenance and Air Force context.

Research starts with literature review: it provides theoretical background, and explains the main ideas of DT. This phase lays the groundwork for how DT is currently being used for future deployment in aviation and other, more industrial high-tech fields.

The following section will highlight an international case study-based approach. We examine examples from the commercial aviation industry, the defense industry and air forces around the world. The goal is to discover best practices, problems of implementation and takeaways for the aviation organizations as a whole.

The thesis then develops a digital maturity assessment tool based on the literature and case studies. The tool is created to assess an organization's readiness to adopt DT for aircraft maintenance. It illustrates where the strengths, weaknesses and where investment is needed in the future.

Finally, the results demonstrate that the findings can be used to suggest a roadmap for aviation and air force organizations, including the Air Force, for making progress in moving from today to a digitally-mediated maintenance environment. This roadmap is an incorporation of international practice with military aviation's needs and challenges.

The body of the thesis is as follows in terms of structure.

Chapter 1 presents the topic, sets the objectives and purpose and questions of research.

In Chapter 2 is presented the literature analysis, along with the definition of DT and its use in MRO.

Chapter 3 analyzes international case studies of industry and air forces.

Chapter 4 describes the existing maturity assessment models.

Chapter 5 includes the methodology developed for building the model for the digital maturity assessment, followed by its layout.

Chapter 6 suggests a roadmap, that includes recommended actions, based on the research conducted and the score achieved by the maturity model application.

Chapter 7 includes a case study of the evaluation of the developed model, tested in a real-life MRO organization in aviation area and the analysis of the results of this assessment.

Chapter 8 draws conclusions as well as recommendations for future research.

This structure guarantees that the study can progress relatively smoothly through the transition between theory to practice and international experience to concrete recommendations. Following this framework, the thesis intends to develop analytical and practical suggestions towards the practical usable results on the part of decision makers.

### 1.3. Ground Rules and Assumptions (GR&A)

All researched projects must follow a clear definition of GR&A to stay meaningful. As DT in aircraft maintenance is a focal subject, this thesis has set several boundaries and working assumptions regarding the analysis. The rules do not restrict the value of the study, but ensure that the study outcome can be practical and relevant to the context of civilian and military aviation organizations.

It is assumed, first and foremost in aviation maintenance that safety remains a top priority. Whether using predictive analytics, digital twins, or AR/VR tools, any digital solution can be successful only if its focus is improving or at least maintaining aviation safety. Cost savings and efficiency gains are important, but these cannot happen if they come at the cost of safety.

The second assumption is that the use of digital technologies is not a substitute for human experience, but a complement. Technicians will remain the cornerstone of maintenance. DT is to give them more data, more tools and safer workplaces, not to take them out of the picture.

The third ground rule is to concentrate on aircraft maintenance and MRO processes. Although DT can cover other fields in aviation, such as flight operations or

mission accuracy, this thesis focuses on the maintenance domain. By focusing this area, the approach will be more in depth instead of a general treatment of many unrelated fields.

One other assumption is that availability and quality of data are essential. DT uses information recorded from sensors, maintenance logs and operational systems. The analysis is based on the assumption that organizations utilizing DT, will own the infrastructure or invest in the infrastructure to collect, store and process the data securely.

Furthermore, the research assumes that cybersecurity is solid, despite the fact that the model questionnaire dives into cybersecurity issues and IT problems. As DT brings digital interconnections and cloud-based systems, it is an absolute requirement to secure sensitive data from cyber-attacks. This is such an assumption which influences how the use of digital tools is assessed and adopted into the maturity assessment framework.

It is also assumed that practices set out in the model can be the best benchmarks but each and every aviation maintenance organization, will have to modify them to their own environment. Each country has its own budget limitations, regulations and operational requirements. As such, international case studies are presented in this study as sources of inspiration and direction, rather than as solutions that can be prepared in advance.

The GR&A's set by the thesis guarantee that their analysis keeps practical, feasible and focused on the specific challenges of aircraft maintenance in the DT epoch.

## **Chapter 2.      Digital Transformation Overview**

### **2.1.    Theoretical Background of DT**

DT is the radical change brought by digital technologies in all areas of an organization (Rogers, 2016). It is not a simple document digitization, but includes redesigns, changing the business model and adopting a new organizational culture. It is a holistic process that reforms a business models and culture, and not only a process of adapting new technologies.

The successful implementation of DT, provides important advantages to organizations, such as increased efficiency and reduced costs, improved service quality and enhanced competitiveness.

#### **2.1.1.   DT Key Pillars**

DT is based on five key pillars (Rogers, 2016):

1.    Strategy: Digital strategy is more than an extension of traditional business strategy. It is designed to generate value through new digital products and services adapted to the demands of the marketplace.
2.    Processes: The digitization of processes leads to process effectiveness and efficiency, but also motivates redesign for the digital era.
3.    Organization: It requires the restructuring of the organizational chart, with an emphasis on agility and cross-departmental collaboration.
4.    Culture: The hardest and most critical pillar is culture change. With its focus on skills, it aims to develop a mindset of continuous learning through experimentation.
5.    Technology: The adoption of latest technological tools and infrastructure (cloud computing, mobile technologies, Artificial Intelligence - AI, etc.) aids in process automation and improvement.

### 2.1.2. DT Key Technologies

DT is driven by the strategic integration of several key technologies that have transformed the way businesses operate and innovate. Such technologies function as catalysts of new business models, customer experience and operational efficiency.

1. Cloud computing provides computing resources over the internet, eliminating the need for companies to own and maintain their own physical IT infrastructure (such as huge servers consuming great amounts of energy and need big space for storage). It is a key element to DT due to its scalability, flexibility and cost-effectiveness (Buyya et al., 2013). In this manner businesses can quickly deploy new applications and manage massive amounts of data, accelerating innovation.

2. Artificial Intelligence (AI) and its subset, Machine Learning (ML), allow machines to accomplish tasks that typically require human intelligence. They enable organizations to automate complex processes, discover more about data and personalize customer communication.

3. The Internet of Things (IoT) is a physical network, which includes sensors and software that collect and share data. IoT gives the capability to collect real-time data from equipment, that can provide operational benefits and enhance maintenance in a business environment. Real-time tracking and monitoring of supply chain performance are used to create new data-driven services which are very important (Paulouski, 2025).

4. Big Data refers to huge, composite data sets that are analyzed to reveal patterns and trends. It fuels AI and ML, offering the raw material for refined analytics. Organizations that effectively make proper use of data analytics, can use it as a strategic advantage to gain a competitive advantage and make better business decisions (Davenport, 2014). By using Big Data, organizations can transform their operations from reactive to proactive, anticipating risks of market changes and customer needs.

5. Blockchain is a distributed digital record that securely records the transactions occurring in a network. Blockchain key features (immutability, transparency and decentralization) make it highly suitable for applications requiring secure record-keeping and trusted transactions (Swan, 2015). In supply chain management, blockchain ensures the authenticity and traceability of a product, reducing fraud and improving the level of trust in the working relationship among partners.

However, DT comes with its difficulties. The main barriers to DT implementation include employee resistance to change, a lack of specialized personnel and the need for critical initial investments in technology and infrastructure.

## 2.2. DT in Aircraft Maintenance

The aviation industry is the perfect area to illustrate the significance of the DT, in many domains, such as aircraft services, maintenance, and MRO. This transformation is the end of the classical ‘reactive’ maintenance and brings a new era of data-driven and anticipatory systems. The long-term aim of DT is to improve safety, cut costs and advance the overall performance across the aircraft’s lifecycle.

The complexity of modern aircraft and the need for strict safety standards make MRO an important area for digitalization. Fundamental technologies supporting this shift are sensor networks that generate much more data than in any previous technology, which is then used to predict failures in components through machine learning algorithms. This transition from a time-based approach to a condition-based approach enables maintenance to occur only when is required to reduce aircraft downtime. Condition-based maintenance is a main argument in current MRO strategy (Khalid et al., 2023).

Digital tools are one of the most important applications of DT in MRO, that aims to enhance maintenance processes and human performance. For instance, AR technology can offer real-time hands-free instructions, diagrams and historical data, overlaid onto the equipment of technicians, reducing human error and training duration. Moreover, the application of a digital twin (a digital replica of a physical asset) enables simulation of maintenance procedures as well as testing scenarios, without the risks of an actual aircraft failure or mishap. The combined effect of these developments is a cleaner, safer, and cost efficient MRO ecosystem, which is a significant topic discussed at great length in industry publications (*Aircraft IT MRO V14.1*, 2025).

DT in the aviation industry is critical. The introduction of DT in aircraft maintenance has taken MRO organizations to the next level, beyond individual technological domains of strategic significance. This is a standard shift where conventional, time-consuming models become the digital ecosystem, that revolutionizes business models and reduces operational overheads, raises efficiency and lowers ground

time for aircraft. Moreover, predictive maintenance, coupled with enhanced communication, increases greatly the safety of flight operations and thus, DT becomes an essential factor for the sustainability and competitiveness of the industry evolution.



## **Chapter 3. International Practices of DT in Aircraft Maintenance**

### **3.1. International Practices of DT in Aircraft Maintenance Overview**

DT of MRO is most understanding, if considered through the supported strategic practices, which combine different technologies for specific business purposes. This chapter will examine the important aspects of DT in aviation and uses some of the best-case studies from the commercial aviation and military sectors in practice.

#### **3.1.1. Predictive and Prognostic Maintenance**

Both predictive and prognostic maintenance methods represent a significant step up, from the usual routine process. Although, these two methods are often used interchangeably, they have different goals and uses, thanks to data analytics and AI.

Predictive Maintenance (PdM) is a strategy that applies continuous data to predict the exact time when an element is likely to fail. It implements real-time data analytics, ML and data merging platforms to prepare for failures before they happen, optimizing maintenance schedules, minimizing downtime and cutting costs for the organizations.

At the heart of this practice is to do maintenance just in time, if condition-monitoring indicators indicate that a part, or system is degrading. Rather than schedule a mechanical part replacement (e.g. an aircraft engine replacement that happens after 500 flight hours), predictive maintenance collects data through various sensors, like vibration, temperature or pressure monitors, allowing the maintenance technicians to determine the real condition of the asset before ordering replacement actions (Mobley, 2002).

This is one of the fundamental strategies for modern industrial applications, that cover early detection of high level physical wear and degraded performance (Lughofer & Sayed-Mouchaweh, 2019). The goal is to avoid unnecessary maintenance, reduce downtime and prevent unexpected failures.

This approach transforms MRO from a static, time-driven model to an intelligent, data-driven one. This is based on the convergence of IoT sensors, Big Data, AI and ML.

Big data come from operational IoT sensors, that are embedded in aircraft components and constantly gather information. AI algorithms analyze this data and predict when a component is likely to fail. Condition-based maintenance is a major aspect of a modern MRO strategy. (Khalid et al., 2023).

Prognostic Maintenance, known as Prognostics and Health Management (PHM) is a more forward-looking approach. Predictive maintenance can answer when an asset, part or system might fail, while prognostic maintenance seeks to find out the Remaining Useful Life (RUL) of the asset, component or system.

PHM systems monitor degradation trends gradually to assess the future health of a part, or system (Kim et al., 2017). The most important step in such process is prognostic; since RUL estimation is the key element in most modern approaches to maintenance (Mishra, 2018).

This is a complex task that makes it possible to make bigger, more strategic, long-term decisions. By accurately predicting RUL, an airline may optimize its spare parts inventory, schedule major overhauls with greater precision and maximize the operational life of the aircraft and the fleet. In other words, predictive maintenance pays particular attention to immediate future, precluding an imminent failure, and prognostic maintenance, in contrast, concentrates purely on long term viewpoint, predicting how long a component will last. Both are vital components of data-driven, cutting-edge maintenance that drive efficiency, cost savings and enhanced safety across the aviation industry.

Predictive maintenance platforms based on AI/ML gives the MRO providers the ability for more accurate foresight, as well as efficient management of operations. These platforms help to foresee and therefore maintain, the flow of parts into maintenance facilities and warehouses and align this flow with inventory and workforce levels needed, as well as the lead time needed for suppliers. In this manner, these platforms lower the turnaround times of MRO shops and consequently reduce the downtime of airlines.

The system of predictive maintenance platforms uses sophisticated algorithms for predicting both scheduled and unscheduled maintenance requirements. It forecasts the number of parts that should be serviced, as well the type of work to be done (inspection, repair or overhaul) and the list of materials needed for each maintenance task. It enables

procurement teams to order parts ahead of time and inventory to be on hand when required, instead of being held back by delays from suppliers.

*Table 1. Distinctive Differences between Predictive and Prognostic Maintenance (Credit: Own Elaboration)*

| Feature                   | Predictive Maintenance                                                  | Prognostic Maintenance                                                        |
|---------------------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| <b>Primary Focus</b>      | <b>Diagnosis:</b> Detection of an existing anomaly or degradation.      | <b>Prediction:</b> Estimation of the time before a functional failure occurs. |
| <b>Key Question</b>       | "Is there a problem developing right now?"                              | "How much time is left until the part fails?"                                 |
| <b>Main Metric</b>        | <b>Condition Indicators:</b> Vibration, temperature, oil debris levels. | <b>Remaining Useful Life (RUL):</b> Calculated in flight hours or cycles.     |
| <b>Data Usage</b>         | Real-time monitoring of current health status.                          | Statistical models and AI to project future degradation.                      |
| <b>Operational Impact</b> | Reduces unscheduled maintenance by identifying early warnings.          | Optimizes the global supply chain by planning removals weeks in advance.      |
| <b>Maturity Level</b>     | Intermediate Digital Maturity.                                          | Advanced Digital Maturity (Digital-Oriented).                                 |

Importantly, the platform also determines the workforce and technician requirements needed, which aids in the long term planning of the resources, an important issue in an industry where specialized training can take more than six months to complete (Aviation Maintenance Magazine, 2024).



*Figure 1. Aero NextGen Tests AI/ML Platform for Proactive Maintenance (Credit: Aero NextGen Inc - <https://avm-mag.com>)*

Finally, the overall effect of the system is to support maintenance providers from reactive to proactive data-driven decision-making. Through the combination of smart analytics and robotic process automation, the platform cuts down on expensive Aircraft-On-Ground (AOG) situations, enhances planning precision and results in a more resilient and efficient aerospace maintenance ecosystem.

### 3.1.2. Enhanced Technician Performance and Training

The modern digitalization of the aviation maintenance is transforming how technicians are trained and more importantly how they operate. Modern technologies are revolutionizing the training for aircraft maintenance technicians and in turn, how they perform their duties. The purpose of updating this evolution is to make work more efficient, safer and less prone to errors (Ceruti et al., 2019). It transforms how we work from paper manuals and physical mock-ups, with data-driven and automated technologies.

AR and VR are leading this kind of transformation. Technicians now use these technologies in a simulated and safe training environment, prior to make a high-risk hands-on work with an actual aircraft. In that sense, VR can produce highly detailed, full-scale digital replicas of aircraft parts, including jet engines or landing gear systems and other major parts, enabling solid practice without causing wear to expensive equipment or grounding the aircraft.

AR technology overlays digital instructions, schematic diagrams and real-time data onto a technician's view of the real world. With an AR goggle set, a technician can see step-by-step guidance directly on the component in question, with a virtual arrow pointing to where to unscrew a bolt, or a digital overlay displaying the precise torque specification. Through this hands-free and guided approach there is less room for error and technicians increase efficiency very fast.

USAF Maintenance Operations and Training in Augmented Reality (MOTAR) is the prime example of how AR is used in more than just training. It is extended to live maintenance support where technicians can see wiring diagrams or torque specifications in their field of sight (Williams, 2018). In this way, AR reduces task completion times and

error rates and in turn, enhances procedural compliance, not only for training purposes but also in real-life maintenance (Cuellar, 2022).



Picture 1. Boeing utilizes a variety of extended reality systems. (Credit: Boeing - <https://avm-mag.com>)

On the other hand, VR remakes the training environment. As a rule, training for a technician involves access to physical aircraft or simulators, which is resource-demanding and often limited in availability. VR is able to remove these limitations and allows technicians to work within immersive and dynamic environments by re-skilling in maintenance procedures without causing damage of any kind to the equipment. In military aviation, VR has been utilized to simulate rare or high-risk maintenance tasks that would otherwise occur only in operational settings, in order to address skill discrepancies and prepare for these situations.

Table 2. Comparison between Virtual Reality (VR) and Augmented Reality (AR) in MRO (Credit: Own Elaboration)

| Feature           | Virtual Reality (VR)                                                                       | Augmented Reality (AR)                                                           |
|-------------------|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Environment       | <b>Fully Synthetic:</b> The user is completely immersed in a digital world.                | <b>Mixed Reality:</b> Digital elements are overlaid on the physical world.       |
| User Experience   | Complete isolation from the physical surroundings.                                         | Interaction with the real aircraft remains possible.                             |
| Primary MRO Use   | <b>Training &amp; Simulation:</b> Practicing complex tasks in a safe, virtual environment. | <b>On-site Assistance:</b> Remote expert guidance and digital work instructions. |
| Hardware          | Head-mounted displays (HMDs) that block natural vision.                                    | See-through smart glasses (e.g., HoloLens) or handheld tablets.                  |
| Strategic Benefit | Cost-effective education without requiring a physical aircraft.                            | Reduction of human error and faster task completion on the hangar floor.         |
| Maturity Level    | Advanced Digital Simulation                                                                | Integrated Shop-Floor Digitalization                                             |

### 3.1.3. Automation, Robotics and Data-Driven Insights

Robotics and automation are more than just a comprehensive technical support. Robots have been increasingly used for repetitive, physically intensive or hazardous tasks, such as aircraft inspections, surface preparation and paint application (Plastropoulos et al., 2025).

Besides, combining AI and data analytics gives new visibility into a technician's personal performance and training. AI systems are able to use analysis of data from maintenance logs and training simulations, in order to provide customized training methods, identify gaps in skills and recommend specific training modules to specific technicians. This data-based approach helps to not only enhance skill acquisition but also guarantee better standards of competency throughout the workforce (Greeley, 2024). Ongoing data monitoring and review allow early detection of potential human behavior.





*Picture 2 Robots Put Pratt & Whitney on Path to Industry 4.0 (Credit: Pratt & Whitney - <https://aviationweek.com>)*

Technologies like AR, VR, robotics and AI are revolutionizing the aircraft MRO workforce. By providing technicians with data, improving training and automating ordinary procedures, these technologies improve efficiency, minimize errors and make aviation environment safer and more reliable.

These are not “add-on” tools, but they transform the very structure of technician training, how work is done and how safety and efficiency are ensured. These technologies cover particular pain points in the MRO process and together they offer synergies, in an ecosystem consistent with DT’s larger vision.

Robotics takes this digital modernization of MRO on to another level, by automating inspections and repetitive physical tasks. They include robotic drones that are able to inspect airframes, fuel tanks and maintenance infrastructure or runways more precisely than ever before. Equipped with sensors and high-resolution cameras, these drones can spot surface cracks, corrosion or structural imperfections, that may escape human inspectors’ attention. Robotic systems can also carry out risky work (as for example, inspections in narrow access or chemical contaminated areas), thereby minimizing the danger posed to human workers.

The USAF is already using robotic inspection units to conduct fuselage checks and has shown the benefits of adapting shorter inspection cycles and at the same time increased accuracy.

In a similar way, Airbus has researched robotic-assisted painting and drilling systems in its factories, proving that robotics can work not only across production lines, but also within sustainment processes, enabling even more rapid turnaround times of aircraft in service.



*Picture 3. Nordico Dino Robot Washes an Aircraft (Credit: AviationPros - <https://www.aviationpros.com>)*

Taken together, AR, VR and robotics represent complementary dimensions of the digital MRO ecosystem. The convergence of these technologies leads to measurable benefits: reduced human error, faster turnaround times, lower training costs and improved safety margins.

The long-term implication is that the role of the human technician is shifting from manual execution toward a more supervisory and analytical function, where digital tools augment human expertise, rather than replace it.

This transformation aligns with the concept of the "augmented workforce," where human decision-making is empowered by digital technologies, ensuring that maintenance in both commercial and military aviation becomes more reliable, cost-effective and resilient.



#### 3.1.4. Digital Twins

A digital twin in aviation, is a living, software-based replica of an aircraft (or an aircraft's system or component) that reflects its condition and history from its operation. In contrast to static maintenance records or record data systems, the digital twin can act as a real-time representation that allows a fast, data-rich view of the aircraft (or system, or component), connecting multiple data sources via IoT to one central database.

Condition based maintenance is one of the most powerful applications of digital twin technology. With the use of real-time data streams, which report pressure, temperature, vibration and material stress, the digital twin is no longer limited to the fixed timing of part replacements. Instead of simply replacing a wing flap if it has reached some given number of flight hours, the digital twin enables the aircraft to predict at what point its performance will really begin to drop. Through this procedure, it supports the introduction of preventive measures for less waste, prevents costly failures and ultimately increases both safety and efficiency (Duraiyan, 2025).

In addition to monitoring, the digital twin contributes to maintenance planning and optimization. It leads to better understanding of the safest, quickest and resource-efficient repair method because it can match the repair on paper (onscreen) and test a variety of different techniques in a virtual environment.

These simulations can predict the tools, the required spare parts, the workforce needed and even the time for a maintenance task, improving MRO assets to forecast and plan. This does not only enhance fleet readiness, but it also leads to lower costs by avoiding unnecessary downtime. In practice, this takes MRO from an operational response that is heavily manpower-intensive, to a data-driven operation.



*Picture 4 Interoperability and Standardization Initiatives for Digital Twins [Credit: NATO Modelling and Simulation Group (NMSG) - <https://www.linkedin.com/>]*

However, an increasing dependence on digital twins has created new vulnerabilities. Cybersecurity is a critical enabler, because these models rely on large-scale data exchange among aircraft, ground systems and cloud platforms. Safeguarding such sensitive operational and maintenance data from cyber threats is essential to ensure both the reliability of the system and the security of flight operations.

On the other hand, robotics is gradually being integrated into Non-Destructive Inspections (NDI), where robots perform more accurate repetitive inspections in a shorter time frame than humans (Plastropoulos et al., 2025). VR tools enhance maintenance training by providing technicians risk-free environments in which they learn and perform complex tasks before applying them to real aircraft (Dela Peña, 2025). The digital twin framework unites all these technologies to create a digitally empowered maintenance ecosystem, contributing significantly to operational safety, cost reductions and changes the way of how aviation sustainment is managed.

#### 3.1.5. Paperless Maintenance in Aviation

One aspect of the digital transformation in modern aviation maintenance is defined by the replacement of paper-bound and sequential workflows with connected and data-centric processes that run on mobile devices, cloud platforms and integrated training and logistics systems.

Airlines and military operators that have adopted electronic technical logs, digital working cards and integrated maintenance systems, report faster and more reliable turnarounds and a reduction in AOG events, because records, manuals and troubleshooting historical data are available to engineers and technicians at the point of work (flightline or maintenance hangars)<sup>1</sup>.

Industry case studies illustrate typical benefits: real-time access to approved documentation, electronic signatures for regulatory compliance and measurable efficiency gains once paper hand-offs are eliminated. These results are achieved when digital record-keeping is coupled with standardized data structures and strong change management, across maintenance, engineering and Quality Assurance (QA) teams.

The transition is not purely technical; it is also organizational. Even well-equipped maintenance organizations can find themselves operating in a hybrid state where paper persists in parts of the process, due to legacy culture, fragmented IT assets or uncertainty about the acceptance of digital regulations.

Successful programs therefore sequence the following transformation: first digitize documents and workflows, then integrate planning, records and configuration control and finally layer analytics and predictive capabilities on the unified data. When this trajectory is followed, paperless maintenance becomes the operational baseline and advanced capabilities - such as predictive maintenance, digital twins and immersive training - can be implemented without re-engineering the data layer (Razya, 2024).

### 3.1.6. Secure Supply Chain

To fully understand the operational and security challenges of a modern aviation supply chain, it is essential to define three intersecting concepts that form the cornerstone of digital MRO logistics: Supply Chain Integrity, Airworthiness, and Cyber-Physical Systems (CPS).

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<sup>1</sup> Flightline Maintenance: is the maintenance performed on the flightline (at the aircraft parking area) to ensure immediate operational readiness. It includes inspections, minor repairs, servicing, and quick component replacements with minimal downtime.

Hangar Maintenance: is the maintenance performed inside a maintenance hangar involving scheduled, in-depth, or heavy work. It includes major inspections, repairs, modifications, and component overhauls requiring time, tools, and full access.

Supply Chain Integrity refers to the comprehensive assurance that every component, spare part, and material flows through the supply chain without unauthorized tampering, substitution, or degradation. In aviation, maintaining this integrity is critical to preventing the infiltration of Suspected Unapproved Parts (SUPs), which pose catastrophic risks to flight safety. From a regulatory standpoint, both the Federal Aviation Administration (FAA) and the European Union Aviation Safety Agency (EASA) mandate strict traceability and certification controls under regulations such as EASA Part-145 and FAA 14 CFR Part 145. These frameworks require that every part installed on an aircraft must be accompanied by authorized release certificates (such as an EASA Form 1 or FAA Form 8130-3), establishing an unbroken, legally compliant chain of custody from the manufacturer to the hangar floor.

Airworthiness is defined as the measure of an aircraft's suitability for safe flight, which is directly dependent on its conformity to its approved type design and its condition for safe operation. It is not a static state but a continuous operational requirement managed under Continuing Airworthiness Management Organization (CAMO) standards. Any compromise in the supply chain directly threatens airworthiness; hence, certification rules dictate that maintenance organizations must verify the airworthiness status of incoming components prior to installation, bridging logistics directly with regulatory compliance.

Cyber-Physical Systems (CPS) represent the integration of physical assets—such as aircraft engines, landing gears, and smart warehouse sensors—with computational algorithms, networked communication, and secure digital ledgers. In a digitalized MRO environment, every physical component becomes a node in a CPS. By linking the physical part's life-cycle with its digital twin and immutable records, CPS enables automated compliance tracking and real-time monitoring of airworthiness parameters. Under EASA and FAA digital transition guidelines, the deployment of such cyber-physical architectures must adhere to rigorous software certification and data integrity rules (such as ED-202A / DO-326A cybersecurity standards for airworthiness), ensuring that the digital thread backing the physical aircraft is robust against both cyber threats and mechanical failures

A secure end-to-end chain of control for every component in an enterprise is based on a combination of advanced technologies such as cyber-physical systems, blockchain and real-time data analytics.

When it comes to the aircraft maintenance supply chains, the most significant challenge is the complexity and also the international nature. Parts are designed from a variety of suppliers; they are sold through various vendors and finally they are maintained by MRO companies worldwide. This sophisticated network opens countless opportunities for uncertified or unauthorized parts, to make their way into the system.

Most of the existing procedures are based on fragmented information and human-written documentation, which make it very difficult to verify a part's authenticity and origin in real time. Installing a defective component at the early stage of assembly can lead to catastrophic consequences not only for the manufacturer but also for the user. In that case, the system needs to be more secure and reliable.

A proper way to solve this problem, is to have a decentralized, unchanged history documentation for each individual part. By treating each component as an individual part of a cyber-physical system, their path can be tracked digitally, from the very early time of its manufacturing. With a decentralized application (such as blockchain), each transaction (from certification through maintenance procedures and installations to aircraft) is staked out into an immutable, time-stamped block. This maintains both a clear and reliable account that cannot be altered or erased. Modern integration of the physical and digital systems is so vital that controlling and securing the digital domain is very critical to flight safety and aircraft physical security and integrity (Alrefaei et al., 2021).

Additionally, embedding IoT sensors into each individual component provide an uninterrupted stream of real-time performance data. This data, if linked with AI-enabled analytics, provide the ability to MROs to track a component's state over its life cycle and monitor its functionality. The system, when is fed with the historical data of the component, can automatically alarm if something is abnormal and identify anomalous activities or anticipate future system failures. In combination, these technologies transition the industry from a reactive, manual verification to a proactively automated and secure system.

Furthermore, Just-in-Time (JIT) logistics is a unique application of digital transformation, that impacts the aviation maintenance supply chain. Rather than keeping

a large and expensive inventory of spare parts, the JIT model, ensures that all the parts (procurements, repairables or consumables) are delivered to the maintenance facility on time for repair or inspection tasks. This also reduces waste, storage costs and delays due to part shortages, and results in a smoother and more efficient maintenance.

### 3.2. DT in Aviation International Practices Case Studies

In order to understand the global significance of the implementation of these technologies, there is a need to explore how countries and organizations are effectively applying them in real world conditions.

This section includes international case studies on digital transformation in aviation maintenance, illustrating methods, problems and optimal practices. These examples demonstrate methods that improve security, efficiency, safety and quality.

In other words, the aviation industry embraced digital transformation to strengthen maintenance efficiency, safety, and readiness. Airlines and military companies leverage tools like predictive maintenance, digital twins, collaborative robots, VR/AR training and AI analytics.

The following table presents some typical case studies that show various digital transformation strategies in aviation maintenance, emphasizing technological innovation and measurable outcomes.

These case studies illustrate, in great detail, how DT strategies transformed operational capability, safety and cost management. Airbus, for example, use predictive analytics and digital twins to address problems in a proactive manner, the F-35 program improved logistics and readiness of the fleet with integrated systems.

Such cases demonstrate that successful digital strategies (like predictive maintenance with Skywise, system upgrades in the F-35 program and innovating with robotics or AI used by other companies) yield new maintenance processes, high fleet readiness, data-driven decision-making and increased sustainability.

Table 3. Case Studies of DT in Aviation Maintenance (Credit: Own Elaboration)

| Organization                   | Digital Transformation Initiative                                                                                                | Key Outcomes                                                                                                                 |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|
| Airbus                         | Implementation of the "Hangar of the Future" combining various technologies to speed up maintenance and improve efficiency.      | Enhanced maintenance processes, reduced turnaround times, and improved efficiency in handling increased maintenance demands. |
| Airbus                         | Deployment of Skywise Core, a data platform connecting over 11,900 aircraft for predictive maintenance and optimized operations. | Improved fleet performance, reduced maintenance costs, and enhanced operational efficiency through real-time data analytics. |
| Lockheed Martin (F-35 Program) | Utilization of virtual and augmented reality for maintenance training and repair tracking.                                       | Enhanced training capabilities, reduced maintenance errors, and improved readiness without diverting real-world assets.      |
| Elbit Systems                  | Development of advanced pilot training and flight school simulation solutions.                                                   | Improved aircrew readiness, enhanced training effectiveness, and optimized operational performance.                          |
| US Air Force                   | Implementation of the Maintenance Operations and Training in Augmented Reality (MOTAR) system for maintenance training.          | Accelerated learning, improved performance, and facilitated remote training through immersive 3D experiences.                |
| US Air Force                   | Deployment of robotics for aircraft maintenance, including the development of autonomous inspection systems.                     | Improved safety, reduced turnaround times, and enhanced maintenance efficiency through automation.                           |
| Finnair                        | Implementation of MROTools.io for tool tracking and workflow optimization.                                                       | Reduced tool misplacement incidents, improved maintenance efficiency, and enhanced safety protocols.                         |
| Air Europa                     | Adoption of mobile applications for paperless maintenance processes.                                                             | Streamlined maintenance workflows, reduced paperwork errors, and improved turnaround times.                                  |
| Asia Digital Engineering (ADE) | Development of predictive maintenance software and an online aircraft parts marketplace (Aerotrade).                             | Reduced average repair times by 20–30%, enhanced parts availability, and improved operational efficiency.                    |
| Etihad Airways Technical       | Digital transformation initiatives during the COVID-19 pandemic.                                                                 | Maintained operations amidst challenges, improved maintenance processes, and ensured safety compliance.                      |
| Air-Cobot (France)             | Development of a wheeled collaborative mobile robot for aircraft inspection.                                                     | Enhanced inspection accuracy, reduced human error, and improved maintenance turnaround times.                                |
| Qantas                         | Utilization of AI for dynamic flight routing and fuel optimization.                                                              | Achieved 2% fuel savings (~\$92 million annually), improved scheduling efficiency, and reduced operational costs.            |

### 3.2.1. Airbus "Skywise" Case Study: A Digital Thread for PdM

Airbus Skywise is a central data platform in the company's digital strategy. Developed with Palantir Technologies, it serves as an open system that connects airlines, manufacturers and repair shops.

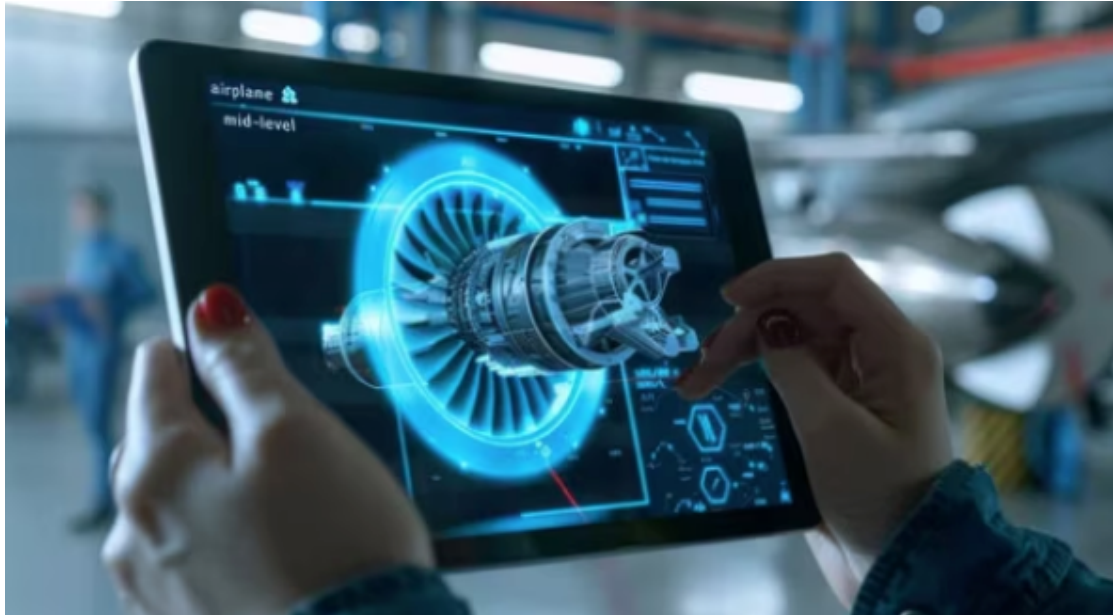
“Skywise” aims to resolve data challenges by consolidating multiple data sources into a single, secure cloud-based platform. This includes data from aircraft sensors, service records, business systems and parts usage (Airbus, 2017).

The platform creates a digital thread, which is the single point of data that can be used as a record of the continuous life cycle of the aircraft. It stores thousands of real-time data points from each flight of all aircraft and employs AI and ML to analyze them, in order to generate actionable tasks.



For example, Vietnam Airlines used Skywise Predictive Maintenance for its A321 fleet, leveraging the platform's analytics to improve operational efficiency significantly.

The airline's early warnings on potential problems allowed it to anticipate and plan maintenance proactively, greatly saving the airline expensive delays and cancellations. Better forecasts of part failures also led to better inventory control (Airbus, 2023).



*Picture 5. Transformation from a reactive maintenance model to a proactive maintenance strategy informed by comprehensive aircraft and operational data (Credit: Boeing - <https://services.boeing.com>)*

Engineers and repair crews use digital twins to simulate various scenarios, such as to change parts or software for new features that are deployed and downloaded via remote monitoring, prior to installing on the aircraft. This also prevents serious failures. For instance, Skywise data detected a minor bleed air valve design issue on an A330 engine, which the Airbus engineers worked out by fixing the defect world-wide, before the problem arise (Airbus, 2025).

### 3.2.2. F-35 Program Case Study

The F-35 Lightning II is one of the most sophisticated and challenging military aircraft platforms. To address risks on a global scale, the manufacturer of F-35, Lockheed Martin (LM), has already developed a comprehensive digital transformation strategy, which is centered on the digital thread and digital twin. This is an essential strategic option



not just in the development and manufacture of aircraft, but in the maintenance and sustainability that must take place over time, a factor very critical to fleet readiness.

The Autonomic Logistics Information System (ALIS) was central to the F-35's digital sustainment strategy, as its core data infrastructure for maintenance. But ALIS had problems in many areas, such as bad usability, and accuracy of data. Maintainers were facing difficulties in using the interface, and inaccurate or missing data grounded aircraft without any justification and required manual workarounds (like spreadsheets) to solve the problem.

The “false indications” flagged by ALIS system increased up to 80% in 2015 and led to unnecessary maintenance. Moreover, ALIS had a heavy and bulky hardware kit and the deployment outside the mother base was very challenging, with the server units weighing about 200 pounds each, requiring an entire room to deploy and limiting flexibility of operation in remote locations (U. S. Government Accountability Office, 2024).

In recognition of the challenges posed by ALIS, the Department of Defense (DOD) launched a multi-year program to rectify these limitations by implementing the Operational Data Integrated Network (ODIN), the first of its kind, cloud-native, user-friendly solution to replace ALIS.



*Picture 6. USAF F-35 Technician Downloading Data from Aircraft. (Credit: TWZ - <https://twz.com>)*

ODIN includes a cloud-native architecture for fast updates and flexible data management, transitioning from a fixed system to a cloud environment. The ODIN Base Kit is 75% lighter and smaller in dimensions than ALIS hardware, and it fits into two transportable cases under 70 pounds each, which simplifies deployment of the operational units.

ODIN also delivers upgraded performance, with hardware and software improvements reducing administrative workload and processing by up to 50% (Joint Program Office, 2022). Debriefing portable memory devices, used for pilot – maintainer interface, are now twice as fast with ODIN hardware.

ODIN, like ALIS, will serve as the digital thread that connects all the aspects of the aircraft's lifecycle, from prognostic maintenance and health management to logistics and training of the personnel (including technicians, IT engineers, logistics, managers and supervisors). The transition to ODIN aims to reduce technicians' workload, and at the same time to increase mission-capability and to provide a more agile, reliable support for the fleet.

The F-35 program uses digital twin technology in both production and sustainment, with virtual models continuously updated with real-world data. In manufacturing, these allow for simulations to identify issues and optimize workflows, reducing production time by 25% and costs by 10% (Ashley, 2025). Known data for each aircraft (tail number), including unique configuration, stress history and repairs (Lockheed Martin, 2025), helps maintainers view structural health in 3D, reducing research time and aiding efficient maintenance planning. All the above-mentioned data are stored and accessible through ODIN to users (with secured and crypto access provisions), giving them all the available information needed for maintenance and statistical purposes.

### 3.2.3. Elbit Systems Case Study: Integrated Logistics Support (ILS)

The International Flight Training Center (IFTC) at Kalamata Air Force Base is a leading example of digital transformation in military aviation training. Run by the Hellenic Air Force and Elbit Systems, the IFTC brings together advanced aircraft, simulators and logistics systems to create a single digital ecosystem (Perry, 2021).

While the center primarily provides next-generation pilot training, it also models Integrated Logistics Support (ILS) and embeds DT principles across the supply chain to ensure readiness, availability and sustainability.

In the past, military aviation logistics were slow and bogged down by bureaucracy. Paperwork, separate departments and long waits for spare parts made the process inefficient.



*Picture 7. IFTC Logistics Warehouse at Kalamata AB. (Credit: MesogeiosTV - <https://www.mesogeiosTV.gr>)*

The program follows the main principles of ILS: analyzing support needs, ensuring parts are available, training staff, maintaining technical documentation, planning maintenance and designing systems that are reliable and easy to fix (Blanchard, 2004). By including these elements in contracts, the focus shifts from reacting to problems to managing systems throughout their life, based on readiness goals.

Building on ILS principles at the IFTC, the security and resilience of the supply chain are key to sustaining readiness, even during periods of high geopolitical unrest and uncertainty, when supply chains are corrupted. In a performance-based training environment, availability targets depend on the timely delivery of spare parts, consumables and technical services. DT enables a transparent, adaptive logistics backbone, which makes the IFTC in Kalamata AB a reliable pillar of flight training across Europe.

### 3.2.4. USAF Case Study: Robotic Inspection & UAV Integration

The USAF is revolutionizing aircraft maintenance with robots and drones. This transition helps address the issues of inspecting large, older planes, such as the B-52, where manual checks by technicians can be time consuming, difficult and dangerous to do. Traditional procedures take hours to erect scaffolds and lift equipment, which can lead to delays and safety concerns. Now, the USAF uses drones and robots to make maintenance in a digital and data-driven way (Satam, 2024).



*Picture 8 The inner workings of a US B-52 are represented in augmented reality goggles (photo by Senior Master Sgt. Ted Daigle - <https://www.afgsc.af.mil>)*

At Barksdale Air Force Base, operators showed how a completely autonomous drone could scan a B-52 bomber aircraft in just a few minutes. The drone flew a pre-determined path around the plane, taking hundreds of detailed photos of the exterior surfaces.

These images were transmitted via SEMPRES-T, a secure mobile communications platform. SEMPRES-T integrates 5G connectivity, cloud access, satellite uplinks and zero-trust security protocols. With this networked infrastructure, imagery was uploaded and processed in real time at the flightline. This replaced the previously paper-based, sequential workflow for inspection reporting from aircraft airframe technicians - maintainers (Daigle, 2024).

The imagery was then analyzed using Boeing's AI system: Automated Damage Detection Software (ADDS). ADDS detects surface anomalies, which are irregularities on the aircraft's exterior, including corrosion (metal degradation), paint delamination



(peeling or separation of paint layers), missing seals (absent or damaged barriers that prevent leaks) and exposed fasteners (visible screws or rivets). This AI analysis demonstrated a consistent, repeatable ability to mark these issues, thereby reducing the human visual inspections. Demonstrations at Barksdale and Dyess Air Force Bases showed that these systems enable maintenance teams to obtain actionable findings more quickly. This produces a digital record that can be archived, searched and integrated into broader sustainment databases, used for fleet monitoring (Caldwell, 2024).

The adoption of drones for exterior fuselage inspection aligns with Department of the Air Force guidance for small Unmanned Aircraft Systems (UAS) and contractor operations. For example, Air Force Manual (AFMAN) 11-502 appears in Defense Contract Management Agency Instruction (DCMA INST) 8210-1D. This alignment enables flight-line experiments to transition to compliant operations and apply standardized data-handling and cybersecurity protections.



*Picture 9. Digital Engineering for the Future (photo by Kenneth McNulty - <https://www.afmc.af.mil>)*

This is just one example of the USAF's push to digitize maintenance. Other projects use drones with advanced cameras and analytics to check runways and airfield conditions. These systems measure Pavement Condition Indices (PCIs), which are scores for pavement health. Researchers at the Air Force Civil Engineer Center and MIT have shown that using drone imagery to calculate PCIs reduces the work required for legacy paper-based inspections. This method gives structured, time-labeled data for tracking trends and planning ahead (Pietersen, 2022).

The USAF has also previously investigated working with ‘skin crawlers,’ or robotic crawlers that crawl and climb through difficult-to-reach parts of aircraft. Early work on such robotic assistants laid the foundation for some of the drone-oriented methods using mobility, a sophisticated series of sensors, and AI analytics (Siegel et al., 1997).

There are many benefits to this digital transformation. Inspection cycle times have decreased, with scans now completed in minutes rather than hours or even days. This has led to greater personnel safety because technicians spend less time working at height and in confined areas. This digital thread, from image capture to AI-based anomaly detection, to integration into sustainment databases, is aligned with the Department of the Air Force's vision for predictive maintenance and lifecycle management. The digital ecosystem allows proactive monitoring of fleet structural health, increasing both aircraft availability and mission readiness.

### 3.2.5. Royal Air Force (RAF) Case Study: Red 6 Advanced Tactical Augmented Reality System (ATARS)

The Royal Air Force (RAF) has been experimenting with Red 6's Advanced Tactical Augmented Reality System (ATARS) on the BAE Systems Hawk T2. It's part of a push to modernize live flight training by adding synthetic elements to the cockpit.

ATARS provides vivid, dynamic virtual images (enemy aircraft, weapon effects, friendly wingmen etc) on a pilot's visor during his actual flight. It allows air crews to rehearse difficult-to-fight combat situations in a simulated reality without the need for large groups of real aircraft to fly or additional hours flying other planes.

In late 2024, BAE Systems, Red 6, and the RAF pilots provided in-flight demonstrations at RAF Valley. Test pilots reported that they could identify, engage and defeat virtual enemies and interact with synthetic wingmen in the moment of flight. This demonstrated both the stability of the Hawk and the usefulness of in-cockpit augmented training (RAF, 2024).

The RAF first examined the airframe and determined whether ATARS would match the cockpit, the pilot practices and the electronic systems of Hawk T2 as well. In-flight AR testing in the Hawk, under BAE Systems and Red 6, to help the UK train in the

future. ATARS is a bridge between simulators on the ground and real flights, which maintains the authentic feel of flying, while also including repeatable virtual threats and partners (BAE Systems, 2000). UK Ministry of Defense believes that these tests are a potential new training initiative. AR displays could drive costs down and increase capacity as the RAF retires older fleets and has fewer available aircraft to take on.



Picture 10. Red 6 Aerospace Helmet (Credit: Lockheed Martin - <https://dallasinnovates.com>)

From a DT perspective, ATARS activity marks a shift from geographically limited, resource-demanding training to a data-rich, on-aircraft, real-time training during real flights, using synthetic augmentation. This blends the realism and physiological fidelity (the authentic physical experience) of live flight with the flexibility and repeatability of simulation. Instructors can script the number of simulated enemies or training scenarios that would be unrealistic or too costly to stage with real aircraft. Each sortie's synthetic layer is software-defined so that training syllabus can evolve quickly. Flight data and aircraft metrics can be captured for debriefing and analytics and exposure to advanced tactics can be increased without additional fuel, maintenance, or adversary support hours.

In summary, ATARS turns the cockpit into part of a bigger digital training network. It lets scenarios to be scaled as software while keeping the real feeling of flying a jet (Hoyle, 2025).

Although ATARS's primary focus is combat pilot training, it also indirectly impacts aircraft maintenance operations. The system lets pilots conduct advanced tactical training without the need for additional physical aggressor aircraft. By substituting live

adversary aircraft with synthetic ones, projected through augmented reality, ATARS reduces the flight hours required for both fighter fleets and trainee aircraft.

With fewer flight hours, there is less need for maintenance because airframes, engines and subsystems go through fewer cycles and less stress. Specifically the main benefits, provided by ATARS, are the following:

- **Reduced Wear and Tear:** By using aggressor aircraft less and limiting tough training maneuvers, ATARS helps reduce mechanical fatigue and the frequency of part replacements.
- **Optimized Maintenance Scheduling:** With fewer live flights, fleets spend less time in major maintenance, releasing more resources for aircraft operating missions.
- **Resource Allocation Efficiency:** Ground crews support fewer training flights, allowing maintenance teams to focus on aircraft critical to readiness rather than spending time on training-only missions.
- **Cost Efficiency in Maintenance:** Fewer spare parts are consumed, fewer inspections are triggered and overall sustainment costs are lowered.

#### 3.2.6. MOTAR Case Study: Member, Operations, Training, Analytics and Reports.

Member, Operations, Training Analytics and Reports (MOTAR) serves as an “application store” for training, enabling different bases and courses to exchange VR lessons, 3D models and performance data in one place, in a standardized and secure way. This prevents duplication among the Air Force and also ensures that these digital training tools can be used across the force, not just within one classroom. In this way, the USAF achieves cost efficiency in maintenance, while fewer spare parts are used, fewer inspections are needed and maintenance costs are decreased. MOTAR brings all of that to a single hub.

MOTAR was developed to deal with an important issue: the majority of military AR/VR projects were simply in pilot mode, they operated locally but could not scale. Using MOTAR, the Air Force developed a platform for managing content, permissions and data.



For instance, a VR course on engine repair at an aircraft currently can be uploaded, shared with several units and updated when process varies, all from one place. Instructors can also get analytics on student progress, so teachers can correct the instruction (Miriam A. Thurber, 2021)

The shift is about more than just wearing VR goggles – it is a shift in the way the training is been performed:

- Moving from one application to an ecosystem: MOTAR ensures AR/VR lessons can be repurposed, updated, tracked and monitored.
- Moving from static lessons to real data: Instructor teams can spot student struggles, which tools they engage with most frequently and how quickly they progress.
- From slow training pipelines to speedier readiness: Maintainers can repeat procedures (e.g., inspections or engine servicing) in a safe, virtual environment with VR before working on actual aircraft.

Early results show that MOTAR cuts training time, prompts more memory and reduces travel and classroom prices. Most important of all, it provides new, unexperienced technicians more maintenance interaction in a safe environment before they get their hands dirty with an actual airplane. This facilitates training that is safer, faster and more consistent, all the components of the digital change.

## **Chapter 4.**      Maturity Assessment Models of DT

### 4.1.    Existing Maturity Assessment Models of DT

Before exploring more specifically digital maturity assessment tools and models within the aircraft maintenance area, it is important to review a few prominent existing frameworks in the larger industry. The philosophy of these frameworks can be used to develop more specialized tools for aviation MRO.

One of the earliest and most widespread frameworks is the Capability Maturity Model Integration (CMMI), which creates a five-level scale for evaluating process maturity on the order of “Initial” to “Optimizing” (CMMI Product Team, 2006). Although originally it was created for software engineering, it has subsequently been repurposed into multiple industries and is still a reference point.

Another tool, is Digital Transformation Capability Maturity Model (DX-CMM), which evaluates an organization’s readiness for DT by such dimensions as strategy, culture, people and processes. This model consists of six maturity stages, from "Incomplete" to "Innovating" (Novita Sari et al., 2023)

Other attempts have been made in the aviation domain with a specific perspective. For instance, the aim is to use Digital Transformation Maturity Model (DTMM) for the Airline Industry to assist airlines to self-assess their digital progress and compare that to other industry standards (Kıyıklık et al., 2022) .

Now, the Digital Maturity Assessment Model (DMAM) has been presented, combining elements of CMMI and design-science research. It’s centered around four dimensions of technology, strategy, organization and people. This model is particularly applicable for resource-constrained organizations like military settings (Omol et al., 2025).

Besides those, there are also two well-known tools developed for industry benchmarking. The Singapore Smart Industry Readiness Index (SIRI) provides a systematic guide that helps to measure digital readiness in three main domains: process, technology and organization. It has been applied beyond manufacturing to aerospace and

defense industries (Singapore EDB, 2020). Likewise, the DREAMY (Digital Readiness Assessment Maturity) model was developed to help organizations, especially in Europe, assess their overall digital readiness in a systematic manner that highlights key strategic alignment and human factors (De Carolis et al., 2025)

While some maturity assessment models are available, such as CMMI, DX-CMM, DMAM, SIRI, and DREAMY, they are all generic frameworks of DT assessment. They offer helpful constructs for assessing progress in strategy, technology, organization and people but they cannot be applied to the unique challenges of aircraft maintenance with an eye on their implications for practice. The more in close proximity to aviation domain model, is the Airline DTMM, which is a product developed in the context of the airline industry, but again not the maintenance field. This underscores an important gap: even though there are widespread existing tools for general assessment of digital readiness, there is no recognized framework that is specifically for MRO in the aviation field.

This gap is one of the primary aims of this thesis, through the modification of the current practices, the development of an assessment system that accounts for particular purposes of aircraft maintenance.

*Table 4. Existing DT Maturity Assessment Models (Credit: Own Elaboration)*

| Model                                                            | Origin / Focus                                               | Dimensions                                                   | Levels of Maturity                          | Relevance to Aircraft MRO                                                      |
|------------------------------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------|---------------------------------------------|--------------------------------------------------------------------------------|
| <b>CMMI</b> (Capability Maturity Model Integration)              | Software engineering, later extended to processes in general | Process management, quality, improvement                     | 5 levels (Initial to Optimizing)            | Indirect – provides a baseline for process maturity but not aviation-specific  |
| <b>DX-CMM</b> (Digital Transformation Capability Maturity Model) | General digital transformation                               | Strategy, culture, people, processes                         | 6 levels (Incomplete to Innovating)         | Useful for overall DT assessment, but not tailored to MRO                      |
| <b>Airline Digital Transformation Maturity Model</b>             | Aviation sector (airlines)                                   | Business strategy, operations, technology, customer focus    | Multiple stages (from Initial to Advanced)  | Closest to aviation, but at airline level, not maintenance-specific            |
| <b>DMAM</b> (Digital Maturity Assessment Model)                  | Cross-industry                                               | Technology, strategy, organisation, people                   | Staged maturity approach                    | Relevant to resource-constrained organisations; adaptable to military/aviation |
| <b>SIRI</b> (Singapore Smart Industry Readiness Index)           | Manufacturing / Industry 4.0                                 | Process, technology, organisation                            | Structured index with assessment dimensions | Widely applied; useful benchmarking, but not directly MRO-related              |
| <b>DREAMY</b> (Digital Readiness Assessment Maturity Model)      | European research                                            | Strategic alignment, human factors, organisation, technology | Stage-based                                 | Helpful for holistic assessment, but not aviation-specific                     |

To better understand the maturity assessment models, Table 4 summarizes the key frameworks that are most often cited in the literature. While some of them (such as CMMI or DX-CMM) are general, others (like the Airline model) are move closer to the aviation sector. This overview highlights that the existing models, no matter if they are designed

specifically for MRO or not, which strengthens the case for developing an adapted framework for aircraft maintenance.

#### 4.1.1. Capability Maturity Model Integration (CMMI)

The CMMI is one of the most popular models of evaluating organizational maturity. CMMI was a program of the Software Engineering Institute (SEI) at Carnegie Mellon University, focused on software development process enhancement in the early 1990s. However, the field expanded and its scope is currently spread across aerospace, defense, and manufacturing (Chrissis et al., 2011).

The model is designed for five stages of maturity (of processes and organizational capability), as shown in Figure 12.

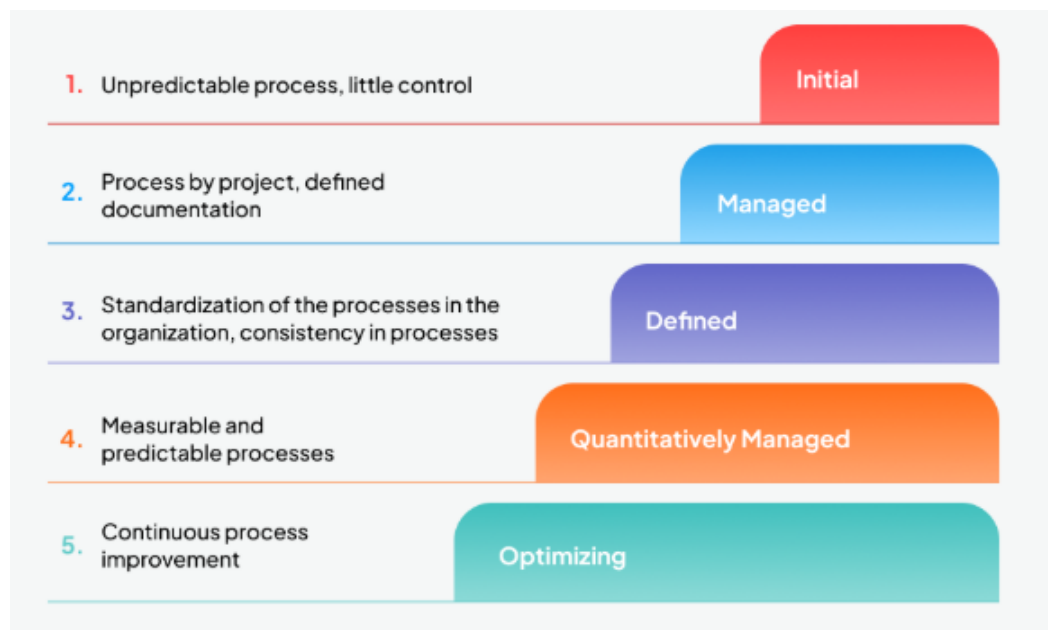


Figure 2. Maturity Levels of CMMI (Credit: Complyan - <https://complyan.com>)

CMMI promotes a staged process that can assist organizations to understand how mature they are at the moment, what are their current levels of maturity and how much improvement they need to do. It indicates not only what to change, but also what can be done incrementally, step by step, so that the ad hoc, reactive processes become more continuous improvement focused.

The cornerstone of CMMI is process discipline which is its principal strength. It reduces variability and increases reliability by urging organizations to document, standardize and monitor processes. This is particularly significant for industries such as

aerospace, where safety and compliance are tied to the execution of consistent, well-controlled processes. Therefore, CMMI as a reference model for achieving quality and efficiency has been adopted in industries such as defense contractors, aerospace manufacturers and MRO providers (Chrissis et al., 2011).

One of the drawbacks of CMMI is that it does not explicitly relate to DT. The focus is on process maturity rather than digital endorsement. It is important towards structured and reliable working, while yet misses aspects of DT, like data analytics, digital technologies or ecosystem collaboration that are principal in modern digitization.

Despite these limitations, CMMI illustrates the advantages of a staged maturity model and demonstrates how systematic progress can be made over the years. The model offers inspiration for how maturity can be defined and assessed, especially as it relates to aircraft maintenance. The challenge is to convert the CMMI logic into the context of digital transformation, where technology integration and predictive capabilities are as important as process discipline.

#### 4.1.2. Digital Transformation Maturity Model (DTMM) for the Airline Industry

While other digital maturity models (such as CMMI) have been developed on the principle of being widely applicable across sectors, there has been an effort to tailor a single model for the airline industry. In 2022, Kızılkılıç, Kusacksi and Mbowe proposed a DTMM model appropriate for the airline area. It is one of the first academic attempts to address the needs of the aviation sector in relation to digital readiness (Kızılkılıç et al., 2022).

The model encompasses six dimensions that are of particular relevance for airline operations: strategy, organization, technology, operations, innovation and ecosystem.

- “Strategy” deals with the issue of the airline having a vision for the digital transformation and how the plan fits into the airline business strategy.
- The dimension of “Organization” examines its internal architecture (including structure, culture and leadership) and whether the workforce is prepared to adopt new tools.

- “Technology” examines the uptake of digital tools, IT infrastructure and data management practices.
- “Operations” measure the adoption of digital processes into everyday business (e.g. customer-facing, logistics, and scheduling).
- “Innovation” measures the airline's capacity to experiment, adapt and embrace rising technologies.
- “Ecosystem” dimension takes into account the larger partnerships (suppliers, regulators, technology providers etc.) that shape the direction of DT.

A strong aspect of this model is its own self-assessment tool, enabling an airline to assess itself on these six dimensions. This also helps provide not only a snapshot of current state of digital maturity but also a better targeting of improvement of areas.

The model has a scoring system for an overall maturity score, as presented in Table 5.

*Table 5. The Proposed DTM-Phases - Credit: Ibn Haldun University (Kıyıklık et al., 2022)*

| Phase 1                                                                                                                         | Phase 2                                                                                                     | Phase 3                                                                                                                                                                                                        | Phase 4                                                                                                                                        | Phase 5                                                                                                               |
|---------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| Score <= 19                                                                                                                     | Score <=38                                                                                                  | Score <=57                                                                                                                                                                                                     | Score <=76                                                                                                                                     | Score <=95                                                                                                            |
| <br>Snail                                    | <br>Turtle               | <br>Rabbit                                                                                                                  | <br>Car                                                    | <br>Rocket                       |
| The organization operates from a legacy perspective and does not intend to go digital. The firm does not see DT as a necessity. | Digital is a blurred area. They make some plans for going digital. However, none of them have gone to live. | The organization is conducting intentional experiments on going digital. Results are at a promising and capable level. Agents of change search for the support of managers for new technologies and resources. | A dedicated DT team is formed. The new team infrastructure takes shape as roles, models, and processes to support the DT, which is solidified. | Digital is the new way of doing business. A new ecosystem is established. Digital is in every aspect of the business. |

During a pilot application, the maturity score of a participating airline was 62 out of 100. The score indicated that while the airline had made significant progress in adopting digital practices, there were still major gaps in technology integration and ecosystem collaboration (Kıyıklık et al., 2022).

Significance of this model is its aviation aspect. Unlike the general models, such as CMMI and DX-CMM, which are just “model theory tools”, this framework incorporates airline operational factors, such as aviation regulatory issues, customer expectations and the significance of ecosystem partnerships. It also proves that the management’s decision regarding maturity in aviation is a blend of internal factors of the airline and those outside from it.

In this thesis, the airline maturity model is crucial, because it illustrates sector-specific models of sector-specific maturity that can and should be provided. While this was originally designed for carriers as a whole, instead of for maintenance, this model also sets a good example for a helpful guide. The six dimensions can be used to guide the creation of a comparable framework for just aircraft maintenance and MRO focused exclusively on aircraft maintenance and MRO, as it focuses on safety, compliance and technical complexity.

In conclusion, the Airline DTMM is a specific illustration of how digital maturity frameworks can be tailored to an industry. It is not directly applicable to MRO, however, it shows how useful it is to have tools that represent the sector.

#### 4.1.3. The Digital REdiness Assessment MaturitY (DREAMY) Framework

The DREAMY Framework, that proposed by Anna De Carolis, Claudio Sassanelli, Federica Acerbi, Marco Macchi, Sergio Terzi and Marco Taisch, and was published in the International Journal of Production Research, is a comprehensive way to guide manufacturing companies through the DT process (De Carolis et al., 2025).

The key point of DREAMY relates to an urgent need, that the majority of the organizations cannot evaluate how their existing digital presence compares to the potential digital future or are not fully equipped to apply new technologies and tools. Like other existing maturity models, which are often part of a large (though not complete) approach, DREAMY emphasizes only to parts of the overall company structure and workflows.

DREAMY includes two primary parts: a Maturity Model (MM) and digitalization roadmap tool. The MM is inspired by the CMMI and consists of five maturity levels: Initial, Managed, Defined, Integrated/Interoperable and Digital-Oriented.

On the other hand, DREAMY has evaluated five core functions of manufacturing: Design and Engineering, Production Management, Quality Management, Maintenance Management and Logistics & Supply Chain Management.

These domains are analyzed on four dimensions of analysis: Management and Execution, Monitoring and Control, Technology and Organization. There is also a "Digital Backbone" section that addresses these areas with an overview of the company's IT systems and their interrelationships.

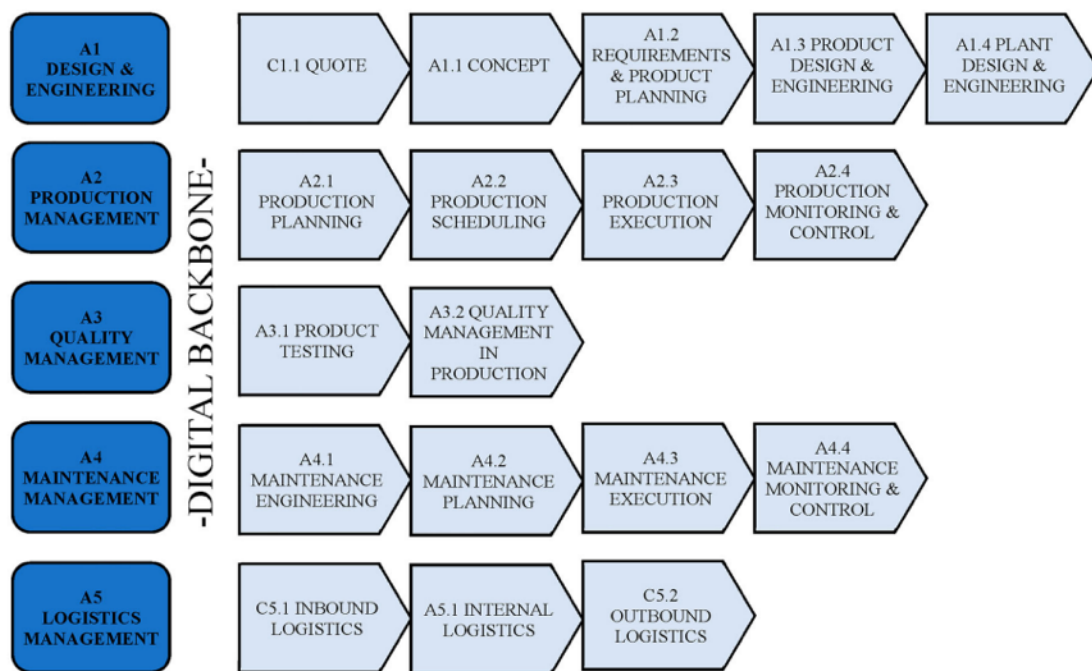


Figure 3. DREAMY Areas and sub-areas of analysis - Credit: International Journal of Production Research (De Carolis et al., 2025)

The digitalization roadmap tool uses the results of the MM, exported in specific forms, such as radar charts and guidelines, to identify opportunities, address weaknesses and develop structured action plans to adopt Industry 4.0<sup>2</sup> and move towards Industry 5.0<sup>3</sup>.

<sup>2</sup> Industry 4.0 is the intelligent networking of machines and processes for industry with the help of information and communication technology. It is centered on the implementation of Cyber-Physical Systems (CPS) within production, enabling autonomous data exchange, triggering actions, and independent control throughout the entire value chain (Platform Industrie 4.0, 2014).

<sup>3</sup> Industry 5.0 is an evolutionary model that provides a vision of industry that aims beyond efficiency and productivity as the sole goals, and reinforces the role and the contribution of industry to society. It places the well-being of the worker at the center of the production process and uses new technologies to provide prosperity beyond jobs and growth while respecting the planetary boundaries (European Commission, 2021).



DREAMY supports the assessment of digital maturity in all operations in a holistic and integrated way, provides actionable and prescriptive directions for improvement actions, supports strategic technology investments and enables benchmarking against industry standards.

#### 4.1.4. Digital Transformation Maturity Model in the Field of Project Management.

An important addition to how we assess digital maturity by creating a specific method for evaluating the readiness of an organization for digital processes in the area of Project Management (PM). This is a particularly useful model for this research as it is based on the same academic thinking, looking at where industrial management and digital development meet (Nakopoulos, 2025).

The Nakopoulos model's assessment of organizational capabilities happens in two stages, first filtering, and then in more detail analysis. Phase one uses 21 important measurements of performance to see if a company has the fundamental digital tools and ways of working it needs to be assessed further. Companies that are above this basic level then move to the second phase, a thorough analysis of 10 areas of knowledge (in line with standards such as the PMBOK®), with 11 supporting elements and more than 100 specific points to consider.

The way the model gives points is on a scale of five levels of maturity: from Level 1, which is doing things by hand and as needed, to Level 5, where Artificial Intelligence and the analysis of large amounts of data are fully used to make decisions in the moment. Using moving, visual displays such as Power BI, the model gives managers a straightforward “digital roadmap”, clearly showing where improvements are needed and what work must be done first for a successful digital change. Within this thesis, the Nakopoulos model is a standard against which to measure maturity of processes, and it is different from the maturity model developed in this thesis which is specifically about looking at how to maintain and ensure the safety of aircraft.

## 4.2. NATO Digital Backbone

While the maturity models discussed in the previous section help us determine whether a single organization is ready for digital transformation, military operations are rarely conducted alone. In alliances like the North Atlantic Treaty Organization (NATO), air forces need to work together. To make this happen, NATO is building a technical framework called the NATO Digital Backbone (NDBB) (North Atlantic Treaty Organization, 2024)

The NDBB is the technical infrastructure that connects everyone and everything in the Alliance. It guarantees that data can travel across all domains (Land, Air, Maritime, Space and Cyberspace). The main goal is to change how NATO operates. Instead of focusing on just connecting cables and networks (network-centric), the NDBB focuses on the data itself (data-centric). This means that data collected by sensors installed on aircraft – ships – vehicles etc. should be able to reach the decision-makers who need it, instantly and securely.

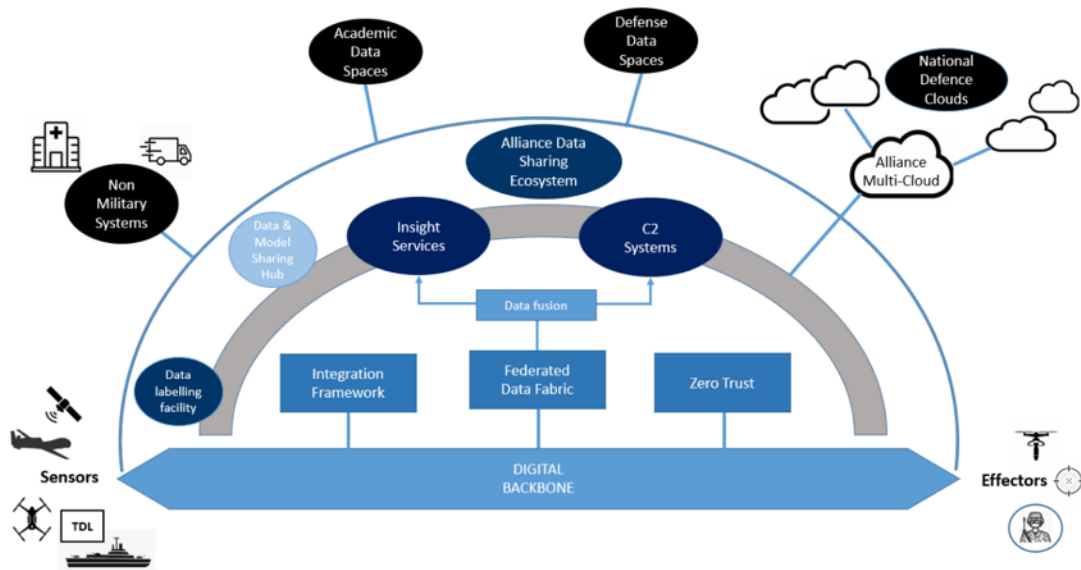


Figure 4. Context of Digital Backbone (Credit: NATO - <https://www.nato.int>)

The NDBB has been built in layers, described in its Reference Architecture (DBRA). These layers are important for modern aircraft maintenance:

- The Transport Fabric: This is the "highway" for data. It uses standard IP networks to ensure all communications are unified and resilient.

- Federation of Clouds: NATO uses a "Cloud-first" approach. However, it doesn't rely on a single big cloud. It connects national clouds and NATO clouds. This allows for a "Cloud-to-Edge" ecosystem.

- Data Exploitation: This is the top layer where the actual analysis happens, using AI to turn raw data into useful insights.

#### 4.2.1. Key Principles for Maintenance

For the NDBB to work in maintenance (MRO), it follows three main rules (principles):

1. Interoperability by Design: Systems must be built to talk to each other from day one. In a joint mission, if a technician from one country needs to fix an aircraft from another ally, their digital tools need to be compatible.

2. Data Sovereignty: This is important for national Air Forces. It means that each nation keeps control over its own data, without unveiling sensitive information about its fleet's readiness or technology.

3. Data-Centric Security (Zero Trust): The NDBB assumes the network might be compromised, so it protects the data file itself.

#### 4.2.2. Why NDBB Matters for MRO

The NDBB is the "glue" that makes advanced maintenance possible in a military or civil organization, in different and demanding conditions, even in a war zone. It connects the "operational edge" (the aircraft and the mechanic on the ground) to the strategic level. By using this backbone, the Air Force can move data from a drone inspecting a fuselage directly to a central AI system for analysis. It ensures the correct spare parts and the right data reach the right place, enabling proper predictive maintenance and higher fleet readiness across the Alliance.

## **Chapter 5.**      Development of a Maturity Assessment Tool for DT Implementation in Aircraft Maintenance

### 5.1. Overview

The ability of a maintenance organization to plan, execute and control the transition in a structured way does not depend only on the technologies that it adopts, but also on its overall level of digital maturity.

In this context, the aim of this thesis is to develop an assessment model for DT maturity in aircraft maintenance, designed for the specific needs of aviation organizations and military maintenance structures. The approach follows the logic used by Nakopoulos in project management (Nakopoulos, 2025), that combines a general assessment of digital maturity with a more concentrated analysis per PMBOK knowledge area (Project Management Institute, 2021).

The model of this thesis is built in two stages. The first stage looks at horizontal dimensions of DT across the whole organization. The second projects these same dimensions into key functional areas of aircraft maintenance, so that maturity can be examined both “in width” and “in depth”.

At the first level, the model considers a set of common digital maturity dimensions: strategy and governance, policies and security, information systems and digital backbone, process digitalization, data and analytics, organization and alliances, human resources and digital skills and a culture of ongoing improvement. These dimensions are inspired by well-known frameworks such as CMMI and DREAMY, as described in Chapter 4.

At the second level, the same dimensions are applied to selected maintenance domains: maintenance planning and control, line and base maintenance, quality and airworthiness, PHM and predictive maintenance, ILS and logistics support, technical documentation and configuration management, training and competencies of maintenance personnel. In this way, the model can show exactly where the organization is strong or weak in terms of DT within the maintenance environment.

The model follows Nakopoulos' philosophy of maturity models (Nakopoulos, 2025). It uses a five-level scale of digital maturity (from Initial to Digital-Oriented) and a clearly defined set of indicators for each dimension and maintenance domain. Data are

collected through a structured Likert-type questionnaire<sup>4</sup> (0–4) and then aggregated into topic and overall maturity scores.

Finally, the results are visualized, so the organization can not only see its current level of digital maturity but also design a realistic roadmap for its digital transformation in aircraft maintenance.

Overall, the thesis aims to fill a clear gap in the literature. There are several generic digital and organizational maturity models (such as CMMI, DX-CMF and DREAMY), but there is still no a specialized, practical model that systematically assesses the DT maturity of organizations in aircraft maintenance.

## 5.2. Synthesis of Assessment Tool

### 5.2.1. Definition of Maturity Levels (Maturity Score Bands)

The first step is to define a standard, five-level digital maturity scale (scored from 0 to 4) to be used across all dimensions and functional areas of maintenance. The logic of the scale follows the classic maturity models (CMMI, DREAMY, etc.), but is adapted to the aircraft maintenance environment.

- Level 1 – Initial

Digital practices are absent or fragmented and mainly based on manual processes and individual proposals. There is no clear strategy for DT in maintenance and the use of systems or data depends on the experience of specific individuals.

- Level 2 – Managed

Basic processes and some (limited) digital tools exist (e.g. simple individual applications), but their implementation is not unified throughout the organization. A first attempt at standardization is underway, but system interconnectivity is absent or limited and adoption continues mainly through empirical practices.

- Level 3 – Defined

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<sup>4</sup> A Likert-type scale is a psychometric measurement format used to assess respondents' levels of agreement, frequency, or importance regarding a specific statement. In a digital maturity context, a 0-4 point scale quantifies qualitative performance, where 0 typically represents a non-existent capability and 4 represents an optimized, data-driven process .

Maintenance processes are standardized and documented and digital solutions have been integrated into the organization's “basic routine.” There are clear roles and responsibilities, standard templates and a consistent way to record and use maintenance data. The interconnection of the systems is still not totally deployed across the departments of the organization.

- Level 4 – Integrated

Information systems (e.g. MRO/CMMS, ERP, sensor systems, PHM tools) are interconnected and support a single “digital backbone”. Data is recorded and performance indicators are systematically monitored and a significant part of DT is based on data analysis and not only on experience.

- Level 5 – Digital Orientated

The organization operates a fully data-driven mindset across the entire maintenance spectrum. Technologies such as predictive analytics, digital twins, mobile/AR technical support and automated workflows are utilized in a coordinated manner. At the same time, a spirit of continuous improvement and innovation is clearly established. Digital maturity in maintenance is directly linked to the organization’s operational readiness.

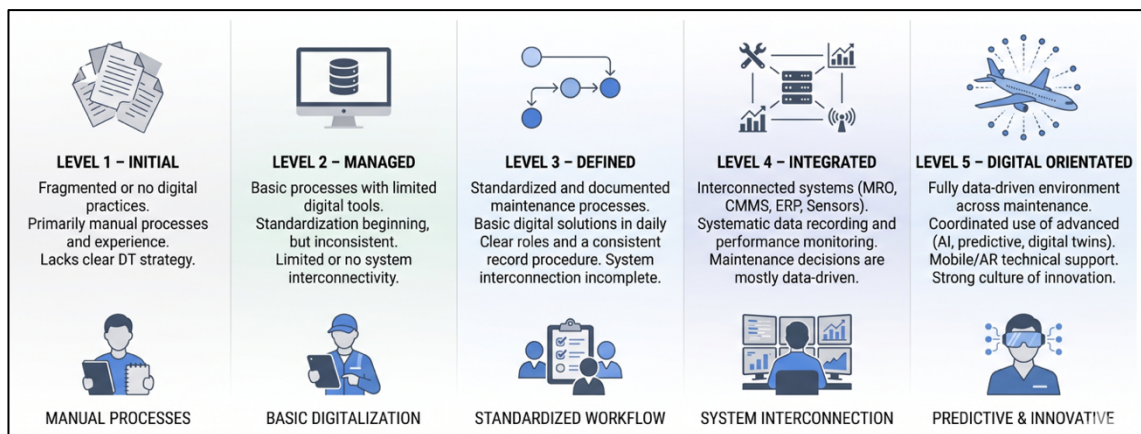


Figure 5. Digital Maturity Levels for Aircraft Maintenance (Credit: Own Elaboration)

This scale serves as a “common language” for the entire model: each evaluation criteria, across dimensions and functional areas, is mapped to one of the above levels, enabling comparisons and the extraction of a tailored improvement roadmap.

### 5.2.2. Horizontal Digital Maturity Dimensions

The next step is to define horizontal digital maturity dimensions that apply to the entire maintenance organization, not just specific areas. This approach is based on established frameworks like CMMI and DREAMY which all consider strategy, technology, processes and people (CMMI Product Team, 2006).

The eight horizontal dimensions used in the present maturity model, are the following:

- Dimension 1 - DT Strategy and Governance

This dimension examines whether there is a clear DT strategy for aircraft maintenance, how it links to the organization's broader mission (e.g. fleet availability, mission readiness) and whether there are administrative managers that manage progress and set priorities (Nakopoulos, 2025).

- Dimension 2 - Policies, Compliance and Cybersecurity

This dimension focuses on data governance and the protection of sensitive maintenance information, using digital signatures, ensuring traceability and obeying to aviation and defense regulations (for military organizations), such as airworthiness rules and security policies. It also covers how cybersecurity is included in the maintenance of IT systems and various IT projects (Novita Sari et al., 2023).

- Dimension 3 - Information Systems and Digital Backbone

This dimension assesses the maturity of the IT background, including systems, tools and applications and their integration and interoperability. Key questions include how well these systems are connected and communicate, whether data flows in near real time and whether there is a clear “digital backbone” instead of several isolated applications developed separately and working individually.

- Dimension 4 - Process Digitalization and Redesign in Maintenance

This dimension goes beyond just deploying systems and examines in what depth and extend, maintenance processes have been digitalized and redesigned. It considers if the operations are executed in a paperless way, whether digital workflows and e-approvals (e-signatures) are used and if processes have been simplified to fully use digital tools instead of just copying old paper methods.

- Dimension 5 - Data and Analytics

This dimension examines the quality, the availability and the capability to use data from maintenance operations (work orders, sensor streams, reliability data, logistics information). It also specifically evaluates the capability of the organization to generate and leverage secondary data, which is the cumulative indices, forecasts, and refined metrics produced by processing primary data through information systems, rather than to collect raw data, which is essential, but very premature (Emiris & Eirinakis, 2025). In this frame, the Dimension 5 considers whether the organization remains in descriptive reporting or also uses the secondary data for diagnostic, predictive and even prescriptive analytics to support maintenance planning, PHM and decision-making at different levels.

- Dimension 6 - Organization, Roles and Inter-functional Collaboration

This dimension focuses on how maintenance works with other key functions like Operations, Supply Chain, Engineering and IT. It checks if roles and responsibilities are clear, if there are cross-department teams, committees or forums and whether structures like a maintenance transformation office or Project Management Office (PMO) help coordinate digital projects across departments (Nakopoulos, 2025).

- Dimension 7 - People and Digital Skills

This dimension focuses on the digital capabilities of technicians, engineers, planners and managers: their ability to work with the existing systems, understand data and use tools such as PHM platforms, mobile apps or AR/VR for training and task execution. It also considers whether there is an organized approach to upskilling (learning new tools and methods, recurrent training, advance certifications).

- Dimension 8 - Culture of Continuous Improvement and Innovation

Dimension 8, checks if the organization uses KPIs, feedback and lessons learned to keep improving its digital tools and processes. It looks at how often pilot/testing projects are executed, how results are expanded or stopped, how feedback works among the departments to support the self-improvement and whether trying new things and learning from mistakes is supported.



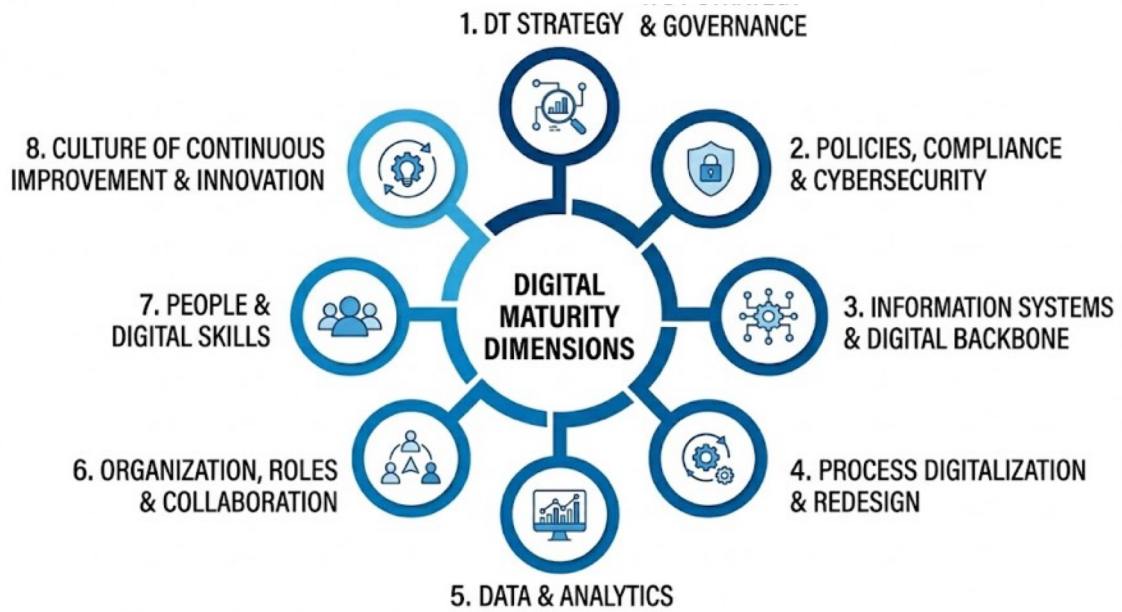


Figure 6. The 8 Digital Maturity Dimensions (Credit: Own Elaboration. Generated by Gemini AI - Google, March 2026)

In the next step, these eight dimensions form the horizontal “backbone” of the maturity model, will be applied to the selected maintenance domains to assess digital maturity in a way that is both consistent, across the organization and specific to the realities of aircraft maintenance.

### 5.2.3. Selection of Maintenance Domains

In line with the logic used in DREAMY for manufacturing, the proposed model for aircraft maintenance uses a set of clearly defined maintenance domains (or “verticals”). Each domain represents a clear group of processes, systems and roles within the wider MRO environment.

Three practical criteria guide the selection of domains:

1. They must cover the core activities that determine fleet availability and airworthiness.
2. They must reflect how maintenance is actually organized in aviation.
3. They must be sufficiently distinct so that targeted improvement actions can be designed and scheduled per domain, as a mitigation plan.

Based on these criteria, the model designed in this thesis, uses the following maintenance domains:

- Maintenance Domain 1 - Planning and Control

This domain includes long-term and short-term planning of maintenance events, hangar and bay scheduling, work package preparation, resource assignment and coordination with operations. It is the “brain” of the maintenance system and is crucial for translating digital capabilities (data, forecasts, PHM outputs) into executable plans.

- Maintenance Domain 2 - FlightLine and Hangar Maintenance Execution

The focus of Domain 2, is on the actual execution of tasks on the aircraft, both along the flightline and the maintenance executed inside the hangar, as defined in Section 3.1.5 reference comments. It covers job cards, task guidance (e.g. use of mobile devices or AR), defect and malfunctions recording, sign-off and supervision. This domain is the area where occurs the most hands-on interaction between technicians and digital tools.

- Maintenance Domain 3 - Quality, Airworthiness and Compliance

This domain covers quality assurance and quality control activities, audits, findings, occurrence reporting and interactions with regulatory and military legislation (for military aircraft maintenance cases). It also includes digital record-keeping and traceability, both of which are central topics in existing maintenance and airworthiness regulations.

- Maintenance Domain 4 - PHM / Predictive Maintenance and Digital Twins

Domain 4 examines the use of the data produced by the aircraft sensors, the health monitoring systems, the prognostics, the estimation of Remaining Useful Life (RUL) and the digital twin applications for aircraft or aircraft systems<sup>5</sup> (if this is feasible). It aligns with international practices for data-driven and condition-based maintenance in the sector of aviation.

- Maintenance Domain 5 - ILS, Supply Chain and Logistics Support

This domain emphasizes on logistics practices and procedures, such as spare parts, inventory, repair cycle management, AOG handling, supplier integration and, in more advanced cases, the use of IoT or blockchain for tracking parts and guaranteeing

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<sup>5</sup> An Aircraft System considered the integrated set of mechanical, electrical, electronic, hydraulic, and software-based subsystems, each composed of individual components (parts), that enable an aircraft to operate safely and effectively. These systems can function independently, yet are designed to interact and work together to support overall aircraft operation, including (but not limited to) propulsion, control, navigation, communication, and safety.

supply-chain integrity. This domain connects the pure maintenance phase of the aviation MRO with the logistic support and supply chain.

- Maintenance Domain 6 - Technical Documentation and Configuration Management

Domain 6 covers the electronic Technical Publications (e-TechPubs), update and version control of manuals and procedures, configuration status and interfaces to Original Equipment Manufacturer (OEM)<sup>6</sup> portals and engineering change processes. It secures that technicians always use the correct configuration and the latest updated and approved data, which is very crucial for flight safety.

- Maintenance Domain 7 - Training and Competency Management for Maintenance Personnel

Finally, this domain includes initial and recurrent training, AR/VR-based training solutions, e-learning platforms, competency tracking and recertification. It directly links the digital transformation of maintenance with the development of the human workforce, in line with the “people” dimension.

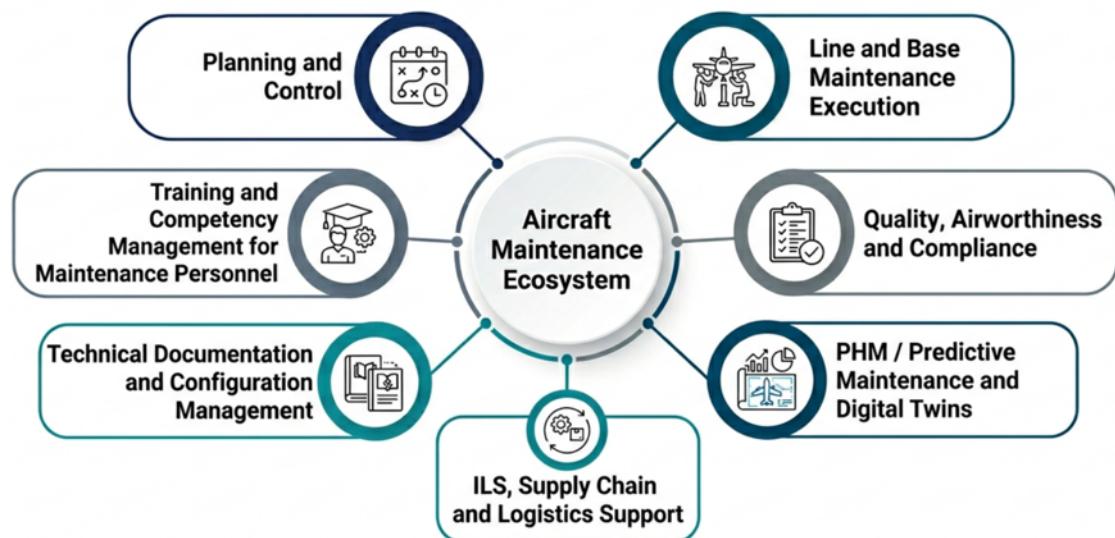


Figure 7. The 7 Maintenance Domains (Credit: Own Elaboration. Generated by Gemini AI - Google, March 2026)

By examining the common horizontal digital maturity dimensions (strategy, policies, digital backbone, data, organization, skills, culture) across all the maintenance domains, the model can reveal general important weaknesses (for example, generally low

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<sup>6</sup> OEM: A company that designs, manufactures, and supplies original components, systems, or equipment used in an aircraft. OEMs produce parts built to certified specifications and are responsible for their design authority, quality, and support throughout the lifecycle

data maturity) and domain-specific gaps (for example, strong digital backbone in planning but weak digital adoption of the processes in flightline maintenance).

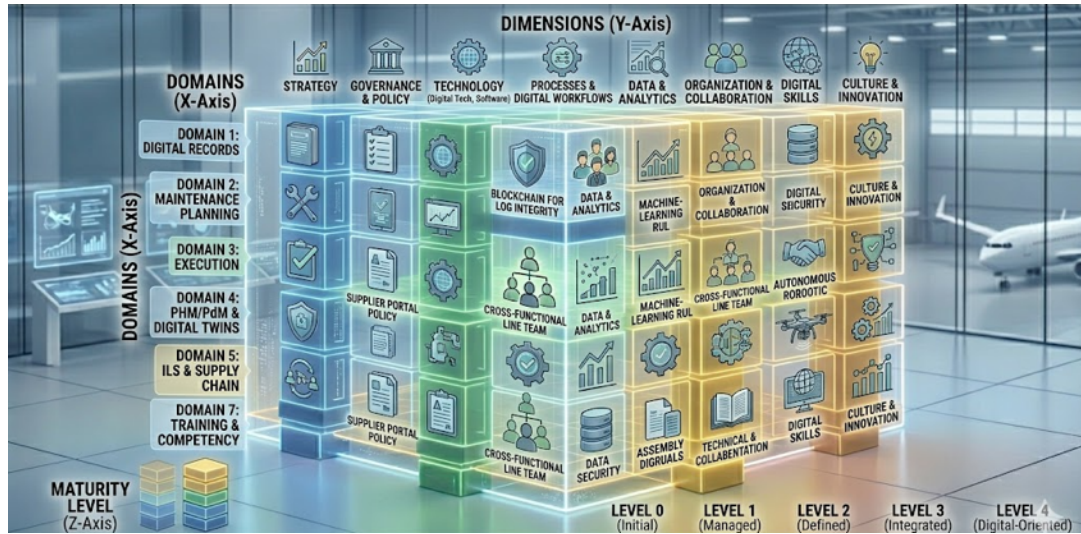


Figure 8. 8 Dimensions x 7 Domains - Digital Transformation Maturity Matrix for Aircraft MRO (Credit: Own Elaboration. Generated by Gemini AI - Google, March 2026)

#### 5.2.4. Maturity Matrix Structure and Assessment Indicators

Once the horizontal dimensions and the maintenance domains have been set, the next step is to bring them together in a structure that is simple to understand and practical to use. The model does this through a matrix: on one axis, we place the standard 8 digital maturity dimensions (as described in Chapter 5.2.2) and on the other axis, the selected maintenance domains (included in Chapter 5.2.3). Each cell of this matrix represents a concrete aspect of digital maturity in maintenance, for example Data & Analytics in PHM or People & Digital Skills in Line Maintenance.

For every cell, we define a small number of assessment indicators. Each indicator is a short, clear statement that can be rated on the five-point maturity scale described earlier. In this way, broad concepts such as “technology” or “organization” are broken down into practices that maintenance professionals can recognize in their daily work.

To keep the model usable, each cell typically contains 1 to 2 indicators. More indicators would make the questionnaire heavy and time-consuming, especially for personnel working in an intense maintenance environment.

Every indicator is directly linked to the five maturity levels (from Initial to Digital-Oriented). Instead of using a separate, complicated scoring guide, the meaning of

each score is built into the answer options themselves – starting from “not present/ad-hoc” and going up to “fully implemented, integrated and continuously improved”. This helps different respondents interpret the scale in a common way and makes the results easier to explain to managers and Subject Matter Experts (SMEs).

At the end of this step, the matrix is fully populated with indicators for all combinations of dimensions and maintenance domains. These indicators are used to construct the questionnaire of the Maturity Model and to calculate maturity scores at different levels (cell, dimension, domain and overall level).

### 5.3. Model - Digital Maturity Assessment Tool for Aircraft Maintenance

All the design choices of the previous subsections are gathered in a unique model and turned into a practical assessment tool. The aim is to provide a structured and easy-to-use tool, that aviation maintenance organizations can apply to measure their current level of digital maturity in aircraft maintenance and identify areas for improvement.

Building the matrix of DT dimensions and maintenance domains, this section presents the full set of the indicators and the corresponding questionnaire, along with the scoring and total logic that produces maturity scores for the evaluated organizations. This model is the core of the thesis, because it is the instrument that allows the theoretical framework of Chapters 2 and 3 to be translated into real measurements and at the end into a very helpful digital-transformation roadmap for DT implementation.

Table 6 presents the core structure of the assessment model. The rows correspond to the horizontal digital maturity dimensions (Chapter 5.2.2) and the columns to the selected maintenance domains (Chapter 5.2.3). Each cell represented by an indicator (e.g. A1, B2, C3 etc.), is evaluated by specific questions in the questionnaire.

Table 6. *Digital Maturity Matrix (Dimensions × Maintenance Domains) (Credit: Own Elaboration)*

|                            |                                                         | Maintenance Domain                |                                      |                                        |                                                 |                                          |                                                       |                                     |
|----------------------------|---------------------------------------------------------|-----------------------------------|--------------------------------------|----------------------------------------|-------------------------------------------------|------------------------------------------|-------------------------------------------------------|-------------------------------------|
|                            |                                                         | A. Maintenance Planning & Control | B. Line & Base Maintenance Execution | C. Quality, Airworthiness & Compliance | D. PHM / Predictive Maintenance & Digital Twins | E. ILS, Supply Chain & Logistics Support | F. Technical Documentation & Configuration Management | G. Training & Competency Management |
| Digital Maturity Dimension | 1. Strategy & Governance                                | A1, A2                            | B1                                   | C1                                     | D1                                              | E1                                       | F1                                                    | G1                                  |
|                            | 2. Policies, Compliance & Cybersecurity                 | A3                                | B2                                   | C2, C3                                 | D2                                              | E2                                       | F2                                                    | G2                                  |
|                            | 3. Information Systems & Digital Backbone               | A4, A5                            | B3                                   | C4                                     | D3                                              | E3                                       | F3                                                    | G3                                  |
|                            | 4. Process Digitalisation & Workflow Automation         | A6                                | B4, B5                               | C5                                     | D4                                              | E4                                       | F4                                                    | G4                                  |
|                            | 5. Data & Analytics                                     | A7                                | B6                                   | C6                                     | D5, D6                                          | E5                                       | F5                                                    | G5                                  |
|                            | 6. Organisation, Roles & Cross-Functional Collaboration | A8                                | B7                                   | C7                                     | D7                                              | E6                                       | F6                                                    | G6                                  |
|                            | 7. People & Digital Skills                              | A9                                | B8                                   | C8                                     | D8                                              | E7                                       | F7                                                    | G7, G8                              |
|                            | 8. Culture of Continuous Improvement & Innovation       | A10                               | B9                                   | C9                                     | D9                                              | E8                                       | F8                                                    | G9                                  |

### 5.3.1. Questionnaire

This subsection introduces the questionnaire that puts the model into practice and explains how each answer is scored. Every question corresponds to one cell of the matrix and is rated on a five-point Likert scale, scored from 0 to 4 (corresponding to the five maturity levels: initial, managed, defined, integrated and digital oriented, as described in section 5.2.1).

By using the same scale for all questions, the questionnaire turns what people experience in their daily maintenance work into comparable digital-maturity scores that can later be grouped per dimension and per domain.

Digital Maturity Matrix questionnaire:

#### **Section A – Maintenance Planning & Control**

##### **A1 – DT strategy in planning**

To what extent is maintenance planning linked to the organization's DT strategy (e.g. use of PHM, paperless workflows, data-driven planning)?

0: No connection.

- 1: Basic / Ad-hoc links.
- 2: Formal digital connection for planning (Not applied everywhere).
- 3: Fully Integrated maintenance planning.
- 4: Digital-Oriented planning (Focus on innovation).

## **A2 – Governance of digital initiatives in planning**

Is there a clear governance structure (roles, committees, reporting) overseeing digital initiatives related to maintenance planning and scheduling?

- 0: No governance structure.
- 1: Informal (Unclear roles).
- 2: Defined governance (Roles and committees, but no connection to goals).
- 3: Integrated governance (Systematic tracking via KPIs, unified program management).
- 4: Dynamic governance (Agile structures, continuous evaluation).

## **A3 – Policies & compliance in planning systems**

To what extent do formal policies (data governance, cybersecurity, change control) cover the IT tools used for planning and control (MRO/CMMS, planning tools)?

- 0: Absence of policies.
- 1: Basic policies (Not tailored to maintenance).
- 2: Defined rules (Not universal).
- 3: Full compliance.
- 4: Proactive security (Automated).

## **A4 – Integration of planning tools with MRO/CMMS**

How well is the maintenance planning system integrated with the MRO/CMMS platform (automatic exchange of work packages, status, feedback)?

- 0: No integration.
- 1: Basic integration (Isolated interfaces).
- 2: Structured integration (Systems communicate, but with some boundaries).
- 3: Full integration.
- 4: Smart integration (Automated).

## **A5 – Integration with Operations / Flight Ops systems**

Is there electronic, near real-time integration between maintenance planning and operations/flight planning systems (e.g. aircraft status, utilization, constraints)?

- 0: No electronic integration.
- 1: Fragmented (Periodic file exchange).
- 2: Structured but delayed (not in real-time).
- 3: Real-time integration.
- 4: Fully dynamic (Shared real-time dashboards, forecasting and joint planning).

#### **A6 – Digital workflows for work package preparation and approvals**

To what range are work package creation, approval and release managed through digital workflows (e-approvals, audit trail) rather than manual processes?

- 0: Entirely manual.
- 1: Basic digitization (PDF/Excel and emails, manual flows).
- 2: Semi-automated workflows.
- 3: Fully digital workflows (Electronic signatures, paperless operation).
- 4: Smart workflows (Automatic).

#### **A7 – Use of data and analytics in planning**

How far are historical data, PHM outputs and analytics used to optimize maintenance intervals, workload forecasting and hangar capacity?

- 0: No use of data/analytics.
- 1: Basic reports (Historical data).
- 2: Structured analysis (Periodic use, no dynamic updates).
- 3: Diagnostic & Predictive analytics (Forecasting).
- 4: Automated AI models and PHM for dynamic planning.

#### **A8 – Cross-functional collaboration in planning**

To what extent do planning teams work in an integrated way with Operations, Engineering, ILS and IT (joint meetings, shared dashboards, common KPIs)?

- 0: Siloed operation.
- 1: Informal collaboration (Occasional meetings, no shared digital tools).
- 2: Formal collaboration (Regular meetings and joint reports, separate systems).
- 3: Integrated collaboration (Shared dashboards, KPIs, workflows).
- 4: Unified cross-functional operation.



#### **A9 – Digital skills of planners and controllers**

How would you rate the digital skills of maintenance planners (use of planning tools, data interpretation, understanding of PHM outputs)?

- 0: Inadequate (Basic PC skills).
- 1: Basic (Core functions of MRO tools).
- 2: Adequate (Familiarity with digital tools).
- 3: Advanced (Full utilization of tools).
- 4: Use of AI, continuous self-improvement.

#### **A10 – Continuous improvement culture in planning**

Is there a systematic process to review planning performance (e.g. delays, re-planning), capture lessons learned and adjust tools and processes?

- 0: No systematic process.
- 1: Informal reviews (No systematic recording).
- 2: Formal recording of lessons learned, no adjustment of the tools.
- 3: Continuous improvement (KPIs for processes improvement).
- 4: Innovation (Automated feedback).

### **Section B – FlightLine & Hangar Maintenance Execution**

#### **B1 – Alignment of execution with DT strategy**

Are digital tools (mobile devices, AR, digital job cards) for flightline/hangar maintenance, part of the organization's DT roadmap?

- 0: No digital tools.
- 1: Basic / Ad-hoc (Isolated digital tools).
- 2: Inconsistent implementation across teams.
- 3: Integrated digital tools (Part of the daily maintenance).
- 4: Digital-Oriented (Deployment of advanced digital tools – AI applications).

#### **B2 – Safety, compliance and cybersecurity at the hangar/flightline**

How clearly are safety, airworthiness and cybersecurity requirements built into the selection and use of digital tools at the point of work?

- 0: Ignored.
- 1: Basic (General IT rules).
- 2: Defined (Clear safety/cyber rules).

- 3: Integrated (Strict, continuous compliance and cybersecurity).
- 4: Proactive (Automated monitoring and dynamic updates).

**B3 – Availability and integration of digital tools for maintenance**

To what range do technicians use integrated digital tools (MRO terminals, tablets, mobile apps) directly at the aircraft, with access to work orders and data?

- 0: No digital tools.
- 1: Basic (Shared devices).
- 2: Structured (Personal devices, no full access to data).
- 3: Integrated (Personal devices, real-time access to data).
- 4: Smart (Advanced devices).

**B4 – Digital job cards and paperless task execution**

Are job cards and task instructions primarily managed in digital form, with electronic sign-off and time stamping?

- 0: Only paper-based.
- 1: Basic (PDFs or static digital files).
- 2: Semi-digital (Some paper handling or dual entries).
- 3: Fully paperless.
- 4: Smart digital job cards (automatic, real-time data).

**B5 – Workflow automation during task execution**

Do deviations, defects and additional findings trigger digital workflows (e.g. automatic creation of findings, notifications to engineering, approvals)?

- 0: Deviations and defects are reported verbally or via paper forms.
- 1: Defects are typed into a system manually, no automated routing.
- 2: Digital reporting, manual engineering review.
- 3: Automatic notifications and approvals.
- 4: Intelligent workflows (AI integration).

**B6 – Use of operational and sensor data during troubleshooting**

To what extent do technicians have access to live or recent data (sensor data, trends, fault history) to support troubleshooting?

- 0: No access

- 1: Basic access (Historical data downloaded or printed).
- 2: Digital access, no live sensor data.
- 3: Real-time access to live sensor data.
- 4: Predictive (Troubleshooting is actively guided by AI/PHM).

**B7 – Team organization and coordination in digital environments**

How well are shift leaders and supervisors using digital boards/dashboards to allocate work, monitor progress and reassign tasks?

- 0: No digital boards/dashboards.
- 1: Basic (Spreadsheets or static digital lists, no real-time updates).
- 2: Digital boards, periodic updates, no real-time data.
- 3: Integrated (Live digital dashboards).
- 4: Automated (AI integration).

**B8 – Digital skills and training of technicians**

How confident are technicians in using the available digital tools (tablets, readers, AR devices, diagnostic tools)?

- 0: Inadequate.
- 1: Basic (Simple data entry).
- 2: Adequate (Simple use of digital tools).
- 3: Advanced (Use of complex diagnostic tools and applications).
- 4: Innovative.

**B9 – Continuous improvement in flightline/hangar execution**

Is there a structured process to collect feedback from technicians on digital tools and procedures and to improve them over time?

- 0: No feedback.
- 1: Informal feedback.
- 2: Periodic surveys.
- 3: Digital feedback loops.
- 4: Automatic – AI driven.

**Section C – Quality, Airworthiness & Compliance**

**C1 – Integration of quality & airworthiness into DT governance**

Are quality and airworthiness representatives actively involved in DT governance and decision-making?

- 0: Not involved.
- 1: Basic / Ad-hoc (Involved occasionally).
- 2: Formal involvement (Reactively, not proactively)
- 3: Integrated (They are core members of DT governance)
- 4: Digital-Oriented (They lead the DT and safety strategy)

## **C2 – Digital policies for records and traceability**

To what range are there formal policies covering digital record-keeping, traceability, maintenance and audit requirements for maintenance data?

- 0: No policies.
- 1: Basic (General IT policies, not specifically tailored to aviation maintenance).
- 2: Formal digital policies, not common across all departments)
- 3: Digital policies across all maintenance systems.
- 4: Policies dynamically updated and automatically supported by smart systems.

## **C3 – Cybersecurity for safety-critical records**

How robust are cybersecurity controls for systems holding safety and airworthiness, critical information?

- 0: Inadequate.
- 1: Basic (Standard IT security, no specialized protection).
- 2: Cybersecurity policies for safety records, but no audits or proactive updates.
- 3: Robust and multi-layered cybersecurity.
- 4: Advanced, AI-driven cybersecurity.

## **C4 – Integration of QA/QC tools with MRO/CMMS**

Are quality findings, audits and corrective actions managed in systems that are integrated with the maintenance and configuration databases?

- 0: No integration.
- 1: Digital QA/QC records, require manual entry into the systems.
- 2: Partial integration, still information silos.
- 3: Fully interconnected systems, automatically linked databases.
- 4: Intelligent systems, automatic updates, predictive maintenance.

### **C5 – Digitalization of audits and inspections**

To what extent are audits, inspections and findings captured in digital form with workflows for review and closure?

- 0: Manual.
- 1: Digital forms, manual reviews and closures.
- 2: Semi-digital (Still require manual or paper-based actions).
- 3: End-to-end digital audits, inspections, electronic signatures, and closures
- 4: Advanced (Augmented by automated digital tools).

### **C6 – Use of data & analytics in quality monitoring**

Are analytics used to monitor trends in defects, findings and to support preventive or corrective actions?

- 0: No analytics used.
- 1: Basic (Historical data only).
- 2: Regular data analysis, trends identification, manual processes, no proactive capabilities.
- 3: Analytics used for trend monitoring, preventive actions driven.
- 4: Advanced AI/ML models, automatic corrective actions.

### **C7 – Cross-functional handling of quality issues**

How well do quality, maintenance and engineering teams collaborate through shared digital tools when dealing with findings and corrective actions?

- 0: Siloed teams
- 1: Informal communication.
- 2: Common digital systems, disconnected collaboration.
- 3: Integrated collaboration.
- 4: Fully automated cross-functional collaboration.

### **C8 – Skills in digital QA/QC tools**

How would you rate the competence of QA/QC personnel in using the organization's digital tools [QMS (Quality Management System), reporting, dashboards]?

- 0: Inadequate.
- 1: Basic (Basic data entry, no reporting, no dashboards).
- 2: Adequate (digital QA/QC tools and basic dashboards).
- 3: Advanced (Customized reports, navigating dashboards, interpreting analytics).

4: Innovative usage of data, AI automation.

**C9 – Continuous improvement culture in quality & compliance**

Is there a structured learning loop where quality data feed back into process redesign, training and system enhancements?

0: None.

1: Informal (Occasional improvements).

2: Formal continuous redesign processes, slow updates.

3: Continuous improvement (Systematic usage of quality data and KPIs).

4: Automated feedback constantly optimizes processes and standards.

**Section D – PHM / Predictive Maintenance & Digital Twins**

**D1 – Strategic role of PdM and digital twins**

Is the use of PdM and digital twin concepts clearly defined as part of the maintenance and fleet strategy?

0: No PdM/Digital twins.

1: Basic / Ad-hoc (No clear strategy).

2: Limited implementation.

3: Core PdM and digital twin concepts.

4: Advanced predictive capabilities and dynamic digital twin simulations used as strategy drivers.

**D2 – Policies and data governance for PHM data**

Are there clear rules for ownership, sharing and protection of PHM and sensor data (including OEM and alliance data-sharing agreements)?

0: No policies.

1: General data rules, no specific agreements or protections for complex PHM/OEM data.

2: Formal data sharing and protection policies.

3: Well-managed data governance policies.

4: Proactive (advanced cybersecurity protocols for real-time PHM data).

**D3 – Integration of PHM tools with operational and maintenance systems**

How well are PHM platforms connected with MRO/CMMS, planning and fleet management systems?

- 0: No integration.
- 1: Manually exported/imported PHM data.
- 2: Partial integration, manual verification.
- 3: PHM tools automatically connected with MRO/CMMS and planning systems.
- 4: Dynamic PHM tools for real-time automatic maintenance scheduling.

#### **D4 – Embedding PHM outputs in maintenance processes**

To what extent are PHM alerts and RUL (Remaining Useful Life) estimates linked to actual maintenance actions (work orders, inspections, spares planning)?

- 0: Not embedded.
- 1: Basic (Manual alerts).
- 2: PHM outputs trigger maintenance actions, manual work order creation.
- 3: Automatically generated work orders, inspections, and trigger spares procurement.
- 4: AI generates the work order and optimizes the timing and resources required.

#### **D5 – Use of analytics and modelling in PHM**

How advanced are the analytics used (from simple thresholds to machine-learning models and scenario analysis)?

- 0: No analytics or modelling tools.
- 1: Basic (Simple, static threshold alerts, no predictive modelling).
- 2: Standard statistical models and historical trend analysis).
- 3: Advanced Machine-Learning models for diagnostics and RUL predictions.
- 4: Prescriptive (Self-learning AI models).

#### **D6 – Use of digital twin concepts for critical systems**

Are digital twin models used for selected systems (engines, avionics, structures) to simulate behavior and support maintenance decisions?

- 0: Not used.
- 1: Basic digital replicas, no simulation of behavior.
- 2: Digital twins for specific critical systems, offline analysis.
- 3: Active digital twins.
- 4: Real-time, dynamic digital twins.

#### **D7 – Cross-functional coordination around PHM**

Do maintenance, engineering, IT and operations jointly review PHM results and decide on interventions?

- 0: No cross-functional review.
- 1: Informal (Occasional, ad-hoc).
- 2: Regular meetings for PHM outputs review, separate systems usage.
- 3: Integrated (Shared live dashboards).
- 4: Unified digital environment, AI used for immediate, collaborative interventions.

#### **D8 – Skills and understanding of PHM among maintenance staff**

How familiar are planners, engineers and technicians with PHM concepts and the interpretation of PHM outputs?

- 0: Inadequate.
- 1: Basic.
- 2: Adequate.
- 3: Advanced (Complex machine-learning outputs and RUL estimates).
- 4: Leading (Predictive models refinement).

#### **D9 – Continuous improvement of PHM models and processes**

Is there a feedback loop where actual maintenance findings and in-service behavior are used to improve PHM models and thresholds?

- 0: No feedback loop
- 1: Informal feedback.
- 2: Formal feedback.
- 3: Systematic feedback for continuous improvement.
- 4: Automated machine-learning feedback.

### **Section E – ILS, Supply Chain & Logistics Support**

#### **E1 – Strategic alignment of ILS/logistics with DT**

Is the digitalization of ILS and supply-chain support part of the overall maintenance DT strategy?

- 0: No digitalization, no alignment.
- 1: Basic / Ad-hoc (No alignment with maintenance).
- 2: Digital ILS, fragmented execution.



3: Digital ILS and supply-chain support are core.

4: Supply-chain digitalization drives proactive maintenance strategies.

**E2 – Policies for supplier data, contracts and security**

Are there defined policies for digital collaboration with suppliers (data exchange, portals, cybersecurity clauses)?

0: No policies.

1: Basic policies.

2: Formal policies for digital exchange with suppliers.

3: Enforced policies for secure digital data exchange with all suppliers.

4: Dynamic, smart contracts and automated audits.

**E3 – Integration of logistics systems with MRO/CMMS and planning**

How well are inventory, procurement and repair-cycle systems integrated with maintenance planning and execution?

0: No integration.

1: Manual data entry or spreadsheet uploads to share data with maintenance.

2: Partial connection.

3: Integrated connection, real-time visibility.

4: Smart connection, automatic procurement and supply chain optimization.

**E4 – Digitalization of ILS processes**

To what extent are ILS activities (spares forecasting, repair loop, AOG handling) supported by digital workflows and electronic records?

0: Only manual (Paperwork).

1: Basic digital files, manual workflow.

2: Semi-digital (Manual intervention needed).

3: Fully digital.

4: AI driven, smart automation.

**E5 – Use of data & analytics in logistics performance**

Are analytics used to monitor and improve stock levels, lead times, repair turnaround and AOG events?

0: No analytics used.

- 1: Basic (Only historical data).
- 2: Regular data analysis, no proactive capabilities.
- 3: Use of analytics for demand forecasting and stock level optimization.
- 4: Advanced AI models for dynamic supply chain.

#### **E6 – Cross-functional collaboration between maintenance and logistics**

How effectively do maintenance and ILS/logistics teams cooperate through shared systems and common KPIs?

- 0: Maintenance and ILS: Siloed .
- 1: Informal communication (no digital tools).
- 2: Common KPIs and regular meetings, but separate and disconnected systems.
- 3: Integrated cooperation (shared live dashboards, common and real-time KPIs).
- 4: Unified digital environment, cross-functional teams.

#### **E7 – Digital skills of logistics and ILS personnel**

How confident are logistics staff in using digital tools linked to maintenance (portals, planning interfaces, analytics)?

- 0: Inadequate.
- 1: Basic data entry in logistic tools.
- 2: Adequate (digital ILS tools usage).
- 3: Advanced (Complex applications and planning interfaces usage).
- 4: Advanced data tools and AI applications to continuously innovate supply chain operations.

#### **E8 – Continuous improvement and innovation in ILS**

Is there a structured effort to test and scale new digital solutions in the supply chain (e.g. RFID tracking, blockchain, advanced forecasting)?

- 0: None.
- 1: Informal.
- 2: Structured but slow scaling across supply chain.
- 3: Continuous improvement.
- 4: Innovative (Blockchain applications and AI forecasting tools).

### **Section F – Technical Documentation (tech-docs) & Configuration Management**

**F1 – Strategic importance of digital tech docs and configuration control**

Is the digital management of technical publications and configuration treated as a strategic enabler in the DT roadmap?

- 0: No strategic role.
- 1: Basic / Ad-hoc.
- 2: Formal but inconsistent across the organization.
- 3: Core.
- 4: Digital-Oriented.

**F2 – Policies and compliance for digital manuals and configuration records**

Are there clear policies on digital control of manuals, revisions, configuration status and their regulatory acceptance?

- 0: No policies.
- 1: Basic policies.
- 2: Formal policies but enforcement varies.
- 3: Universal and enforced policies.
- 4: Automated and dynamic policies (proactivity).

**F3 – Integration of tech-doc systems with MRO/CMMS and engineering**

To what extent are e-TechPubs, IPC and configuration databases integrated with maintenance and engineering tools?

- 0: No integration.
- 1: Basic integration (Manual uploads, static PDFs or basic links).
- 2: Partial integration, manual cross-checks.
- 3: Full and automatic integration.
- 4: Smart integration (real-time update of engineering models and maintenance tools).

**F4 – Digitalization of documentation workflows**

Are processes such as revision distribution, acknowledgements and use of manuals during maintenance fully digital?

- 0: Manual processes.
- 1: PDFs used, manual distribution of updates.
- 2: Semi-digital (some workflows require paper).
- 3: Fully digital (manual usage at the point of work).

4: Smart automation.

**F5 – Use of data & analytics in configuration and documentation**

Is configuration data used to identify modification status versus defects or to support decisions on upgrades?

0: No data analytics used.

1: Basic (Historical data used for manual reporting).

2: Formal (Periodically analyzed data).

3: Diagnostic & Predictive.

4: Advanced AI models usage.

**F6 – Collaboration between maintenance, engineering and documentation teams**

How well do these teams work together using shared systems when introducing changes or resolving documentation issues?

0: Siloed.

1: Informal communication, no shared digital tracking.

2: Common system, disconnected workflows.

3: Integrated (Shared, real-time digital platforms).

4: Fully automated cross-functional collaboration.

**F7 – Digital skills for tech-doc and configuration tools**

How competent are staff in using the digital platforms for documentation and configuration?

0: Inadequate.

1: Basic (No complex configuration tools).

2: Adequate (Standard digital tech-doc platforms for daily tasks).

3: Advanced (Complex configuration databases and digital documentation systems).

4: Leading (Staff improves maintenance efficiency).

**F8 – Continuous improvement in documentation and configuration management**

Is there a mechanism to capture feedback from technicians and engineers and reflect it in documentation and configuration procedures?

0: No mechanism.

1: Informal mechanisms.

- 2: Formal mechanisms (Periodic feedback, slow process).
- 3: Continuous improvement.
- 4: Automated, continuous feedback.

## **Section G – Training & Competency Management**

### **G1 – Strategic framework for digital training in maintenance**

Is there a clear strategy for developing digital skills and competencies across maintenance roles (technicians, planners, engineers)?

- 0: No strategy.
- 1: Basic / Ad-hoc procedures.
- 2: Formal strategy for digital skills, but inconsistent across different maintenance roles.
- 3: Clear, funded strategy ensures continuous digital skills development across all maintenance roles.
- 4: Digital competency development is core driver for innovation.

### **G2 – Policies for certification and digital records of competencies**

Are training, recertification and competency records managed through digital systems, with clear policies and auditability?

- 0: No policies.
- 1: Basic (Lack of formal auditability or automated tracking).
- 2: Digital policies for training records, but manual enforcement and auditing processes.
- 3: Strict policies for training and competency digital records.
- 4: Automatic recertification policies and non-compliant personnel auto-prevention from task assignment.

### **G3 – Integration of training systems with maintenance data**

To what extent are training needs informed by real maintenance data (findings, errors, new technologies introduced)?

- 0: No integration.
- 1: Basic integration (Manual training updates).
- 2: Periodically updated training systems based on new systems introductions.
- 3: Fully connected training systems to maintenance data, dynamic updates.
- 4: Automatically generated training modules by AI.

#### **G4 – Use of digital and immersive training methods**

How widely are digital methods (e-learning, simulators, AR/VR) used for maintenance training?

- 0: No digital methods (Paper-based and on-the-job training).
- 1: Basic digital methods (static PDFs or basic e-learning videos).
- 2: Interactive e-learning platforms and digital testing.
- 3: Advanced digital methods (maintenance simulators and AR/VR).
- 4: Continuous training with AR/VR and digital twin simulations.

#### **G5 – Use of data & analytics in training effectiveness**

Are data collected and analyzed to assess training effectiveness and to adjust training programs?

- 0: No data collection.
- 1: Basic records.
- 2: Regular data analysis to track basic training KPIs.
- 3: Diagnostic & Predictive.
- 4: AI correlates training data with maintenance for best training models - methods.

#### **G6 – Collaboration between training, maintenance and HR**

How well are training activities coordinated with maintenance management and HR planning?

- 0: Siloed.
- 1: Informal coordination.
- 2: Regular meetings, disconnected systems for management and planning.
- 3: Integrated (Shared digital dashboards).
- 4: Unified – autonomous digital environment.

#### **G7 – Current digital skill level of maintenance personnel**

How would you rate the overall digital skill level of the maintenance workforce?

- 0: Inadequate.
- 1: Basic level (Simple data entry, no data interpretation).
- 2: Adequate (Standard use of digital maintenance tools).
- 3: Advanced level (Complex digital platforms and diagnostic tools).

4: Innovation and IT issues troubleshooting.

#### **G8 – Support for self-learning and continuous upskilling**

Does the organization provide platforms, time and incentives for continuous self-learning in digital tools and methods?

0: No platforms – digital tools.

1: Basic platforms – digital tools.

2: Learning platforms, but no clear incentives.

3: Integrated platforms and clear incentives for continuous upskilling).

4: Continuous self-learning and AI-generated content.

#### **G9 – Culture of learning and innovation**

Is there a recognizable culture that encourages experimentation, learning from mistakes and adoption of new digital practices in maintenance?

0: None.

1: Informal.

2: Formal processes but slow adoption of new practices.

3: Culture of continuous improvement.

4: Culture of innovation.

### **5.4. Data Collection Process**

The data collection process is intended to be simple enough for everyday maintenance environments, but still to remain structured, in order to produce reliable maturity scores. In line with other digital-maturity studies that use survey-based instruments, the main data collection method is an online questionnaire developed directly from the model described in Chapters 5.2 and 5.3.

The questionnaire is implemented in Google Forms<sup>7</sup>, which offers an easy way to distribute the survey, collect responses and export the data to Google Sheets for further analysis. Each question in the form corresponds to one indicator in the “dimension ×

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<sup>7</sup> Questionnaire Link: <https://forms.gle/9vjqDyVTbaMRZZRW7>

domain” matrix and uses the common 0–4 Likert scale described in Chapter 5.3.1, allowing the answers to be directly mapped to the five maturity levels.

To capture a holistic and realistic view of digital maturity in aircraft maintenance, the questionnaire will be sent to multiple stakeholders from different departments of the examined organization: maintenance planners and controllers, flightline and 2<sup>nd</sup> level maintenance<sup>8</sup> engineers, supervisors, quality and airworthiness personnel, ILS and supply-chain staff, IT specialists supporting maintenance systems, training and high-level managers.

This multi-perspective sampling follows the recommendations of maturity-model applications in both project management and DT, where it is important to combine managerial and operational views rather than rely on an individual group.

The Google Form Questionnaire, begins with a short section of demographic questions (role, unit, squadron or department and years of experience), followed by the main body of questions organized by maintenance domain.

Also, at this initial sector of the questionnaire, respondents are informed about the purpose of the study, the anonymity of their responses and that results will be used only at an aggregated level. Once the data collection window closes, the responses from Google Sheets are cleaned and imported into the analysis environment, where the scoring will be applied to calculate cell-level, dimension-level, domain-level and the overall digital maturity index, as described at the very next chapter.

## 5.5. Scoring and Calculation of Digital Maturity Indices

This section explains how the responses of the questionnaire are converted to numerical scores and how these scores are calculated at different levels of the model. The objective is to maintain a clear logic for the scoring, and at the same time to remain consistent with the maturity-model philosophy.

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<sup>8</sup> 2nd Level Maintenance (Intermediate Maintenance): Maintenance performed at an intermediate support level, beyond basic flightline tasks, involving more complex inspections, fault isolation, and component repair or replacement using specialized tools and test equipment.



All questions are answered using a five-point scale that corresponds directly to the five maturity levels defined in Chapter 5.2.1, from Initial to Digital-Oriented. Each response is treated as a numerical value from 0 to 4.

Using this scoring system, the model produces four levels of results:

- A score for each question.
- A score for each cell (dimension  $\times$  domain).
- Group scores for each dimension and each domain.
- One overall digital maturity index for aircraft maintenance.

These values form the quantitative basis for the analysis and the development of a targeted DT roadmap in Chapter 6.

#### 5.5.1. Question-Level Scores

For each question  $Q_i$  in the questionnaire, an average score is calculated across all participants. If a question receives  $n$  valid responses with values  $x_1, x_2, x_3, \dots, x_n$ , the question score is:

$$\text{Score}_{Q_i} = \frac{\sum_{k=1}^n x_k}{n}$$

This value represents the observed maturity of the specific practice addressed by question  $Q_i$ .

#### 5.5.2. Cell-Level Scores (Dimension $\times$ Domain)

Each cell of the matrix of Table 6 corresponds to one combination of digital maturity dimension and maintenance domain and is calculated by one (or in some cases by two) questions. In the case of two questions corresponding to one cell, the cell score is simply calculated as their average.

This score ( $\text{Score}_{cell}$ ) expresses, on the same 0–4 scale, the maturity of that specific aspect (e.g. Data & Analytics in PHM, Process Digitalization in Line Maintenance).

### 5.5.3. Dimension-Level Scores

Each digital maturity dimension (e.g. Strategy & Governance, Data & Analytics) appears in several cells across different maintenance domains. To obtain a single score per dimension, the model uses the average of all the related cell scores ( $Score_{cell,dimension}$ ).

$$Score_{dimension} = \frac{\sum Score_{cell,dimension}}{number\ of\ cells\ in\ this\ dimension}$$

This calculation shows how mature the organization is in a given capability area overall, regardless of where it is applied (planning, execution, PHM, etc.).

### 5.5.4. Domain-Level Scores

Each maintenance domain (e.g. FlightLine & Hangar Maintenance, ILS & Logistics) is represented by several cells, one for each dimension. In the same manner with the dimension scoring, a domain score is obtained by averaging all cell scores belonging to that domain ( $Score_{cell,domain}$ ).

$$Score_{domain} = \frac{\sum Score_{cell,domain}}{number\ of\ cells\ in\ this\ domain}$$

This score reflects the digital maturity of the specific maintenance domain as a whole, regardless the manner it is applied to it (strategy & governance, policies, culture) and allows direct comparison between domains.

### 5.5.5. Overall Digital Maturity Index

To get a single, global indicator of digital maturity in aircraft maintenance, the model uses the mean of all cell-level scores ( $Score_{cell}$ ) in the matrix.

$$\text{Overall Maturity Index} = \frac{\sum Score_{cell}}{total\ number\ of\ cells}$$

This selection keeps the calculation method in a simple and full transparent way, because every cell (dimension  $\times$  domain) contributes equally to the overall index.

Alternative formulations (such as averaging all dimension scores or all domain scores) gives the same numerical values as long as no additional weights are applied to the domains or the dimensions.

## 5.6. Maturity Assessment Model Characteristics

### 5.6.1. The Maturity Assessment Model as an Evolving Framework

Things in aviation are always changing rapidly, and what now defines a maintenance organization as digital oriented will be probably considered basic in the near future. As aviation MRO is an area that transforms so quickly, the maturity assessment tool described above, cannot be deployed as a ‘tick-box’ checklist that you apply once and forget. Instead, it is always evolving and improving, in order to reflect current practices and technology improvements.

The matrix-structure of the assessment tool allows new standards and innovative practices to be easily added to what’s already in place, taking into consideration that more self-operating robots for inspections and digital tools for malfunction prediction will appear and a much stronger application of the principles of Industry 5.0 will inevitably emerge. Essentially, a maintenance organization can keep on adjusting the evaluation criteria, to implement new technological capabilities, without needing to rebuild the assessment’s model.

The model actually grows and evolves with the digital progress of the organization. By reviewing the levels of maturity and the specific areas being measured, to align with the newest best practices in the industry, the model is designed to remain relevant and useful to guide high-level managers of the MRO organizations over the technology landscape.

### 5.6.2. Maturity Assessment Model Customization

At this stage, there are not applied special weights for specific dimensions or domains of the matrix. This intentional simplification follows the recommendation of the existing maturity assessment models, which emphasize the clarity and expedite the interpretation, especially in the first assessments of the MRO organizations.

If a particular organization that wants to emphasize the DT in certain areas (for example airworthiness or PHM), weights can be added in future application of the model, but the core scoring logic remains based on straightforward means.

### 5.6.3. Multilevel Maturity Assessment

Nowadays, airlines and aviation maintenance organizations almost never do everything by themselves. Due to the fact that the aircraft MRO object is huge, it is a typical practice for aviation organizations to outsource several maintenance areas, like logistics and parts overhauls.

There are cases that maintenance organizations might spend a vast amount of money to become “Digital Operated”, but an outsourcer (e.g. a third-party logistics company) uses old fashioned tactics (for example manual procedures and printed spreadsheets to handle logistics). In this case, the digital transformation collapses and the information flow is disrupted at the point where the two organizations connect.

To cover this gap, the suggested assessment for maturity can be a mandatory requirement for companies working for or with aviation MRO organizations. Essentially, an organization can assess maturity on multiple levels, and extend its control over digital processes beyond its own field of action. When choosing and finalizing a contract with a third-party supplier, the main organization can require the potential partner to complete the maturity assessment for the specific area they are responsible for.

This means that beyond cost, delivery options and lead times, the Service Level Agreement (SLA) between the MRO organization and the external partner, will have a firm requirement for digital ability. For example, a supplier might have to get and keep a minimum score of 3.00 (Defined) in “ILS, Supply Chain & Logistics Support” to get the contract. This ensures the partner is digitally advanced enough to link smoothly with the main organization’s CMMS, allowing automatic data sharing and appropriate computer security. If the supplier doesn’t reach the required score, will either be excluded from the bidding process or be obligated by the contract to update the commonly used digital systems.

Keeping these digital systems working together in a unified digital platform is not a one-time process, it needs regular effort. To effectively oversee this larger digital

network, the main organization should build the Deming Cycle<sup>9</sup> (also known as the Plan-Do-Check-Act or PDCA method) into their routine for managing agreements with suppliers.

This changes the maturity model from a single test into a continuing process:

Plan: the main organization clearly states the digital maturity score they expect in the original contract for specific MRO domains or DT dimensions, relative to the outsourcer, specifically outlining what they expect regarding data exchange, automated processes, and system connections.

Do: the external partner begins to handle the outsourced area, using digital tools and executing the service of the agreement (e.g. maintenance, logistics etc.) as planned.

Check: the main organization regularly monitors the outsourcer by having them repeat the relevant parts of the maturity assessment. This check shows if the partner's digital ability is staying on track with the contract, or if their performance is causing siloed information.

Act: if the assessment shows scores going down or problematic areas (MRO domains or DT dimensions), both sides must fix the problem. The partner might have to upgrade a particular software connection to get connection in real time again, or the main organization might need to share a digital process that has deployed to help the partner get back on course.

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<sup>9</sup> The Deming Cycle, also known as the Plan-Do-Check-Act (PDCA) cycle, is an iterative four-step management method used for the continuous improvement of business processes and products. In the context of digital transformation, it serves as a dynamic framework for aligning outsourced MRO operations with the primary organization's digital standards through constant planning, execution, assessment, and corrective action.

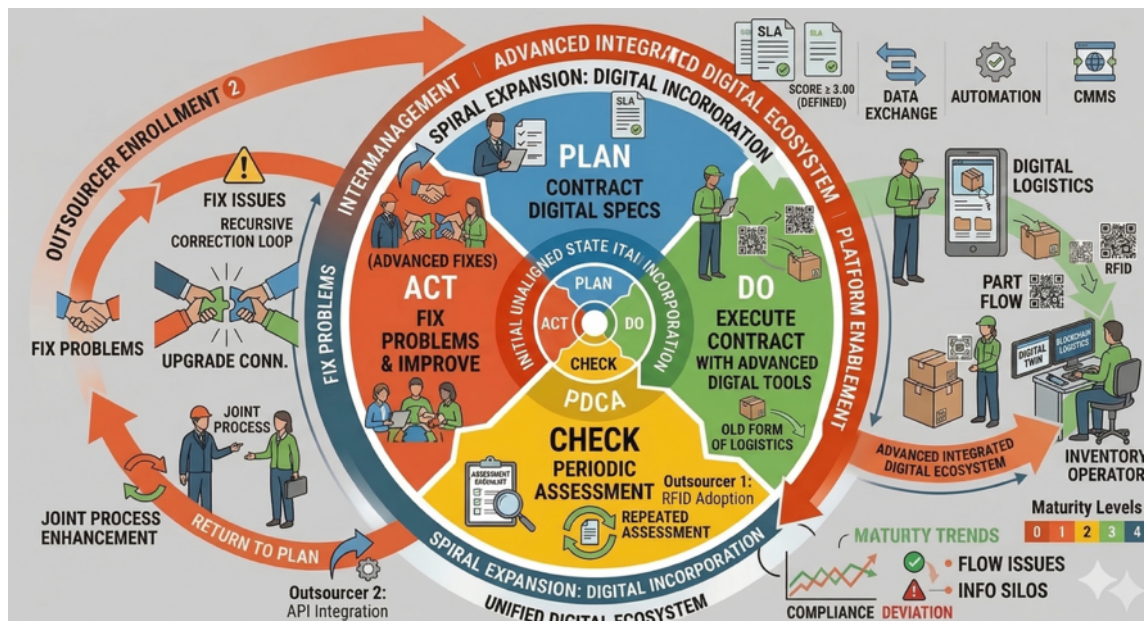


Figure 9. The PDCA Cycle for Digital Maturity in MRO Outsourcing. (Credit: Own Elaboration. Generated by Gemini AI - Google, March 2026)

## **Chapter 6.     Digital Maturity Assessment and Transformation Roadmap**

### **6.1.     Introduction and Maturity Score Bands**

The purpose of this chapter is to move from raw questionnaire scores to purposeful understandings and concrete next steps for upscaling the digital transformation maturity with recommended actions in aircraft maintenance.

The assessment model generates a large number of numerical values: one score per question, per cell (dimension × domain), per dimension, per domain and finally a single overall index. To make these results understandable and comparable, all scores are interpreted using a standard set of maturity bands on the 0–4 scale.

These bands translate average scores into qualitative levels of digital maturity, which are then used throughout the chapter to describe the current situation and to select appropriate actions in the roadmap.

When people fill out those surveys using a scale of five options, they don't generally spread their answers, from one end to the other. Instead, they naturally tend towards the middle options, and don't often pick the highest or lowest. Because of this fact, the assessment breaks down the numbers into ranges that aren't all at the same size. So, the middle numbers (2.00 to 3.00, for instance) get a more careful breakdown to show small shades of difference, while the extreme numbers (0.00 to 0.99 or 3.20 to 4.00) are lumped into broader groups.

Statistically speaking, more responses are packed into the middle, and fewer are at either end, so these different sized groupings describe the answers more precisely than equal blocks of 0.80 organization.

The bands of the average scoring are in total accordance with the 5 maturity levels, as defined in Chapter 5.2.1. These bands, with different ranges as described earlier, in order to exclude the phenomenon of the human nature to avoid very high or very low scores, a tendency that often leads to a central bias, are presented in the following Table 7.

Table 7. *Digital Maturity Level Bands (Credit: Own Elaboration)*

| Maturity Level          | Score Range        | Description of Digital Maturity Status                                                                                                                                                                                                                                                                                                           |
|-------------------------|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Initial</b>          | <b>0.00 – 0.99</b> | Digital practices are absent. Processes are mostly manual, paper-based, and reactive. Different units tend to work in their own ways, and any use of digital tools is sporadic and uncoordinated. There is little knowledge of digital transformation as an organized effort.                                                                    |
| <b>Basic / Managed</b>  | <b>1.00 – 1.99</b> | Some digital tools and practices are in place, but they are fragmented and not standardized. Processes are more organized than at the Initial level, yet they depend heavily on individual actions. Integration between systems is weak or absent, and data is rarely used systematically for decision-making.                                   |
| <b>Defined</b>          | <b>2.00 – 2.59</b> | Processes and digital tools are documented and applied in most situations. The organization has established a common way of working and a basic digital foundation. However, integration across systems and functions remains limited, and the use of data for proactive actions, planning, and optimization is still at a premature stage.      |
| <b>Integrated</b>       | <b>2.60 – 3.19</b> | Digital tools and processes are well integrated throughout departments. Data flows between systems, and everyday maintenance decisions depend on shared information and agreed KPIs. Evidence (and not assumptions) drives continuous improvement activities.                                                                                    |
| <b>Digital-Oriented</b> | <b>3.20 – 4.00</b> | The organization operates with a high level of digital maturity. Advanced technologies (such as PHM, digital twins, AR/VR, and analytics) are not only deployed but also embedded in routine processes. Data-driven decision-making, learning, and innovation are part of the culture, and digital practices are regularly reviewed and refined. |

These score bands are applied consistently to:

- Dimension scores (showing how mature the organization is in areas such as Strategy, Data & Analytics or People & Skills).
- Domain scores (showing the maturity of each maintenance area, such as Planning, Line/Base, PHM or ILS).
- Where needed, cell scores (showing specific combinations of dimensions and domains).

This common interpretation tactic allows the analysis to move beyond particular numbers and to translate the results in clear terms such as “Planning is at a Defined level” or “PHM/Data is still in a Basic state”. It also provides the link to the roadmap in Sections 6.2 and 6.3, where specific actions are proposed for each domain and dimension depending on the maturity band in which their score is not at the required level.

## 6.2. Dimension-Level Maturity Analysis and Recommended Actions

This section explains the results of the maturity assessment model for each of the model’s eight dimensions. For each one, the maturity band shows what the situation



usually looks like, as a general picture from an external observer, and suggests the most suitable actions to move on through the digital improvement. Once the organizations know the score for a dimension, they can use the description and actions as a starting point for their own plan.

#### 6.2.1. Dimension 1 - Strategy & Governance of Digital Transformation

##### Dimension Score: 0.00–0.99 – Initial

At this level, there is no clear DT strategy for maintenance. Digital initiatives are ad hoc (e.g., new tools used in single sectors) and are often driven by individuals or external vendors. Senior leadership rarely sets digital priorities and there is no formal body, sector or department responsible for management purposes.

##### Recommended Actions:

1. Create a short digital vision for maintenance (why digital matters, main goals).
2. Identify a senior-level sponsor and a small cross-functional team to own DT topics.
3. Map all the existing digital applications and tools to understand overlaps and gaps.
4. Communicate the initial strategy to key stakeholders (maintenance, ops, engineering, IT).

##### Dimension Score: 1.00–1.99 – Basic / Managed

There is a general sense of wanting to go digital, but this idea is broad and not turned into clear goals for maintenance. Governance is loose, with decisions made for each project separately and no overall view and central management. This often leads to conflicting priorities and repeated work.

##### Recommended Actions:

1. Make simple documented DT maintenance roadmap with 3–5 objectives according to the general digital vision.
2. Make a simple governance structure/team with specific roles and a meeting calendar.
3. Prioritize all the existing projects of DT, using some basic criteria (impact, feasibility, cost).
4. Introduce a small set of KPIs for DT (e.g. % paperless work orders, % data-driven planning decisions).

#### Dimension Score: 2.00–2.59 – Defined

The organization has a written strategy for maintenance DT and some structured governance. However, this strategy is not matching completely the wider organizational plans and the way that projects are chosen is still developing. The connection between the strategy, KPIs and daily decisions is sometimes unclear to all stakeholders.

#### Recommended Actions:

1. Align the maintenance DT roadmap with the organization's strategies.
2. Formalize DT portfolio, program or project management (regular business cases, prioritization, monitoring).
3. Strengthen the link between DT KPIs and management reviews (e.g. quarterly DT performance review).
4. Involve quality, safety and airworthiness stakeholders in strategic decisions.

#### Dimension Score: 2.60–3.19 – Integrated

DT in maintenance is managed as a single, coordinated program. Priorities are clear, projects are aligned and progress is measured with KPIs. However, the strategy may still focus more on technology than on results and maintenance alignment to this.

#### Recommended Actions:

1. Shift the focus from “deploy technology” to “deliver operational outcomes” (availability, cost, safety, readiness).
2. Use data from the maturity assessment and DT projects to update and refine the organization's strategy periodically.
3. Embed DT responsibilities in job descriptions and performance objectives of key managers.
4. Strengthen collaboration with external partners (OEMs, MROs, technology providers) under the DT governance model.

#### Dimension Score: 3.20–4.00 – Digital-Oriented

Digital strategy and governance are a core part of maintenance operations. DT is important for budgeting, operational choices and planning. The organization has the ability to update fast and at low cost its plans (the chosen projects) when there is new information or identified opportunities.

#### Recommended Actions:

1. Make a continuous strategic detection plan (by monitoring the new technologies, best practices and changes).
2. Use scenarios to check alternative digital programs.
3. Share lessons learned and governance practices with other organizations (alliances, industry partners, maintenance forums).

The qualitative description of the DT maturity, for the “Strategy & Governance of DT” dimension, along with the correlating recommended actions that need to be taken, according to the dimension -score of the DT maturity assessment tool execution, are presented in the following Table 8.

*Table 8. Qualitative Description and Recommended Actions per Maturity Level Band for Dimension 1 (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                                                          | Recommended Actions (Chapter 6.2.1)                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | No clear DT strategy exists for maintenance; initiatives are ad hoc and driven by individuals or external vendors. No formal governance body is responsible for management.                      | <ul style="list-style-type: none"> <li>• Create a short digital vision for maintenance (why digital matters, main goals) .</li> <li>• Identify a senior-level sponsor and a small cross-functional team to own DT topics .</li> <li>• Map all existing digital applications and tools to understand overlaps and gaps .</li> <li>• Communicate the initial strategy to key stakeholders (maintenance, ops, engineering, IT).</li> </ul>                                                         |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | Broad desire to go digital without clear goals for maintenance. Governance is loose, decisions are made per project without central management, leading to conflicting priorities.               | <ul style="list-style-type: none"> <li>• Make a simple documented DT maintenance roadmap with 3–5 objectives according to the general vision .</li> <li>• Establish a simple governance structure/team with specific roles and a meeting calendar .</li> <li>• Prioritize existing DT projects using basic criteria (impact, feasibility, cost) .</li> <li>• Introduce a small set of KPIs for DT (e.g., % paperless work orders, % data-driven planning).</li> </ul>                           |
| <b>2.00 – 2.59 (Defined)</b>          | Written strategy and structured governance exist, but the strategy is not fully aligned with wider organizational plans. Connections between strategy, KPIs, and daily decisions remain unclear. | <ul style="list-style-type: none"> <li>• Align the maintenance DT roadmap with the organization's strategies .</li> <li>• Formalize DT portfolio/program management (business cases, prioritization, monitoring) .</li> <li>• Strengthen the link between DT KPIs and management reviews (e.g., quarterly performance review) .</li> <li>• Involve quality, safety, and airworthiness stakeholders in strategic decisions.</li> </ul>                                                           |
| <b>2.60 – 3.19 (Integrated)</b>       | DT is managed as a coordinated program with clear priorities and measured progress. The strategy may still focus more on technology than on operational results.                                 | <ul style="list-style-type: none"> <li>• Shift focus from “deploy technology” to “deliver operational outcomes” (availability, cost, safety, readiness) .</li> <li>• Use data from maturity assessments and projects to refine the strategy periodically .</li> <li>• Embed DT responsibilities in job descriptions and performance objectives of key managers .</li> <li>• Strengthen collaboration with external partners (OEMs, MROs, tech providers) under the governance model.</li> </ul> |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | Digital strategy is a core part of maintenance operations, budgeting, and planning. The organization can quickly update plans when new opportunities are identified.                             | <ul style="list-style-type: none"> <li>• Implement a continuous strategic detection plan (monitoring new technologies and best practices) .</li> <li>• Use scenarios to check alternative digital programs .</li> <li>• Share lessons learned and governance practices with alliances, industry partners, and maintenance forums.</li> </ul>                                                                                                                                                    |

### 6.2.2. Dimension 2 - Policies, Compliance & Cybersecurity

#### Dimension Score: 0.00 - 0.99 – Initial

There are few or informal policies for digital maintenance data. Record-keeping, access control and cybersecurity are managed in an unofficial way. This puts the organization at risk for compliance issues and possible loss or misuse of sensitive information.

#### Recommended Actions:

1. Identify regulatory and organizational requirements for digital records, traceability and data protection.
2. Draft basic policies on access control, password rules, removable media and use of personal devices.
3. Start applying simple controls (role-oriented access to critical systems, backup procedures).

#### Dimension Score: 1.00–1.99 – Basic / Managed

Some policies are in place, usually taken from IT or corporate guidelines, but they are not completely fitting to the maintenance needs and sometimes are not followed. Staff has limited awareness of cybersecurity and data governance issues.

#### Recommended Actions:

1. Tailor specific corporate or IT policies for specific types of maintenance (e.g. hangar connectivity, portable devices, offline work).
2. Make standard templates for keeping digital records (e.g. defect reports, approvals etc.).
3. Include policy compliance in internal audits and safety/quality reviews.

#### Dimension Score: 2.00–2.59 – Defined

Policies and procedures for data, records and security are written down and used in most areas, but there are still some gaps, such as with old systems, portable devices, or working with outside partners. How well these rules are acknowledged and enforced can differ between units.

#### Recommended Actions:

1. Conduct a gap analysis to identify where policies are not applied or are difficult to apply.

2. Clarify responsibilities for monitoring compliance in each unit.
3. Improve technical controls (e.g. stronger authentication, logging, strengthening of maintenance systems).
4. Formalize rules for sharing data with external partners (OEMs, contractors).

Dimension Score: 2.60–3.19 – Integrated

Policies, controls and practices are reliable across all maintenance systems. Cybersecurity is included in new DT projects. Staff generally understand what is expected and what can happen if rules are not followed.

Recommended Actions:

1. Integrate policy and cybersecurity reviews into the project lifecycle of all new digital tasks.
2. Introduce regular simulated incidents or exercises to test the response (e.g., a data break training exercise).
3. Use monitoring tools to find and fix non-compliant behavior.
4. Link policy and cybersecurity metrics into the wider risk-management plan.

Dimension Score: 3.20 - 4.00 – Digital-Oriented

The organization actively and systematically manages digital maintenance data and cybersecurity. It not only meets but often predicts regulatory and security requirements.

Recommended Actions:

1. Regularly benchmark policies and controls against industry best practices and new standards.
2. Participate in collaborative cyber-defense or information-sharing initiatives relevant to aviation/defense.
3. Include cybersecurity and data-governance performance in high-level management dashboards.
4. Regularly refine policies based on lessons from incidents, audits and technology change.

The qualitative description of the DT maturity, for the “Policies, Compliance & Cybersecurity” dimension, along with the correlating recommended actions that need to

be taken, according to the dimension -score of the DT maturity assessment tool execution, are presented in the following Table 9.

*Table 9. Qualitative Description and Recommended Actions per Maturity Level Band for Dimension 2 (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                                                  | Recommended Actions (Chapter 6.2.2)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | There are no clear policies for digital maintenance records or cybersecurity. Compliance is handled manually, and there is high risk of data loss or unauthorized access.                | <ul style="list-style-type: none"> <li>• Identify regulatory (e.g., EASA/FAA) and organizational requirements for digital records and data protection.</li> <li>• Draft basic policies regarding access control, data backup, and the use of personal digital devices in maintenance areas.</li> <li>• Start applying simple technical controls (e.g., unique user IDs, role-oriented access, and basic antivirus).</li> </ul>                                                                                          |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | Basic IT policies exist but are not tailored for aircraft maintenance environments (e.g., hangar connectivity, mobile devices). Compliance monitoring is inconsistent.                   | <ul style="list-style-type: none"> <li>• Tailor corporate IT and security policies for specific maintenance needs (e.g., use of tablets on the flight line, wireless security in hangars).</li> <li>• Create standard templates and procedures for digital record-keeping to ensure compliance.</li> <li>• Include digital policy compliance in regular internal audits and management reviews.</li> </ul>                                                                                                              |
| <b>2.00 – 2.59 (Defined)</b>          | Documented policies cover most digital maintenance activities. Responsibilities for cybersecurity and compliance are defined, but enforcement varies across departments.                 | <ul style="list-style-type: none"> <li>• Conduct a gap analysis to identify areas where digital policies are not fully applied and clarify responsibilities.</li> <li>• Improve technical security controls (e.g., multi-factor authentication, automated system logging, and encryption).</li> <li>• Formalize rules for data sharing and cybersecurity with external partners (OEMs, lessors, vendors).</li> </ul>                                                                                                    |
| <b>2.60 – 3.19 (Integrated)</b>       | Policies and cybersecurity are integrated into daily maintenance workflows. Compliance is monitored through digital tools, and risks are managed proactively.                            | <ul style="list-style-type: none"> <li>• Integrate policy and cybersecurity reviews into the project lifecycle of every new digital maintenance task or tool.</li> <li>• Introduce regular simulated incidents (e.g., data breach or system outage drills) to test organizational response.</li> <li>• Use automated monitoring tools to detect and fix non-compliant behavior or security threats in real time.</li> <li>• Link cybersecurity metrics into the overall organizational risk-management plan.</li> </ul> |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | Security and compliance are "by design." Policies are dynamically updated based on threat intelligence and industry best practices. Cybersecurity is a core part of the digital culture. | <ul style="list-style-type: none"> <li>• Regularly benchmark maintenance-specific digital policies against international industry best practices and standards.</li> <li>• Participate in collaborative cyber-defense initiatives with industry alliances and aviation authorities.</li> <li>• Include cybersecurity performance and compliance trends in high-level executive dashboards.</li> <li>• Regularly refine policies based on lessons learned from simulations and technological changes.</li> </ul>         |

### 6.2.3. Dimension 3 - Information Systems & Digital Backbone

#### Dimension Score: 0.00–0.99 – Initial

Maintenance IT is scattered, with many separate systems, spreadsheets and paper records (most of the times manually produced in paper). There is no clear structure or plan for integration.

#### Recommended Actions:

1. Create an inventory of existing maintenance-related systems and tools.
2. Identify obvious overlaps and crucial gaps (e.g. double record keeping, missing CMMS or planning tools).

3. Stabilize and standardize at least one core system for recording tasks, projects, human resources, stakeholders, risks etc.

Dimension Score: 1.00–1.99 – Basic / Managed

Core systems like CMMS and ERP are in place, but they are not well integrated. Users often have to enter the same data more than once, which causes unreliable information and confusion among the users.

Recommended Actions:

1. Prioritize a small number of key integrations (e.g. CMMS - ERP, CMMS - planning).
2. Clean up master data (aircraft IDs, part numbers, locations) and define data ownership.
3. Set minimum technical and data standards for new systems (Application Programming Interfaces - APIs, export formats).
4. Provide basic support and training to improve system usage.

Dimension Score: 2.00–2.59 – Defined

A fairly stable digital backbone exists with some integration, but there are still separate systems and manual workarounds.

Recommended Actions:

1. Develop a more detailed integration roadmap with clear priorities and timelines.
2. Expand interfaces to reduce, or even better to stop, double-entry and manual file uploads.
3. Introduce monitoring of interface health and data quality.
4. Engage IT and maintenance jointly in architecture decisions.

Dimension Score: 2.60–3.19 – Integrated

Key systems are well connected, providing an almost real-time view of maintenance status, inventory and planning. Data flows are reliable and clearly documented.

Recommended Actions:

1. Optimize performance and resilience of the digital backbone (redundancy, failover, response times).
2. Start exposing selected data via dashboards and APIs to other functions.
3. Prepare the digital backbone to support more advanced tools (PHM, digital twins).
4. Frequently review architecture compared to evolving operational and DT needs.

Dimension Score: 3.20–4.00 – Digital-Oriented

The digital backbone is strong, flexible and ready for future needs. It supports advanced analytics, simulation and working with external partners.

Recommended Actions:

1. Adopt architectural guidelines to support future evolution.
2. Integrate with external ecosystems (OEM platforms, alliance data spaces) where appropriate.
3. Experiment with new technologies (edge computing, 5G) where they bring value.
4. Use architecture reviews and technology scouting as ongoing practices.

The qualitative description of the DT maturity, for the “Information Systems & Digital Backbone” dimension, along with the correlating recommended actions that need to be taken, according to the dimension -score of the DT maturity assessment tool execution, are presented in the following Table 10.



Table 10. *Qualitative Description and Recommended Actions per Maturity Level Band for Dimension 3 (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                           | Recommended Actions (Chapter 6.2.3)                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | Maintenance IT is scattered, with many separate systems, spreadsheets, and paper records. There is no clear structure or plan for integration.                    | <ul style="list-style-type: none"> <li>• Create an inventory of existing maintenance-related systems and tools .</li> <li>• Identify obvious overlaps and crucial gaps, such as double record keeping or missing planning tools .</li> <li>• Stabilize and standardize at least one core system for recording tasks, projects, and resources.</li> </ul>                                                                                                                 |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | Core systems like CMMS and ERP are in place, but they are not well integrated. Users often enter the same data more than once, leading to unreliable information. | <ul style="list-style-type: none"> <li>• Prioritize a small number of key integrations, such as CMMS to ERP or CMMS to planning tools .</li> <li>• Clean up master data (aircraft IDs, part numbers) and define clear data ownership .</li> <li>• Set minimum technical and data standards, like APIs or export formats, for new systems .</li> <li>• Provide basic support and training to improve the way systems are used.</li> </ul>                                 |
| <b>2.00 – 2.59 (Defined)</b>          | A fairly stable digital backbone exists with some integration, but there are still separate systems and manual workarounds.                                       | <ul style="list-style-type: none"> <li>• Develop a more detailed integration roadmap with clear priorities and timelines .</li> <li>• Expand interfaces to reduce or stop double-entry and manual file uploads .</li> <li>• Introduce monitoring for interface health and data quality .</li> <li>• Engage IT and maintenance teams jointly in making architecture decisions.</li> </ul>                                                                                 |
| <b>2.60 – 3.19 (Integrated)</b>       | Key systems are well connected, providing an almost real-time view of maintenance status, inventory, and planning. Data flows are reliable and documented.        | <ul style="list-style-type: none"> <li>• Optimize the performance and resilience of the digital backbone, focusing on redundancy and response times .</li> <li>• Start exposing selected data via dashboards and APIs to other organizational functions .</li> <li>• Prepare the digital backbone to support advanced tools like PHM and digital twins .</li> <li>• Frequently review the architecture against evolving operational and transformation needs.</li> </ul> |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | The digital backbone is strong, flexible, and ready for future needs. It supports advanced analytics, simulation, and collaboration with partners.                | <ul style="list-style-type: none"> <li>• Adopt architectural guidelines that support future technological evolution .</li> <li>• Integrate with external ecosystems, such as OEM platforms or alliance data spaces .</li> <li>• Experiment with new technologies like edge computing or 5G where they add value .</li> <li>• Use architecture reviews and technology scouting as ongoing organizational practices.</li> </ul>                                            |

#### 6.2.4. Dimension 4 - Progress Digitalization & Workflow Automation

##### Dimension Score: 0.00–0.99 – Initial

Most processes are still manual and use paper. Digitalization only goes as far as saving documents as PDFs, without changing how the work is done.

##### Recommended Actions:

1. Map key maintenance processes (planning, execution, QA, ILS).
2. Identify “quick wins” for basic digitalization (e.g. replacing fax/email with simple forms).
3. Standardize basic templates and document flows.

4. Ensure that digitalization efforts target high-volume or high-risk processes first.

Dimension Score: 1.00–1.99 – Basic / Managed

Some processes have been digitalized, but they are often just direct copies of the old paper processes, without making them simpler or automated.

Recommended Actions:

1. Review digitalized processes to reject unnecessary steps and approvals.
2. Introduce simple workflow tools for approvals and notifications.
3. Specify clear ownership for each process and its digital representation.
4. Collect user feedback on gaps in current digital workflows.

Dimension Score: 2.00–2.59 – Defined

Digital workflows exist for most important processes and staff know how to use them. However, many workflows still need manual steps.

Recommended Actions:

1. Optimize workflows by applying metrics such as processing time and failure rates.
2. Introduce conditional paths and rules (e.g. risk-based approvals).
3. Integrate workflows with main data sources (so forms are pre-populated where possible).
4. Train process owners in basic process-improvement techniques.

Dimension Score: 2.60–3.19 – Integrated

Digital processes are well designed and part of daily work. Automation is common and allows staff to focus on more valuable tasks.

Recommended Actions:

1. Extend automation to more complex processes (e.g. automated task creation based on triggers).
2. Ensure workflows are fully integrated with other systems (no manual data transfer).
3. Periodically review processes with multifunctional teams to align them with changing needs.
4. Use workflow data to detect bottlenecks and continuously improve.

### Dimension Score: 3.20–4.00 – Digital-Oriented

Processes are digital, flexible and always being improved. The organization can quickly change and roll out new workflows as needs change.

#### Recommended Actions:

1. Implement proper platforms for rapid workflow changes.
2. Embed process experimentation into the culture (A/B testing of process variants).
3. Use advanced analytics to identify new automation opportunities.
4. Share successful digital processes with other units or organizations.

The qualitative description of the DT maturity, for the “Progress Digitalization & Workflow Automation” dimension, along with the correlating recommended actions that need to be taken, according to the dimension -score of the DT maturity assessment tool execution, are presented in the following Table 11.

*Table 11. Qualitative Description and Recommended Actions per Maturity Level Band for Dimension 4 (Credit: Own Elaboration)*

| <b>Maturity Level<br/>(Score Band)</b>    | <b>Qualitative Description</b>                                                                                                      | <b>Recommended Actions (Chapter 6.2.4)</b>                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99<br/>(Initial)</b>          | Most processes are still manual and use paper. Digitalization is limited to saving documents as PDFs without changing the workflow. | <ul style="list-style-type: none"> <li>• Map key maintenance processes including planning, execution, QA, and ILS.</li> <li>• Identify “quick wins” for basic digitalization, such as replacing fax/email with simple digital forms .</li> <li>• Standardize basic templates and document flows .</li> <li>• Ensure digitalization efforts target high-volume or high-risk processes first.</li> </ul>                                              |
| <b>1.00 – 1.99<br/>(Basic/Managed)</b>    | Some processes are digitalized but remain direct copies of old paper-based methods without simplification or automation.            | <ul style="list-style-type: none"> <li>• Review digitalized processes to reject unnecessary steps and approvals .</li> <li>• Introduce simple workflow tools for approvals and notifications .</li> <li>• Specify clear ownership for each process and its digital representation.</li> <li>• Collect user feedback on gaps in current digital workflows.</li> </ul>                                                                                |
| <b>2.00 – 2.59<br/>(Defined)</b>          | Digital workflows exist for most important processes and staff are familiar with them, but many manual steps remain.                | <ul style="list-style-type: none"> <li>• Optimize workflows by applying metrics such as processing time and failure rates .</li> <li>• Introduce conditional paths and rules, such as risk-based approvals .</li> <li>• Integrate workflows with main data sources to enable pre-population of forms .</li> <li>• Train process owners in basic process-improvement techniques.</li> </ul>                                                          |
| <b>2.60 – 3.19<br/>(Integrated)</b>       | Digital processes are well-designed and integrated into daily work. Automation allows staff to focus on higher-value tasks.         | <ul style="list-style-type: none"> <li>• Extend automation to complex processes, such as automated task creation based on specific triggers .</li> <li>• Ensure workflows are fully integrated with other systems without manual data transfer .</li> <li>• Periodically review processes with multifunctional teams to align with changing needs .</li> <li>• Use workflow data to detect bottlenecks and drive continuous improvement.</li> </ul> |
| <b>3.20 – 4.00<br/>(Digital-Oriented)</b> | Processes are digital, flexible, and continuously improved. The organization can rapidly roll out new workflows as needs evolve.    | <ul style="list-style-type: none"> <li>• Implement proper platforms that allow for rapid workflow changes .</li> <li>• Embed process experimentation into the culture, such as through A/B testing of process variants .</li> <li>• Use advanced analytics to identify new automation opportunities .</li> <li>• Share successful digital processes with other units or organizations.</li> </ul>                                                   |

### 6.2.5. Dimension 5 - Data & Analytics

#### Dimension Score: 0.00–0.99 – Initial

Data is not gathered properly in one database or application. It is incomplete and most of the times it is used only for basic reports. Many decisions are still made based only on experience of individuals or leadership.

#### Recommended Actions:

1. Identify all the key data sources and define a minimum set of mandatory fields, that need to be completed.
2. Introduce basic a data-quality check list
3. Introduce a data-ownership list.
4. Start making simple descriptive reports, based on a few critical KPIs.

#### Dimension Score: 1.00–1.99 – Basic / Managed

The organization creates some reports, but they mostly just describe what happened and are often put together by hand. Analytics skills are limited.

#### Recommended Actions:

1. Automate key reports using AI tools where possible.
2. Standardize definitions of core metrics (e.g. TAT, MTBUR, AOG rate).
3. Train a small group of staff in basic data analysis and visualization.
4. Start using data in regular review meetings.

#### Dimension Score: 2.00–2.59 – Defined

A business intelligence system is in place and used for monitoring. Some analysis is done to find causes of problems, but using data to predict or recommend actions is rare.

#### Recommended Actions:

1. Extend diagnostic analytics (root-cause analysis of delays, failures).
2. Integrate data from several systems (MRO, PHM, logistics) into a common model.
3. Develop a roadmap for advanced analytics (predictive models and simulation).
4. Establish a small analytics community (maintenance, engineering, IT).

#### Dimension Score: 2.60–3.19 – Integrated

Data and analytics are most of the times used to make decisions in different areas. Some areas use predictive models and a lot of dashboards are common.

#### Recommended Actions:

1. Develop use cases with analytics and collected data (e.g. predictive TAT, spares forecasting).
2. Make sure that a specific model governance is used (validation, monitoring, retraining/personnel evaluation).
3. Train the managers to interpret accordingly the analytical outputs.
4. Apply prescriptive analytics for the high-impact problems.

#### Dimension Score: 3.20–4.00 – Digital-Oriented

The organization performs all the maintenance tasks as a data-driven procedure. Analytics is used as a key skill, not just an extra capability.

#### Recommended Actions:

1. Integrate analytics into strategic planning and decisions for innovation projects.
2. Invest in data engineers and data scientists for future digital development.
3. Participate in data-sharing and benchmarking initiatives with other organizations.
4. Continuously explore new tactics and analytical methods (e.g. reinforcement learning).

The qualitative description of the DT maturity, for the “Data & Analytics” dimension, along with the correlating recommended actions that need to be taken, according to the dimension -score of the DT maturity assessment tool execution, are presented in the following Table 12.

Table 12. *Qualitative Description and Recommended Actions per Maturity Level Band for Dimension 5 (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                  | Recommended Actions (Chapter 6.2.5)                                                                                                                                                                                                                                                                                                                                                                                                |
|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | Data is not gathered properly in one database; it is incomplete and used only for basic reports. Decisions are primarily based on individual experience. | <ul style="list-style-type: none"> <li>• Identify all key data sources and define a minimum set of mandatory fields .</li> <li>• Introduce a basic data-quality check list and a data-ownership list .</li> <li>• Start making simple descriptive reports based on a few critical KPIs.</li> </ul>                                                                                                                                 |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | The organization creates some reports, but they are mostly descriptive and often compiled manually. Analytics skills are limited.                        | <ul style="list-style-type: none"> <li>• Automate key reports using AI tools where possible .</li> <li>• Standardize definitions of core metrics (e.g., TAT, MTBUR, AOG rate) .</li> <li>• Train a small group of staff in basic data analysis and visualization .</li> <li>• Start using data in regular review meetings.</li> </ul>                                                                                              |
| <b>2.00 – 2.59 (Defined)</b>          | A business intelligence (BI) system is in place for monitoring. Some root-cause analysis is performed, but predictive use of data is rare.               | <ul style="list-style-type: none"> <li>• Extend diagnostic analytics (root-cause analysis of delays and failures) .</li> <li>• Integrate data from several systems (MRO, PHM, logistics) into a common model .</li> <li>• Develop a roadmap for advanced analytics including predictive models and simulation .</li> <li>• Establish a small analytics community (maintenance, engineering, IT).</li> </ul>                        |
| <b>2.60 – 3.19 (Integrated)</b>       | Data and analytics are frequently used for decision-making across different areas. Predictive models are used in some sectors.                           | <ul style="list-style-type: none"> <li>• Develop use cases with analytics and collected data (e.g., predictive TAT, spares forecasting) .</li> <li>• Implement rigorous model governance (validation, monitoring, retraining) .</li> <li>• Train managers to correctly interpret analytical outputs .</li> <li>• Apply prescriptive analytics for high-impact problems.</li> </ul>                                                 |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | Maintenance is a fully data-driven procedure. Analytics is treated as a key core skill rather than an extra capability.                                  | <ul style="list-style-type: none"> <li>• Integrate analytics into strategic planning and decisions for innovation projects .</li> <li>• Invest in data engineers and data scientists for future digital development .</li> <li>• Participate in data-sharing and benchmarking initiatives with other organizations .</li> <li>• Continuously explore new tactics and analytical methods (e.g., reinforcement learning).</li> </ul> |

#### 6.2.6. Dimension 6 - Organization, Roles & Cross-Functional Collaboration

##### Dimension Score: 0.00–0.99 – Initial

At this stage, maintenance work is accomplished in separate groups. Each department—maintenance, operations, logistics, engineering and IT—works mostly on its own, with little coordination. Roles for digital transformation are unclear or missing and many issues are ignored.

##### Recommended Actions:

1. Map the key stakeholders involved in aircraft maintenance and digital initiatives (who does what today).
2. Clarify basic roles and responsibilities, at least at a high level (RACI for core processes).

3. Establish a simple cross-functional forum (e.g. monthly meeting) to discuss maintenance and DT topics.
4. Identify obvious overlaps and gaps within responsibilities and address the most critical ones.

Dimension Score: 1.00–1.99 – Basic / Managed

There is a premature collaboration, most of the times because of certain people or projects, but it is not still organized. The departments have conflicts (e.g. between maintenance and operations) and there is no shared view of the main goal and the important tasks.

Recommended Actions:

1. Define formal working groups for key areas (e.g. planning, PHM, quality).
2. Use KPIs that demand collaboration between departments (e.g. fleet availability, AOG minutes, TAT).
3. Introduce joint decision-making procedures (e.g. change boards with multi-department participation).
4. Establish basic training courses for managers on leadership, collaboration and conflict resolution.

Dimension Score: 2.00–2.59 – Defined

Committees and working groups are in place and roles are clear. However, many times collaboration still depends on individuals and initiatives. Working groups are managing digital projects, but daily work sometimes goes back to working individually.

Recommended Actions:

1. Formalize governance and communication charters for cross-functional teams (scope, authority, decision rules).
2. Make sure that critical digital projects always have collaborative and cross-functional teams and are not owned by a single department.
3. Align performance objectives to support shared KPIs.
4. Capture and share positive examples of effective multifunctional collaboration.

Dimension Score: 2.60–3.19 – Integrated

Collaboration is now a normal part of work. Teams from different departments solve problems from start to finish and digital tools like shared dashboards and task boards help keep things clear. There is still room to improve how the organization works with outside partners.

Recommended Actions:

1. Embed cross-departmental teams not only in projects but also in ongoing operations (e.g. permanent maintenance–ops–ILS cells).
2. Use shared online workspaces and dashboards to make information visible to all stakeholders in real time.
3. Involve external partners (OEMs, MRO providers) in relevant collaborative structures when appropriate.
4. Periodically review organizational structures to ensure they still support the DT roadmap.

Dimension Score: 3.20–4.00 – Digital-Oriented

The organization works as a fully integrated system. There are few barriers between departments, teams are made up of people from different areas and joint efforts include partners and, when needed, alliances.

Recommended Actions:

1. Use lessons learned from DT projects to vanish any organizational barriers where justified.
2. Experiment with new organizational forms (e.g. product/asset-centric squads, digital mission teams).
3. Develop leadership programs focused on leading in a digital, cross-functional environment.
4. Share practices with other organizations and regularly refine them.

The qualitative description of the DT maturity, for the “Organization, Roles & Cross-Functional Collaboration” dimension, along with the correlating recommended actions that need to be taken, according to the dimension -score of the DT maturity assessment tool execution, are presented in the following Table 13.



Table 13. *Qualitative Description and Recommended Actions per Maturity Level Band for Dimension 6 (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                                                        | Recommended Actions (Chapter 6.2.6)                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | Maintenance work is performed in isolated groups. Departments like maintenance, operations, and IT work with little coordination. Roles for digital transformation are unclear or missing.     | <ul style="list-style-type: none"> <li>• Map the key stakeholders involved in aircraft maintenance and digital initiatives .</li> <li>• Clarify basic roles and responsibilities, establishing a RACI for core processes .</li> <li>• Establish a simple cross-functional forum, such as a monthly meeting, to discuss digital topics .</li> <li>• Identify and address the most critical responsibility overlaps and gaps.</li> </ul>                                                  |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | Preliminary collaboration exists due to specific people or projects but remains unorganized. Functional conflicts persist, and there is no shared view of main goals.                          | <ul style="list-style-type: none"> <li>• Define formal working groups for key areas such as planning, PHM, and quality .</li> <li>• Implement KPIs that necessitate cross-departmental collaboration, such as fleet availability or TAT .</li> <li>• Introduce joint decision-making procedures, including multi-department change boards .</li> <li>• Establish leadership training focused on collaboration and conflict resolution.</li> </ul>                                       |
| <b>2.00 – 2.59 (Defined)</b>          | Committees and working groups are established and roles are clear. However, collaboration often still depends on individual initiatives. Daily work may still revert to siloed behavior.       | <ul style="list-style-type: none"> <li>• Formalize governance and communication charters for cross-functional teams, defining authority and rules .</li> <li>• Ensure critical digital projects are always managed by collaborative, cross-functional teams .</li> <li>• Align individual performance objectives to support shared KPIs .</li> <li>• Document and share successful examples of multifunctional collaboration.</li> </ul>                                                |
| <b>2.60 – 3.19 (Integrated)</b>       | Collaboration is a standard part of the workflow. Teams solve problems from start to finish using shared digital tools like dashboards. There is room to improve external partner integration. | <ul style="list-style-type: none"> <li>• Embed cross-departmental teams into ongoing operations, such as permanent maintenance–ops–ILS cells .</li> <li>• Utilize shared online workspaces and dashboards to provide real-time visibility to all stakeholders .</li> <li>• Involve external partners like OEMs and MRO providers in relevant collaborative structures .</li> <li>• Periodically review organizational structures to ensure they support the digital roadmap.</li> </ul> |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | The organization operates as a fully integrated system. Barriers between departments are minimized, and joint efforts routinely include partners and alliances.                                | <ul style="list-style-type: none"> <li>• Use lessons learned from digital projects to remove remaining organizational barriers .</li> <li>• Experiment with agile organizational forms, such as asset-centric squads or digital mission teams .</li> <li>• Develop leadership programs specifically for leading in digital, cross-functional environments .</li> <li>• Share collaboration best practices with other organizations and refine them regularly.</li> </ul>                |

### 6.2.7. Dimension 7 - People & Digital Skills

#### Dimension Score: 0.00–0.99 – Initial

Most staff have little experience with digital tools beyond basic office software. Training covers mainly technical and regulatory topics, with almost no focus on digital skills. New tools are often experienced or treated as a burden or even a threat.

#### Recommended Actions:

1. Assess the existing digital skills for all the key role personnel (technicians, planners, engineers, managers).

2. Introduce a basic course for digital skill training (maintenance systems, data entry, cyber hygiene).
3. Involve well trained and experienced staff in demonstrations of new digital tools to reduce fear and resistance to others.
4. Communicate clearly that the digital skills are the future of maintenance practices.

Dimension Score: 1.00–1.99 – Basic / Managed

Some training is given on specific systems like CMMS or ERP, usually only when they are first introduced. There is no organized plan for digital skills. Many users don't know how use the tools effectively.

Recommended Actions:

1. Develop a simple digital skills framework per role (what each role should be able to do).
2. Offer refresher courses and short “how-to” sessions on existing systems.
3. Create quick reference guides and short videos for everyday digital tasks.
4. Encourage advanced users in each section to help colleagues.

Dimension Score: 2.00–2.59 – Defined

Digital skills are considered important and some training courses are available, but not everyone sees the benefits. Skills like data literacy, PHM knowledge, or usage of advanced tools are still limited only to a few experts.

Recommended Actions:

1. Expand the framework of digital skills to include data literacy, PHM knowledge and usage of AI tools.
2. Introduce combined learning methods (classroom, e-learning, on-the-job coaching).
3. Identify and formally recognize “digital champions” in each area to support adoption.
4. Link completion of digital-skills to competency assessments and career development.

Dimension Score: 2.60–3.19 – Integrated

Digital skills are part of how the organization manages personnel abilities. Most people in key roles have the skills they need to use digital tools and there is continuous effort to keep these skills up to date.

Recommended Actions:

1. Align digital-skills development with the DT roadmap (e.g. PHM training before PHM roll-out).
2. Use performance and error data to identify where additional skills are needed.
3. Offer role-specific advanced training (e.g. analytics for planners, model understanding for engineers).
4. Collaborate with training organizations, OEMs and academic institutions in order to keep content updated.

Dimension Score: 3.20–4.00 – Digital-Oriented

The maintenance teams are working efficiently using the digital tools and are able to adapt new methods. Many relevant learning courses are scheduled tactically and personnel are open for new tools and procedures.

Recommended Actions:

1. Provide digital training platforms and learning content on the job.
2. Support self-learning.
3. Incorporate digital innovation and learning behaviors into promotion and reward criteria.
4. Engage personnel in the design procedure of new digital tools (for both maintenance and academics – learning courses).

The qualitative description of the DT maturity, for the “People & Digital Skills” dimension, along with the correlating recommended actions that need to be taken, according to the dimension -score of the DT maturity assessment tool execution, are presented in the following Table 14.

Table 14. *Qualitative Description and Recommended Actions per Maturity Level Band for Dimension 7 (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                                          | Recommended Actions (Chapter 6.2.7)                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | Digital skills are very basic and limited to office tools. There is no plan for digital training, and personnel often feel resistant or fearful toward new technology.           | <ul style="list-style-type: none"> <li>• Assess existing digital skills for all key roles in maintenance .</li> <li>• Introduce a basic digital skill training course including "cyber hygiene" .</li> <li>• Involve experienced staff in tool demonstrations to reduce resistance .</li> <li>• Communicate that digital skills are the future of maintenance.</li> </ul>                                                      |
| <b>1.00 – 1.99 (Basic / Managed)</b>  | The organization offers some training on specific systems, but it is not coordinated. Digital skills are not yet part of the formal job requirements or career paths.            | <ul style="list-style-type: none"> <li>• Develop a digital skills framework per role (planners, technicians, managers) .</li> <li>• Offer refresher courses and "how-to" sessions on existing digital systems .</li> <li>• Create quick reference guides and short videos for digital tasks .</li> <li>• Encourage advanced users to informally help their colleagues.</li> </ul>                                              |
| <b>2.00 – 2.59 (Defined)</b>          | A structured training plan for digital skills exists. Competency levels are defined for each role, and staff are starting to see the value of digital tools in their daily work. | <ul style="list-style-type: none"> <li>• Expand the skills framework to include data literacy and basic use of AI tools .</li> <li>• Introduce combined learning methods (classroom, e-learning, and hands-on coaching) .</li> <li>• Formally recognize "digital champions" who can support and promote tool adoption .</li> <li>• Link digital skill achievement to competency assessments and career development.</li> </ul> |
| <b>2.60 – 3.19 (Integrated)</b>       | Digital skills are well-integrated into the organization. Training is data-driven, and staff are comfortable using advanced tools for troubleshooting and planning.              | <ul style="list-style-type: none"> <li>• Align digital skill development directly with the goals of the DT roadmap .</li> <li>• Use maintenance performance or error data to identify specific training needs .</li> <li>• Offer role-specific advanced training, such as data analytics for planners or AR for technicians .</li> <li>• Collaborate with OEMs to ensure training content is always updated.</li> </ul>        |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | Personnel are highly skilled and proactive in using digital technology. Learning is continuous and self-driven, and the organization is seen as a leader in digital maintenance. | <ul style="list-style-type: none"> <li>• Provide on-demand digital education platforms accessible from the workplace .</li> <li>• Support self-learning and personal projects related to digital maintenance .</li> <li>• Incorporate digital innovation behaviors into rewards and recognition .</li> <li>• Engage personnel directly in the design and testing of new digital tools.</li> </ul>                              |

### 6.2.8. Dimension 8 - Culture of Continuous Improvement

#### Dimension Score: 0.00–0.99 – Initial

The main attitude is to follow with what has always been done and the main quote is “don’t change what is already working”, even if this is manual and old fashioned. Feedback is rarely been taken into account and when problems come up, people fix the symptoms instead of the root causes. New ideas are faced as risky and are not preferable.

#### Recommended Actions:

1. Start with simple, basic improvement practices (e.g. debriefs after major events).
2. Promote open discussion of problems without blame.

3. Document and share a few success stories where a small change had a significant impact.
4. Ensure leadership wants and values the improvement and the learning.

Dimension Score: 1.00–1.99 – Basic / Managed

Some improvement activities, like quality audits or lean workshops, take place, but they happen sporadically and are usually started by management. Digital tools are brought in as separate projects, not as part of ongoing improvement.

Recommended Actions:

1. Introduce regular Continuous Improvement (CI) meetings at the team level, with simple action logs.
2. Use data from the existing systems to support discussions (not only opinions).
3. Create a small process for proposing and testing minor digital improvements.
4. Recognize teams that implement and sustain improvements.

Dimension Score: 2.00–2.59 – Defined

CI is included in the formal management system, but it can still be characterized as bureaucratic. Some pilot and innovation projects are in progress, but it is still hard to expand successful ideas.

Recommended Actions:

1. Simplify CI processes where they are complex and slow on learning.
2. Establish a structured pilot framework for digital initiatives (success criteria, limited scope).
3. Ensure that there is a clear path for scaling up successful test and innovative projects, including funding and ownership.
4. Link CI and innovation activities clearly to the DT roadmap and maturity results.

Dimension Score: 2.60–3.19 – Integrated

CI and innovation are part of everyday work. All the maintenance teams are using data and feedback to make processes better. Fails are considered as part of the learning procedure, as long as they are safe and controlled.

Recommended Actions:

1. Use dynamic dashboards and maturity-assessment results to identify improvement opportunities.
2. Establish some dedicated days and resources for improvement and innovation (e.g. CI sprints, innovation days).
3. Share best practices and lessons learned among the departments.
4. Involve experienced and well-trained personnel in the design procedure of process changes.

Dimension Score: 3.20–4.00 – Digital-Oriented

The organization has a strong culture of learning and innovation. It is always experimenting, learning and adapting, using digital tools both to help and to improve.

Recommended Actions:

1. Establish formal mechanisms to use and prioritize ideas from across the organization (innovation buses).
2. Participate in wider ecosystems (alliances, industry labs) to co-develop and test new concepts.
3. Use advanced analytics to spot developing opportunities or weak procedures for change.
4. Continuously reflect on and refine the improvement system itself, making sure it is agile and effective.

The qualitative description of the DT maturity, for the “Culture of Continuous Improvement” dimension, along with the correlating recommended actions that need to be taken, according to the dimension -score of the DT maturity assessment tool execution, are presented in the following Table 15.

Table 15. *Qualitative Description and Recommended Actions per Maturity Level Band for Dimension 8 (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                                                   | Recommended Actions (Chapter 6.2.8)                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | The main attitude is to follow what has always been done. Feedback is rarely taken into account, and problems are fixed as symptoms instead of root causes. New ideas are faced as risky. | <ul style="list-style-type: none"> <li>• Start with simple, basic improvement practices, such as debriefs after major events .</li> <li>• Promote open discussion of problems without blame .</li> <li>• Document and share success stories where small changes had a significant impact .</li> <li>• Ensure leadership explicitly wants and values improvement and learning.</li> </ul>                                                                                 |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | Some improvement activities take place sporadically and are usually started by management. Digital tools are introduced as separate projects, not as part of ongoing improvement.         | <ul style="list-style-type: none"> <li>• Introduce regular Continuous Improvement (CI) meetings at the team level with simple action logs .</li> <li>• Use data from existing systems to support discussions instead of relying only on opinions .</li> <li>• Create a small process for proposing and testing minor digital improvements .</li> <li>• Recognize teams that implement and sustain improvements.</li> </ul>                                               |
| <b>2.00 – 2.59 (Defined)</b>          | CI is part of the formal management system but may be perceived as bureaucratic. Some pilot projects are in progress, but scaling successful ideas remains difficult.                     | <ul style="list-style-type: none"> <li>• Simplify CI processes where they are complex and slow on learning .</li> <li>• Establish a structured pilot framework for digital initiatives with success criteria and limited scope .</li> <li>• Ensure a clear path for scaling up successful test projects, including funding and ownership .</li> <li>• Link CI and innovation activities clearly to the DT roadmap and maturity results.</li> </ul>                       |
| <b>2.60 – 3.19 (Integrated)</b>       | CI and innovation are part of everyday work. Teams use data and feedback for process optimization. Failures are considered part of the learning procedure if safe and controlled.         | <ul style="list-style-type: none"> <li>• Use dynamic dashboards and maturity assessment results to identify improvement opportunities .</li> <li>• Establish dedicated days and resources for innovation (e.g., CI sprints or innovation days) .</li> <li>• Share best practices and lessons learned across departments .</li> <li>• Involve experienced and well-trained personnel in the design of process changes.</li> </ul>                                         |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | The organization has a strong culture of learning and innovation, always experimenting and adapting using digital tools to help and improve.                                              | <ul style="list-style-type: none"> <li>• Establish formal mechanisms to prioritize ideas from across the organization (innovation buses) .</li> <li>• Participate in wider ecosystems and alliances to co-develop and test new concepts .</li> <li>• Use advanced analytics to spot developing opportunities or weak procedures for change .</li> <li>• Continuously reflect on and refine the improvement system itself to ensure it is agile and effective.</li> </ul> |

All the above - mentioned recommended actions, driven by the calculated scores of the maturity assessment tool, for every dimension of the model, are collectively presented in the following Table 16.

Table 16. Recommended Actions per Dimension Score Band (Credit: Own Elaboration)

| Score Band                        | 1. Strategy & Governance                                              | 2. Policies, Compliance & Cybersecurity                                                        | 3. Information Systems & Digital Backbone                                 | 4. Process Digitalization & Automation                                     | 5. Data & Analytics                                                       | 6. Organization & Collaboration                                           | 7. People & Digital Skills                                               | 8. Culture of Continuous Improvement                                        |
|-----------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| 0.00 – 0.99<br>(Initial)          | • Create a short digital vision for maintenance.                      | • Identify regulatory and organizational requirements for digital records.                     | • Create an inventory of existing maintenance-related systems.            | • Map key maintenance processes (planning, execution, QA, ILS).            | • Identify key data sources and define a minimum set of mandatory fields. | • Map key stakeholders and current responsibilities.                      | • Assess existing digital skills for all key roles.                      | • Start with simple improvement practices like debriefs.                    |
|                                   | • Identify a senior-level sponsor and a small cross-functional team.  | • Draft basic policies on access control and use of personal devices.                          | • Identify obvious overlaps and crucial gaps.                             | • Identify “quick wins” for basic digitalization.                          | • Introduce a basic data-quality check list.                              | • Clarify basic roles and responsibilities (RACI for core processes).     | • Introduce a basic course for digital skill training and cyber hygiene. | • Promote open discussion of problems without blame.                        |
|                                   | • Map all existing digital applications and tools.                    | • Start applying simple controls like role-oriented access and backups.                        | • Stabilize and standardize at least one core system for recording tasks. | • Standardize basic templates and document flows.                          | • Introduce a data-ownership list.                                        | • Establish a simple cross-functional forum (e.g., monthly meeting).      | • Involve experienced staff in tool demonstrations to reduce resistance. | • Document and share success stories of small changes.                      |
|                                   | • Communicate the initial strategy to key stakeholders.               |                                                                                                |                                                                           | • Target high-volume or high-risk processes first.                         | • Start making simple descriptive reports based on critical KPIs.         | • Identify and address obvious responsibility overlaps.                   | • Communicate that digital skills are the future of maintenance.         | • Ensure leadership explicitly values improvement and learning.             |
| 1.00 – 1.99<br>(Basic / Managed)  | • Create a documented DT roadmap with 3–5 objectives.                 | • Tailor corporate IT policies specifically for maintenance needs (e.g., hangar connectivity). | • Prioritize key integrations (e.g., CMMS-ERP, CMMS-planning).            | • Review digitalized processes to reject unnecessary steps.                | • Automate key reports using AI tools.                                    | • Define formal working groups for key areas (planning, PHM).             | • Develop a digital skills framework per role.                           | • Introduce regular CI meetings at the team level with action logs.         |
|                                   | • Establish a governance team with a meeting calendar.                | • Make standard templates for digital record-keeping.                                          | • Clean up master data and define data ownership.                         | • Introduce simple workflow tools for approvals and notifications.         | • Standardize definitions of core metrics (TAT, MTBUR, AOG).              | • Use KPIs that demand collaboration (fleet availability, TAT).           | • Offer refresher courses and “how-to” sessions on systems.              | • Use data from existing systems to support discussions.                    |
|                                   | • Prioritize projects using basic criteria (impact, feasibility).     | • Include policy compliance in internal audits and reviews.                                    | • Set minimum technical standards (APIs, formats) for new systems.        | • Specify clear ownership for each process and its digital representation. | • Train a small group in basic data analysis and visualization.           | • Introduce joint decision-making procedures (e.g., change boards).       | • Create quick reference guides and short videos for digital tasks.      | • Create a process for proposing/testing minor digital improvements.        |
|                                   | • Introduce a small set of DT KPIs.                                   |                                                                                                | • Provide basic support and training to improve system usage.             | • Collect user feedback on gaps in digital workflows.                      | • Start using data in regular review meetings.                            | • Establish leadership training on collaboration and conflict resolution. | • Encourage advanced users to help colleagues.                           | • Recognize teams that implement and sustain improvements.                  |
| 2.00 – 2.59<br>(Defined)          | • Align the maintenance DT roadmap with organizational strategies.    | • Conduct a gap analysis to identify policy application issues.                                | • Develop a detailed integration roadmap with timelines.                  | • Optimize workflows by applying metrics like processing time.             | • Extend diagnostic analytics (root-cause analysis).                      | • Formalize governance and communication charters for teams.              | • Expand the skills framework to include data literacy and AI tools.     | • Simplify CI processes where they are complex or slow.                     |
|                                   | • Formalize DT portfolio and program management.                      | • Clarify responsibilities for monitoring compliance in each unit.                             | • Expand interfaces to stop double-entry and manual uploads.              | • Introduce conditional paths and risk-based approvals.                    | • Integrate data from several systems (MRO, PHM, ILS).                    | • Ensure critical digital projects have multi-department teams.           | • Introduce combined learning methods (classroom, e-learning, coaching). | • Establish a structured pilot framework (success criteria, limited scope). |
|                                   | • Link DT KPIs to management reviews.                                 | • Improve technical controls (authentication, system logging).                                 | • Introduce monitoring of interface health and data quality.              | • Integrate workflows with main data sources for pre-population.           | • Develop a roadmap for predictive models and simulation.                 | • Align performance objectives to support shared KPIs.                    | • Formally recognize “digital champions” to support adoption.            | • Ensure clear paths for scaling successful test projects.                  |
|                                   | • Involve quality and airworthiness stakeholders in decisions.        | • Formalize data-sharing rules with external partners.                                         | • Engage IT and maintenance jointly in architecture decisions.            | • Train process owners in improvement techniques.                          | • Establish a small analytics community.                                  | • Capture and share positive examples of collaboration.                   | • Link digital skills to competency assessments and careers.             | • Link CI and innovation activities to the DT roadmap.                      |
| 2.60 – 3.19<br>(Integrated)       | • Shift focus from “deploy technology” to “operational outcomes.”     | • Integrate policy reviews into the project lifecycle of new digital tasks.                    | • Optimize performance and resilience of the digital backbone.            | • Extend automation to complex processes (automated task creation).        | • Develop use cases with analytics (e.g., predictive TAT).                | • Embed cross-departmental teams into ongoing operations.                 | • Align digital-skills development with the DT roadmap.                  | • Use dynamic dashboards to identify improvement opportunities.             |
|                                   | • Use maturity results to update the strategy periodically.           | • Introduce regular simulated incidents or exercises.                                          | • Start exposing selected data via dashboards and APIs.                   | • Ensure workflows are fully integrated (no manual data transfer).         | • Put model governance in place (validation, retraining).                 | • Use shared dashboards to make info visible in real time.                | • Use performance/error data to identify training needs.                 | • Establish dedicated time for innovation (e.g., CI sprints).               |
|                                   | • Embed DT responsibilities in manager job descriptions.              | • Use monitoring tools to fix non-compliant behavior.                                          | • Prepare the backbone to support advanced tools (PHM).                   | • Periodically review processes with multifunctional teams.                | • Train managers to interpret analytical outputs correctly.               | • Involve external partners in relevant collaborative structures.         | • Offer role-specific advanced training (e.g., analytics for planners).  | • Share best practices and lessons learned among departments.               |
|                                   | • Strengthen collaboration with external partners under the DT model. | • Link cybersecurity metrics into the risk-management plan.                                    | • Frequently review architecture compared to operational needs.           | • Use workflow data to detect bottlenecks and improve.                     | • Apply prescriptive analytics for high-impact problems.                  | • Periodically review organizational structures.                          | • Collaborate with OEMs to keep content updated.                         | • Involve experienced personnel in process change design.                   |
| 3.20 – 4.00<br>(Digital-Oriented) | • Make a continuous strategic detection plan for technologies.        | • Regularly benchmark policies against industry best practices.                                | • Adopt architectural guidelines to support future evolution.             | • Implement platforms for rapid workflow changes.                          | • Integrate analytics into strategic planning and decisions.              | • Use lessons learned to vanish organizational barriers.                  | • Provide on-demand digital education platforms at work.                 | • Establish formal mechanisms to prioritize ideas (innovation buses).       |
|                                   | • Use scenarios to check alternative digital programs.                | • Participate in collaborative cyber-defense initiatives.                                      | • Integrate with external ecosystems (OEM platforms).                     | • Embed process experimentation into the culture (A/B testing).            | • Invest in data engineers and data scientists.                           | • Experiment with new forms like mission teams or squads.                 | • Support self-learning.                                                 | • Participate in ecosystems (alliances) to co-develop concepts.             |
|                                   | • Share lessons learned and governance with other organizations.      | • Include cybersecurity performance in high-level dashboards.                                  | • Experiment with new technologies (edge computing, 5G).                  | • Use advanced analytics to identify new automation opportunities.         | • Participate in data-sharing and benchmarking initiatives.               | • Develop leadership programs for digital environments.                   | • Incorporate digital innovation behaviors into rewards.                 | • Use advanced analytics to spot weak procedures for change.                |
|                                   |                                                                       | • Regularly refine policies based on lessons and tech changes.                                 | • Use architecture reviews and scouting as ongoing practices.             | • Share successful digital processes with other units.                     | • Continuously explore new tactics and analytical methods.                | • Share practices and regularly refine them.                              | • Engage personnel in the design of new digital tools.                   | • Continuously refine the improvement system itself.                        |



### 6.3. Domain-Level Maturity Analysis and Recommended Actions

This section examines each domain separately. For every maintenance area, the maturity band describes common features and suggests actions.

#### 6.3.1. Domain A: Maintenance Planning & Control

##### Domain Score: 0.00–0.99 – Initial

Planning is mostly reactive. Teams use their own spreadsheets or action lists, that makes it hard to see the full maintenance workload, as a holistic procedure. Urgent needs and calendar inspections drive planning, rather than a clear process. Coordination with operations and logistics is limited.

##### Recommended Actions:

1. Document a simple, common planning process: who plans, using the necessary inputs.
2. Introduce a basic planning tool (could be a simple CMMS module or a standardized spreadsheet), common for everybody.
3. Define minimum data to be caught for every planned event (aircraft, tasks, duration, resources).
4. Start keeping short weekly meetings for planning operations.

##### Domain Score: 1.00–1.99 – Basic / Managed

There is some structure and a main planning tool, but each unit still works in its own way. Plans are short-term and often change at the last minute. Information about aircraft status, resources and spare parts is spread across different systems.

##### Recommended Actions:

1. Align all the planning practices with the basic templates across the units or departments.
2. Connect the planning tool with the MRO/CMMS in order to have an automatic flow of the work orders.
3. Make simple planning KPIs (e.g. schedule precision, number of urgent re-plans) and review them constantly (monthly).
4. Bond maintenance with logistics so that material constraints are known in time.

#### Domain Score: 2.00–2.59 – Defined

Planning is documented and mostly reliable. Plans cover the right time frame and are updated regularly, but they still rely a lot on the planner's experience. Historical data is used, but usually only when needed.

#### Recommended Actions:

1. Use historical data to build basic workload and capacity forecasts per fleet, base and skill set/tasks.
2. Introduce digital workflows for plan approval and change control.
3. Train planners in the use of data and scenario analysis (simple what-if cases).
4. Ensure that plans are accessible and understood by supervisors and technicians.

#### Domain Score: 2.60–3.19 – Integrated

Planning aligns with maintenance execution, operations and logistics. All the key systems are connected, in a way that planners can clearly see the constraints and the dependencies. Data analysis can show the possible bottlenecks before they happen, not just explain them afterward.

#### Recommended Actions:

1. Integrate the outputs and the critical KPIs into planning decision methods (condition-based planning).
2. Make real-time dashboards to monitor the status of the fleet, the capacity of the hangar and the utilization of personnel.
3. Use planning KPIs as the basis for root-cause analysis and continuous improvement.
4. Form a Planning Board with representatives from all the basic departments (Maintenance, Ops, Engineering and ILS).

#### Domain Score: 3.20–4.00 – Digital-Oriented

Planning is predictive and optimized. Advanced tools, simulations and forecasts support decision-making and planning is fully built into strategic fleet and resource management.

#### Recommended Actions:

1. Implement advanced optimization mechanisms (e.g. constraint-based scheduling, multi-scenario simulations).

2. Integrate short-term maintenance planning with long-term capacity and investment planning.
3. Use forecast models to foresee demands for maintenance slots and proactively adjust plans.
4. Benchmark planning performance externally and improve processes and tools based on best practices.

The qualitative description of the DT maturity, for the MRO domain: “Maintenance Planning & Control”, along with the correlating recommended actions that need to be taken, according to the domain -score of the DT maturity assessment tool execution, are presented in the following Table 17.

*Table 17. Qualitative Description and Recommended Actions per Maturity Level Band for MRO Domain A (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description +4                                                                                                                                                                                         | Recommended Actions (Chapter 6.3.1) +2                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | Planning is mostly reactive. Teams use their own spreadsheets or action lists, making it hard to see the full maintenance workload as a holistic procedure. Coordination with operations and logistics is limited. | <ul style="list-style-type: none"> <li>• Document a simple, common planning process: who plans, using the necessary inputs .</li> <li>• Introduce a basic planning tool (e.g., a simple CMMS module or a standardized spreadsheet) common for everybody .</li> <li>• Define minimum data to be captured for every planned event (aircraft, tasks, duration, resources) .</li> <li>• Start keeping short weekly meetings for planning operations.</li> </ul>                         |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | There is some structure and a main planning tool, but each unit still works in its own way. Plans are short-term and often change at the last minute. Information is spread across different systems.              | <ul style="list-style-type: none"> <li>• Align all the planning practices with the basic templates across the units or departments .</li> <li>• Connect the planning tool with the MRO/CMMS in order to have an automatic flow of work orders .</li> <li>• Make simple planning KPIs (e.g., schedule precision) and review them constantly .</li> <li>• Bond maintenance with logistics so that material constraints are known in time.</li> </ul>                                  |
| <b>2.00 – 2.59 (Defined)</b>          | Planning is documented and mostly reliable, but it still relies a lot on the planner's experience. Historical data is used, but usually only when needed.                                                          | <ul style="list-style-type: none"> <li>• Use historical data to build basic workload and capacity forecasts per fleet, base, and skill set/tasks .</li> <li>• Introduce digital workflows for plan approval and change control .</li> <li>• Train planners in the use of data and scenario analysis (simple what-if cases) .</li> <li>• Ensure that plans are accessible and understood by supervisors and technicians.</li> </ul>                                                  |
| <b>2.60 – 3.19 (Integrated)</b>       | Planning aligns with maintenance execution, operations, and logistics. All key systems are connected, and data analysis can show possible bottlenecks before they happen.                                          | <ul style="list-style-type: none"> <li>• Integrate the outputs and the critical KPIs into planning decision methods (condition-based planning) .</li> <li>• Make real-time dashboards to monitor the status of the fleet, hangar capacity, and personnel utilization .</li> <li>• Use planning KPIs as the basis for root-cause analysis and continuous improvement .</li> <li>• Form a Planning Board with representatives from Maintenance, Ops, Engineering, and ILS.</li> </ul> |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | Planning is predictive and optimized. Advanced tools, simulations, and forecasts support decision-making as part of strategic management.                                                                          | <ul style="list-style-type: none"> <li>• Implement advanced optimization mechanisms (e.g., constraint-based scheduling, multi-scenario simulations) .</li> <li>• Integrate short-term maintenance planning with long-term capacity and investment planning .</li> <li>• Use forecast models to foresee demands for maintenance slots and proactively adjust plans .</li> <li>• Benchmark planning performance externally and improve processes based on best practices.</li> </ul>  |

### 6.3.2. Domain B: FlightLine & Hangar Maintenance Execution

#### Domain Score: 0.00–0.99 – Initial

Work on the aircraft is based on paper job cards and personal experience. It is hard to know at any time which tasks are in progress, who is working on them, or what are the main constraints and risks. Feedback from the aircraft is not collected in a structured way or sometimes is not collected at all.

#### Recommended Actions:

1. Map the main task flows (critical paths) from job assignment to sign-off.
2. Introduce the minimum standards for recording task status and main defects (even on paper or a simple spreadsheet).
3. Provide at least one digital access point per hangar bay/flightline bay to view work orders and basic data.
4. Start daily briefings/debriefings to capture progress and problems, like maintenance delays, in a regular way.

#### Domain Score: 1.00–1.99 – Basic / Managed

A main MRO digital system is in place and technicians may use terminals in the hangar, but most work is still done on paper. Mobile devices are uncommon and data is usually entered manually after the work is finished, not during the process.

#### Recommended Actions:

1. Test the use of tablets or rugged laptops for a small team or aircraft type.
2. Introduce digital job cards in parallel (initially) with paper to gain confidence.
3. Train technicians on the basic utilization of digital tools and explain how the data is used.
4. Capture defects and findings directly into the system rather than on handwritten notes.

#### Domain Score: 2.00–2.59 – Defined

Digital tools support the majority of the tasks, but they are not fully connected to the technical documentation and configuration. Supervisors are still using some manual methods (e.g. Microsoft Project or spreadsheets) to assign the work orders and track the progress of the tasks/projects.

#### Recommended Actions:

1. Develop mobile access for work orders and technical manuals to all designated teams.
2. Integrate task execution with documentation and configuration systems.
3. Provide supervisors with simple digital boards showing tasks per technician, status and delays.
4. Standardise how deviations from baseline maintenance and additional findings are recorded.

#### Domain Score: 2.60–3.19 – Integrated

Most of the work is paperless and supported by digital systems. The information that the technicians need at the job site (maintenance hangars/flightline) is available and supervisors have a clear and almost real-time view of what is happening on the field.

#### Recommended Actions:

1. Use historical data to improve standard times and resource planning.
2. Automate operations (e-approvals, traceability).
3. Introduce AR-based guidance for complex or rarely performed tasks.
4. Use execution data to identify training needs and process bottlenecks.

#### Domain Score: 3.20–4.00 – Digital-Oriented

The work environment is fully digital and highly optimized. Technology improves both productivity and safety and the organization keeps finding better ways to work on the aircraft.

#### Recommended Actions:

1. Move towards full paperless operation with feedback procedures and regulator acceptance.
2. Integrate tools and equipment to monitor conditions and reduce safety risks.
3. Use advanced analytics to correlate execution parameters with quality and reliability outcomes.
4. Continuously evaluate and integrate new technologies (robots, drones, advanced NDI) where they add value.

The qualitative description of the DT maturity, for the MRO domain: “FlightLine & Hangar Maintenance Execution”, along with the correlating recommended actions that need to be taken, according to the domain -score of the DT maturity assessment tool execution, are presented in the following Table 18.

*Table 18. Qualitative Description and Recommended Actions per Maturity Level Band for MRO Domain B (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                                                                                     | Recommended Actions (Chapter 6.3.2)                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | Work on the aircraft is based on paper job cards and personal experience. It is hard to know which tasks are in progress or what the main constraints are. Feedback from the aircraft is not collected in a structured way. | <ul style="list-style-type: none"> <li>• Map the main task flows (critical paths) from job assignment to sign-off.</li> <li>• Introduce minimum standards for recording task status and main defects (even on paper or a simple spreadsheet).</li> <li>• Provide at least one digital access point per hangar bay/flight line bay to view work orders and basic data.</li> <li>• Start daily briefings/debriefings to capture progress and problems, like maintenance delays, in a regular way.</li> </ul> |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | A main MRO digital system is in place, but most work is still done on paper. Mobile devices are uncommon, and data is usually entered manually after the work is finished.                                                  | <ul style="list-style-type: none"> <li>• Test the use of tablets or rugged laptops for a small team or aircraft type.</li> <li>• Introduce digital job cards in parallel (initially) with paper to gain confidence.</li> <li>• Train technicians on the basic utilization of digital tools and explain how the data is used.</li> <li>• Capture defects and findings directly into the system rather than on handwritten notes.</li> </ul>                                                                 |
| <b>2.00 – 2.59 (Defined)</b>          | Digital tools support the majority of tasks, but they are not fully connected to tech documentation and configuration. Supervisors still use some manual methods to track progress.                                         | <ul style="list-style-type: none"> <li>• Develop mobile access for work orders and technical manuals to all designated teams.</li> <li>• Integrate task execution with documentation and configuration systems.</li> <li>• Provide supervisors with simple digital boards showing tasks per technician, status, and delays.</li> <li>• Standardize how deviations from baseline maintenance and additional findings are recorded.</li> </ul>                                                               |
| <b>2.60 – 3.19 (Integrated)</b>       | Most work is paperless and supported by digital systems. Information at the job site is available, and supervisors have a real-time view of field operations.                                                               | <ul style="list-style-type: none"> <li>• Use historical data to improve standard times and resource planning.</li> <li>• Automate operations (e-approvals, traceability).</li> <li>• Introduce AR-based guidance for complex or rarely performed tasks.</li> <li>• Use execution data to identify training needs and process bottlenecks.</li> </ul>                                                                                                                                                       |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | The work environment is fully digital and highly optimized. Technology improves productivity and safety, and the organization continuously improves hangar/flight line workflows.                                           | <ul style="list-style-type: none"> <li>• Move towards full paperless operation with feedback procedures and regulator acceptance.</li> <li>• Integrate tools and equipment to monitor conditions and reduce safety risks.</li> <li>• Use advanced analytics to correlate execution parameters with quality and reliability outcomes.</li> <li>• Continuously evaluate and integrate new technologies (robots, drones, advanced NDI) where they add value.</li> </ul>                                       |

### 6.3.3. Domain C: Quality, Airworthiness & Compliance

#### Domain Score: 0.00–0.99 – Initial

Quality and airworthiness depend on manual records, local files and personal knowledge and experience. Problems may be fixed locally, but root causes are rarely addressed and tracking issues is difficult.

#### Recommended Actions:

1. Document QA/QC and airworthiness processes and responsibilities.
2. Centralise all audit reports, findings and occurrence reports in a single data base or repository.
3. Define which records are mandatory and ensure they are captured consistently.
4. Start simple trend tracking (e.g. number of findings per month).

Domain Score: 1.00–1.99 – Basic / Managed

Some digital tools or templates are used, but they are not connected and may differ among units/departments. Corrective actions are tracked, but the process is slow and sometimes incomplete.

Recommended Actions:

1. Introduce a basic digital QMS to store all the findings and track the appropriate corrective actions.
2. Make a standard template for the forms and the workflows for all the audits, inspections and reports.
3. Define the closure milestones for corrective actions and troubleshooting.
4. Monitor the closure milestones for corrective actions and troubleshooting.
5. Make basic courses for initial training on the use of QMS applications.

Domain Score: 2.00–2.59 – Defined

Quality and airworthiness processes are documented and supported by digital tools. However, they are not fully integrated with MRO and configuration systems and analytics are still limited.

Recommended Actions:

1. Integrate QMS with MRO/CMMS and configuration data, if possible.
2. Develop dashboards showing key quality and compliance KPIs (rework, findings per 100 FH, closure times).
3. Formalise feedback channels from QMS into procedure updates and training (maintenance and training manuals and syllabus).
4. Involve quality/airworthiness staff in DT projects from the design phase.

Domain Score: 2.60–3.19 – Integrated

Quality, airworthiness and maintenance data are connected. The organization uses this data to find bigger issues and improve processes and training.

Recommended Actions:

1. Apply root-cause analysis and trend analysis systematically.
2. Use QMS data to prioritise process and system changes with the greatest impact and risk.
3. Align quality objectives with maintenance and DT KPIs.
4. Share lessons learned from quality events across units in a consistent and structured manner.

Domain Score: 3.20–4.00 – Digital-Oriented

Quality and airworthiness management are risk-based and connected to operations and planning.

Recommended Actions:

1. Implement risk-based auditing and inspections made by the results of data analysis.
2. Combine safety, reliability and quality data into integrated risk dashboards.
3. Use digital tools to support proactive risk identification and mitigation.
4. Contribute to industry-wide initiatives and benchmarking on digital quality and airworthiness practices.

The qualitative description of the DT maturity, for the MRO domain: “Quality, Airworthiness & Compliance”, along with the correlating recommended actions that need to be taken, according to the domain -score of the DT maturity assessment tool execution, are presented in the following Table 19.



Table 19. *Qualitative Description and Recommended Actions per Maturity Level Band for MRO Domain C (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                                                        | Recommended Actions (Chapter 6.3.3)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | Quality and airworthiness depend on manual records, local files and personal knowledge. Problems may be fixed locally, but root causes are rarely addressed and tracking issues is difficult.  | <ul style="list-style-type: none"> <li>• Document QA/QC and airworthiness processes and responsibilities .</li> <li>• Centralise all audit reports, findings and occurrence reports in a single database or repository .</li> <li>• Define which records are mandatory and ensure they are captured consistently .</li> <li>• Start simple trend tracking (e.g. number of findings per month).</li> </ul>                                                                                                                                    |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | Some digital tools or templates are used, but they are not connected and may differ among units/departments. Corrective actions are tracked, but the process is slow and sometimes incomplete. | <ul style="list-style-type: none"> <li>• Introduce a basic digital QMS to store all the findings and track the appropriate corrective actions .</li> <li>• Make a standard template for the forms and the workflows for all the audits, inspections and reports .</li> <li>• Define the closure milestones for corrective actions and troubleshooting .</li> <li>• Monitor the closure milestones for corrective actions and troubleshooting .</li> <li>• Make basic courses for initial training on the use of QMS applications.</li> </ul> |
| <b>2.00 – 2.59 (Defined)</b>          | Quality and airworthiness processes are documented and supported by digital tools. However, they are not fully integrated with MRO and configuration systems and analytics are still limited.  | <ul style="list-style-type: none"> <li>• Integrate QMS with MRO/CMMS and configuration data, if possible .</li> <li>• Develop dashboards showing key quality and compliance KPIs (rework, findings per 100 FH, closure times) .</li> <li>• Formalise feedback channels from QMS into procedure updates and training .</li> <li>• Involve quality/airworthiness staff in DT projects from the design phase.</li> </ul>                                                                                                                        |
| <b>2.60 – 3.19 (Integrated)</b>       | Quality, airworthiness and maintenance data are connected. The organization uses this data to find bigger issues and improve processes and training.                                           | <ul style="list-style-type: none"> <li>• Apply root-cause analysis and trend analysis systematically .</li> <li>• Use QMS data to prioritise process and system changes with the greatest impact and risk .</li> <li>• Align quality objectives with maintenance and DT KPIs .</li> <li>• Share lessons learned from quality events across units in a consistent and structured manner.</li> </ul>                                                                                                                                           |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | Quality and airworthiness management are risk-based and connected to operations and planning.                                                                                                  | <ul style="list-style-type: none"> <li>• Implement risk-based auditing and inspections made by the results of data analysis .</li> <li>• Combine safety, reliability and quality data into integrated risk dashboards .</li> <li>• Use digital tools to support proactive risk identification and mitigation .</li> <li>• Contribute to industry-wide initiatives and benchmarking on digital quality and airworthiness practices.</li> </ul>                                                                                                |

#### 6.3.4. Domain D: PHM/ Predictive Maintenance & Digital Twins

##### Domain Score: 0.00–0.99 – Initial

PHM is either ignored, not used or only exists as a future plan on paper. Sensor data may be collected (this is not always feasible), but even when it is collected, it is not analyzed or used for maintenance decisions.

##### Recommended Actions:

1. Map available data sources (onboard sensors, flight data, maintenance logs).
2. Start with basic manual trend monitoring on a small number of critical parameters.
3. Build awareness among engineers and planners about PHM concepts and benefits.

4. Identify one or two high-value use cases where PHM could make a difference.

Domain Score: 1.00–3.99 – Basic / Managed

Some OEM PHM tools or condition-based applications are used, but mostly only for advice. The results are not translated into work orders or planning decisions.

Recommended Actions:

1. Formalise simple alert thresholds and clearly assign responsible stakeholders for their monitor and review.
2. Run pilot tests where PHM alerts are used to adjust maintenance schedules.
3. Document the outcome of these tests (prevented failures, reduced downtime).
4. Ensure PHM data is saved and accessible for further analysis.

Domain Score: 2.00–2.59 – Defined

PHM has a clear role in maintenance, with defined processes. However, it only covers some parameters or systems or aircraft and is only partly connected to planning and logistics systems.

Recommended Actions:

1. Extend PHM use and document the decision logic for each (“if-then” analysis).
2. Integrate PHM outputs with planning and ILS systems (on time slots for procurement, pre-ordered spares).
3. Train planners and engineers to interpret PHM outputs and RUL estimates.
4. Start evaluating where any digital twins could add value.

Domain Score: 2.60–3.19 – Integrated

PHM is part of the daily maintenance planning and supply chain management. It helps the decisions for resources usage and affects the operations and the fleet availability.

Recommended Actions:

1. Increase the coverage of PHM to more systems.
2. Use PHM to improve maintenance intervals and reduce unscheduled maintenance.
3. Establish a cross-functional PHM board to review performance.
4. Begin implementing digital twin models for selected high-impact systems.

### Domain Score: 3.20–4.00 – Digital-Oriented

The organization runs an advanced PHM system. Predictive insights are fully built into both daily and long-term decision-making.

#### Recommended Actions:

1. Use digital twins for scenario analysis and “what-if” scenarios simulation.
2. Continuously improve models using real maintenance findings and operational feedback.
3. Integrate PHM and digital twin data with fleet planning, life-cycle cost analysis and upgrade decisions.

The qualitative description of the DT maturity, for the MRO domain: “PHM/ Predictive Maintenance & Digital Twins”, along with the correlating recommended actions that need to be taken, according to the domain -score of the DT maturity assessment tool execution, are presented in the following Table 20.

*Table 20. Qualitative Description and Recommended Actions per Maturity Level Band for MRO Domain D (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                              | Recommended Actions (Chapter 6.3.4)                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | PHM is either ignored, not used, or only exists as a future plan on paper. Even when sensor data is collected, it is not analyzed or used for maintenance decisions. | <ul style="list-style-type: none"><li>• Map available data sources (onboard sensors, flight data, maintenance logs) .</li><li>• Start with basic manual trend monitoring on a small number of critical parameters .</li><li>• Build awareness among engineers and planners about PHM concepts and benefits .</li><li>• Identify one or two high-value use cases where PHM could make a difference.</li></ul>        |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | Some OEM PHM tools or condition-based applications are used, but mostly only for advice. Results are not yet translated into work orders or planning decisions.      | <ul style="list-style-type: none"><li>• Formalise simple alert thresholds and clearly assign responsible stakeholders for their monitor and review .</li><li>• Run pilot tests where PHM alerts are used to adjust maintenance schedules .</li><li>• Document the outcome of these tests (prevented failures, reduced downtime) .</li><li>• Ensure PHM data is saved and accessible for further analysis.</li></ul> |
| <b>2.00 – 2.59 (Defined)</b>          | PHM has a clear role in maintenance with defined processes. However, it only covers limited parameters and is only partly connected to planning and logistics.       | <ul style="list-style-type: none"><li>• Extend PHM use and document the decision logic for each (“if-then” analysis) .</li><li>• Integrate PHM outputs with planning and ILS systems (on time slots for procurement, pre-ordered spares) .</li><li>• Train planners and engineers to interpret PHM outputs and RUL estimates .</li><li>• Start evaluating where any digital twins could add value.</li></ul>        |
| <b>2.60 – 3.19 (Integrated)</b>       | PHM is part of daily maintenance planning and supply chain management. It actively helps decisions for resource usage and affects fleet availability.                | <ul style="list-style-type: none"><li>• Increase the coverage of PHM to more systems .</li><li>• Use PHM to improve maintenance intervals and reduce unscheduled maintenance .</li><li>• Establish a cross-functional PHM board to review performance .</li><li>• Begin implementing digital twin models for selected high-impact systems.</li></ul>                                                                |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | The organization runs an advanced PHM system where predictive insights are fully built into both daily and long-term decision-making.                                | <ul style="list-style-type: none"><li>• Use digital twins for scenario analysis and “what-if” scenarios simulation .</li><li>• Continuously improve models using real maintenance findings and operational feedback .</li><li>• Integrate PHM and digital twin data with fleet planning, life-cycle cost analysis and upgrade decisions.</li></ul>                                                                  |

### 6.3.5. Domain E: ILS, Supply Chain & Logistics Support

#### Domain Score: 0.00–0.99 – Initial

Logistics support is mostly manual and reactive. It is hard to see stock levels, repair status of repairables and supplier performance. AOG events are treated as emergencies and need significant manual effort.

#### Recommended Actions:

1. Map the end-to-end repair and supply chain for critical parts.
2. Map existing inventory and keep data into one central parts list or basic system.
3. Assign ILS with maintenance.
4. Track at least a few basic indicators (lead times, average repair time).

#### Domain Score: 1.00–1.99 – Basic / Managed

There are used some systems to track and monitor the inventory, but they are not well connected to maintenance planning. Each team focuses on its own area without having the bigger picture of the maintenance.

#### Recommended Actions:

1. Make standard procedures for AOG handling and procurement of critical items.
2. Implement electronic purchases and order tracking.
3. Share information of critical spare parts with maintenance planners.
4. Define service targets with major suppliers (delivery times, quality).

#### Domain Score: 2.00–2.59 – Defined

Logistics processes and systems are used regularly. They are becoming better connected to maintenance planning and MRO tools, but the connection is not complete yet to all systems.

#### Recommended Actions:

1. Integrate logistics systems with MRO planning so that spares availability is visible in planning decisions.
2. Use past usage and failure data to calculate safety stock levels.
3. Evaluate key logistics KPIs (AOG duration, inventory turns, repair turnaround times).

4. Align ILS planning cycles with scheduled maintenance events.

Domain Score: 2.60–3.19 – Integrated

ILS and the supply chain are linked to maintenance operations. The right parts are usually available when needed and data collection and analysis supports proactive decisions.

Recommended Actions:

1. Implement forecasting models for spares demand based on utilization and PHM outputs.
2. Pilot RFID, barcode or other tracking solutions for high-value items.
3. Increase online collaboration with suppliers through portals and applications.
4. Use “what-if” simulations to assess the impact of logistics status changing on fleet readiness.

Domain Score: 3.20–4.00 – Digital-Oriented

The logistics network is highly digital and resilient. Decisions are data-driven and the supply chain helps ensure availability instead of come up against delays and shortages.

Recommended Actions:

1. Introduce advanced analytics for network optimization, supplier risk and cost-to-serve.
2. Move in the direction of more automated replacement for certain classes of items.
3. Integrate logistics performance measures into high-level readiness and DT dashboards.
4. Co-develop digital improvements with major strategic suppliers (e.g. predictive restocking based on shared data).

The qualitative description of the DT maturity, for the MRO domain: “ILS, Supply Chain & Logistics Support”, along with the correlating recommended actions that need to be taken, according to the domain -score of the DT maturity assessment tool execution, are presented in the following Table 21.

Table 21. *Qualitative Description and Recommended Actions per Maturity Level Band for MRO Domain E (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                                                                            | Recommended Actions (Chapter 6.3.5)                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | Logistics support is mostly manual and reactive. It is hard to see stock levels, repair status of repairables, and supplier performance. AOG events are treated as emergencies and need significant manual effort. | <ul style="list-style-type: none"> <li>• Map the end-to-end repair and supply chain for critical parts.</li> <li>• Map existing inventory and keep data into one central parts list or basic system.</li> <li>• Assign ILS with maintenance.</li> <li>• Track at least a few basic indicators (lead times, average repair time).</li> </ul>                                                                                                                              |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | There are some systems used to track and monitor inventory, but they are not well connected to maintenance planning. Each team focuses on its own area without having the bigger picture of maintenance.           | <ul style="list-style-type: none"> <li>• Make standard procedures for AOG handling and procurement of critical items.</li> <li>• Implement electronic purchases and order tracking.</li> <li>• Share information of critical spare parts with maintenance planners.</li> <li>• Define service targets with major suppliers (delivery times, quality).</li> </ul>                                                                                                         |
| <b>2.00 – 2.59 (Defined)</b>          | Logistics processes and systems are used regularly. They are becoming better connected to maintenance planning and MRO tools, but the connection is not yet complete across all systems.                           | <ul style="list-style-type: none"> <li>• Integrate logistics systems with MRO planning so that spares availability is visible in planning decisions.</li> <li>• Use past usage and failure data to calculate safety stock levels.</li> <li>• Evaluate key logistics KPIs (AOG duration, inventory turns, repair turnaround times).</li> <li>• Align ILS planning cycles with scheduled maintenance events.</li> </ul>                                                    |
| <b>2.60 – 3.19 (Integrated)</b>       | ILS and the supply chain are linked to maintenance operations. The right parts are usually available when needed, and data collection and analysis support proactive decisions.                                    | <ul style="list-style-type: none"> <li>• Implement forecasting models for spares demand based on utilization and PHM outputs.</li> <li>• Pilot RFID, barcode, or other tracking solutions for high-value items.</li> <li>• Increase online collaboration with suppliers through portals and applications.</li> <li>• Use “what-if” simulations to assess the impact of logistics status changes on fleet readiness.</li> </ul>                                           |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | The logistics network is highly digital and resilient. Decisions are data-driven, and the supply chain ensures availability instead of facing delays and shortages.                                                | <ul style="list-style-type: none"> <li>• Introduce advanced analytics for network optimization, supplier risk, and cost-to-serve.</li> <li>• Move in the direction of more automated replacement for certain classes of items.</li> <li>• Integrate logistics performance measures into high-level readiness and DT dashboards.</li> <li>• Co-develop digital improvements with major strategic suppliers (e.g., predictive restocking based on shared data).</li> </ul> |

### 6.3.6. Domain F: Technical Documentation & Configuration Management

#### Domain Score: 0.00–0.99 – Initial

Technical documentation and configuration data are scattered across paper files, local drives and personal archives. Finding the right document takes time and increases the risk of using outdated information. Updating technical manuals and preventing the usage of old – non updated documents by maintainers is challenging.

#### Recommended Actions:

1. Identify all current sources of manuals, drawings and configuration records.
2. Define a single “official” source per document type, even if still partly paper-based.
3. Clean up obvious duplicates and mark obsolete documents as such.

4. Set simple rules for how and where new revisions are stored. Define responsible stakeholders for updates.

Domain Score: 1.00–1.99 – Basic / Managed

There are some electronic manuals and digital check lists, but the processes and tools that are used differ for every aircraft type or base. The configuration data are recorded most of the times, but it is not always kept updated automatically.

Recommended Actions:

1. Deploy an e-Tech Pubs platform for revision tracking.
2. Create a basic digital configuration list per aircraft or aircraft type.
3. Standardize the documentation updates and the way they are communicated and acknowledged by users.
4. Train users on how to access digital documentation.

Domain Score: 2.00–2.59 – Defined

Digital documentation and configuration tools are used widely. However, they are not fully connected to MRO and engineering systems, so there are still manual workarounds that need to be done.

Recommended Actions:

1. Integrate all tech documents and configuration tools with MRO/CMMS and other engineering systems.
2. Implement all the digital workflows for document and configuration changes.
3. Make sure that planners and technicians can easily access the relevant configuration status during scheduling or executing maintenance.
4. Introduce digital dashboards to monitor the currency of documentation and configuration.

Domain Score: 2.60–3.19 – Integrated

Documentation and configuration management are fully integrated into maintenance and engineering processes. The risk of using incorrect or outdated information is low.

Recommended Actions:

1. Make sensitive manuals and configuration data accessible at the point of work (hangar bays/flightline) (e.g. via QR codes, integrated screens).
2. Use configuration data to analyze the impact of modifications on maintenance delays and cost.
3. Align the configuration control with the PHM and digital twin developments.
4. Review and update all documentation and configuration processes.

Domain Score: 3.20–4.00 – Digital-Oriented

The organization is moving toward model-based, data-focused configuration management, connected to digital twins and advanced engineering.

Recommended Actions:

1. Explore and implement engineering systems where feasible.
2. Integrate digital twins, configuration data and documentation as a unified “digital thread”.
3. Use configuration data to support long-term design, upgrade and obsolescence management.
4. Share configuration-management best practices with OEMs and partners.

The qualitative description of the DT maturity, for the MRO domain: “Technical Documentation & Configuration Management”, along with the correlating recommended actions that need to be taken, according to the domain - score of the DT maturity assessment tool execution, are presented in the following Table 22.



Table 22. *Qualitative Description and Recommended Actions per Maturity Level Band for MRO Domain F (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                                                                                                                                                         | Recommended Actions (Chapter 6.3.6)                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | Technical documentation and configuration data are scattered across paper files, local drives, and personal archives. Finding the right document takes time and increases the risk of using outdated information. Updating manuals and preventing the use of obsolete documents is challenging. | <ul style="list-style-type: none"> <li>• Identify all current sources of manuals, drawings, and configuration records .</li> <li>• Define a single “official” source per document type, even if still partly paper-based .</li> <li>• Clean up obvious duplicates and mark obsolete documents as such .</li> <li>• Set simple rules for how and where new revisions are stored; define responsible stakeholders for updates.</li> </ul>                                    |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | Some electronic manuals and digital checklists exist, but processes and tools differ by aircraft type or base. Configuration data is usually recorded but not consistently updated automatically.                                                                                               | <ul style="list-style-type: none"> <li>• Deploy an e-Tech Pubs platform for revision tracking .</li> <li>• Create a basic digital configuration list per aircraft or aircraft type .</li> <li>• Standardize documentation updates and the way they are communicated and acknowledged by users .</li> <li>• Train users on how to access digital documentation.</li> </ul>                                                                                                  |
| <b>2.00 – 2.59 (Defined)</b>          | Digital documentation and configuration tools are widely used but not fully connected to MRO and engineering systems, leading to manual workarounds.                                                                                                                                            | <ul style="list-style-type: none"> <li>• Integrate all tech documents and configuration tools with MRO/CMMS and other engineering systems .</li> <li>• Implement digital workflows for document and configuration changes .</li> <li>• Ensure planners and technicians can easily access the relevant configuration status during scheduling or execution .</li> <li>• Introduce digital dashboards to monitor the currency of documentation and configuration.</li> </ul> |
| <b>2.60 – 3.19 (Integrated)</b>       | Documentation and configuration management are fully integrated into maintenance and engineering processes, minimizing the risk of using incorrect or outdated information.                                                                                                                     | <ul style="list-style-type: none"> <li>• Make sensitive manuals and configuration data accessible at the point of work (e.g., via QR codes, integrated screens) .</li> <li>• Use configuration data to analyze the impact of modifications on maintenance delays and cost .</li> <li>• Align configuration control with PHM and digital twin developments .</li> <li>• Review and update all documentation and configuration processes.</li> </ul>                         |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | The organization is moving toward model-based, data-focused configuration management connected to digital twins and advanced engineering.                                                                                                                                                       | <ul style="list-style-type: none"> <li>• Explore and implement model-based engineering systems where feasible .</li> <li>• Integrate digital twins, configuration data, and documentation as a unified “digital thread” .</li> <li>• Use configuration data to support long-term design, upgrade, and obsolescence management .</li> <li>• Share configuration-management best practices with OEMs and partners.</li> </ul>                                                |

### 6.3.7. Domain G: Training & Competency Management

#### Domain Score: 0.00–0.99 – Initial

Training is provided when needed and focuses on fulfilling the minimum requirements. Records are scattered or incomplete and there is small connection between training and performance. Training material is not centralized and managed by one organization/application/tool but is developed by each trainer individually.

#### Recommended Actions:

1. Make a list of mandatory trainings, licenses and qualifications for every role/maintainer specialty and build a maintenance training syllabus.
2. Use a single, central system to keep training records.
3. Assign the responsibility for maintaining training and competency records.

4. Ensure that no training expiry goes unnoticed and re-training/re-evaluation processes are executed on time.

Domain Score: 1.00–1.99 – Basic / Managed

There is a centralized training system, but training scheduling is still managed ad-hoc. Digital tools are used only for administrative courses.

Recommended Actions:

1. Deploy and use a simple training management system, in order to track courses and certifications.
2. Start using e-learning methods for generic topics (familiarization courses, safety, security).
3. Connect training to role authorizations.

Domain Score: 2.00–2.59 – Defined

Training and competency management are organized and documented. Some digital and simulation methods are used, but not yet consistently.

Recommended Actions:

1. Develop competency matrixes per role and link them to specific courses and experiences.
2. Develop training with simulation-based equipment for difficult tasks or emergency procedures.
3. Use findings during maintenance to update and improve training courses.
4. Plan training proactively based on future projects and new technology.

Domain Score: 2.60–3.19 – Integrated

Training and competency management are linked to maintenance performance and digital projects. Skill profiles are established and development plans are used.

Recommended Actions:

1. Align training plans with the digital transformation roadmap (e.g. PHM, analytics, new tools).
2. Use data from maintenance (e.g who uses the equipment/tools, where problems occur) to identify additional training needs (support equipment courses).

3. Coordinate maintenance planning with training schedules in order to minimize operational impact.
4. Encourage career paths that combine technical and digital skills.

Domain Score: 3.20–4.00 – Digital-Oriented

The organization have a highly skilled and digital-experienced maintenance personnel. Learning is a continuous process, driven by data analysis and part of the daily work.

Recommended Actions:

1. Provide on-demand digital education platforms accessible from the workplace.
2. Use analytics to personalize training and to measure the impact of training on performance.
3. Improve practice courses (over the shoulder training, on-the-job training) across units and fleets.

The qualitative description of the DT maturity, for the MRO domain: “Training & Competency Management”, along with the correlating recommended actions that need to be taken, according to the domain - score of the DT maturity assessment tool execution, are presented in the following Table 23.

Table 23. *Qualitative Description and Recommended Actions per Maturity Level Band for MRO Domain G (Credit: Own Elaboration)*

| Maturity Level (Score Band)           | Qualitative Description                                                                                                                                                                                                                  | Recommended Actions (Chapter 6.3.7)                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>0.00 – 0.99 (Initial)</b>          | Training and license tracking are handled manually or through simple local spreadsheets. There is no central view of training needs or expiries. Training is mostly reactive, responding only to urgent certification requirements.      | <ul style="list-style-type: none"> <li>• Create a list of mandatory trainings and licenses per role and a training syllabus.</li> <li>• Use a single, central system to keep training and license records.</li> <li>• Assign clear responsibility for maintaining and updating competency records.</li> <li>• Ensure that no training or license expiry goes unnoticed (basic alerts).</li> </ul>                                              |
| <b>1.00 – 1.99 (Basic/Managed)</b>    | Some digital training tools or a basic Learning Management System (LMS) are in place, but they are not used consistently across all units. Training records are digital but often incomplete or not linked to the actual work performed. | <ul style="list-style-type: none"> <li>• Deploy and use a simple training management system or LMS across all departments.</li> <li>• Start using e-learning modules for generic topics (e.g., safety, security, human factors).</li> <li>• Connect training records to role authorizations within the MRO/CMMS system.</li> <li>• Develop a basic digital skill assessment for maintenance personnel.</li> </ul>                              |
| <b>2.00 – 2.59 (Defined)</b>          | Training and competency management are documented and supported by digital tools. Competency matrices are defined for most roles. However, training content is not yet personalized or data-driven.                                      | <ul style="list-style-type: none"> <li>• Develop competency matrices per role and link them to specific courses and certifications.</li> <li>• Develop simulation-based or computer-based training for high-risk or difficult tasks.</li> <li>• Use maintenance findings and quality data to improve and update training courses.</li> <li>• Plan training proactively based on future technology and fleet updates.</li> </ul>                |
| <b>2.60 – 3.19 (Integrated)</b>       | Training is a standard part of the digital transformation. The organization uses data from maintenance operations to identify training gaps and improve course content. Training plans are aligned with organizational goals.            | <ul style="list-style-type: none"> <li>• Align all training plans with the goals and milestones of the DT roadmap (e.g., PHM, analytics).</li> <li>• Use maintenance performance or error data to identify specific support or equipment training needs.</li> <li>• Coordinate planning with training to minimize the impact on maintenance operations.</li> <li>• Encourage and support technical and digital hybrid career paths.</li> </ul> |
| <b>3.20 – 4.00 (Digital-Oriented)</b> | The organization has a high-performing digital learning environment. Training is on-demand, personalized, and utilizes advanced technologies. Learning is an ongoing part of the digital culture.                                        | <ul style="list-style-type: none"> <li>• Provide on-demand digital education and micro-learning directly from the workplace.</li> <li>• Use analytics to personalize learning paths and measure the impact of training on performance.</li> <li>• Improve and expand high-fidelity practice courses across all units and fleets (e.g., VR/AR).</li> <li>• Engage personnel in the co-creation of digital training content.</li> </ul>          |

All the above - mentioned recommended actions, driven by the calculated scores of the maturity assessment tool, for every MRO domain of the model, are collectively presented in the following Table 24.

*Table 24. Recommended Actions per Maintenance Domain Score Band (Credit: Own Elaboration)*

| Score Band                                | A. Maintenance Planning & Control                                     | B. Line & Base Maintenance Execution                                    | C. Quality, Airworthiness & Compliance                                                   | D. PHM / Predictive Maintenance & Digital Twins                          | E. ILS, Supply Chain & Logistics Support                          | F. Technical Documentation & Configuration                            | G. Training & Competency Management                                      |
|-------------------------------------------|-----------------------------------------------------------------------|-------------------------------------------------------------------------|------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------------|
| <b>0.00 – 0.99<br/>(Initial)</b>          | • Document a simple, common planning process.                         | • Map the main task flows from job assignment to sign-off.              | • Document QA/QC and airworthiness processes and responsibilities.                       | • Map available data sources (sensors, logs, flight data).               | • Map the end-to-end repair and supply chain for critical parts.  | • Identify all sources of manuals, drawings, and records.             | • Create a list of mandatory trainings/licenses per role and a syllabus. |
|                                           | • Introduce a basic planning tool common for everybody.               | • Introduce minimum standards for recording task status/defects.        | • Centralize all audit reports, findings, and occurrence reports in a single repository. | • Start basic manual trend monitoring on critical parameters.            | • Map existing inventory into one central system.                 | • Define a single "official" source per document type.                | • Use a single, central system to keep training records.                 |
|                                           | • Define minimum data to be caught for every planned event.           | • Provide at least one digital access point per hangar/flight line bay. | • Define mandatory records and ensure consistent capture.                                | • Build awareness among engineers/planners about PHM.                    | • Assign ILS with maintenance.                                    | • Clean up duplicates and mark obsolete documents.                    | • Assign responsibility for maintaining competency records.              |
|                                           | • Start daily briefings/debriefings to capture progress and problems. | • Start daily briefings/debriefings to capture progress and problems.   | • Start simple trend tracking (e.g., findings per month).                                | • Identify high-value use cases for PHM.                                 | • Track basic indicators (lead times, repair times).              | • Set rules for revision storage and define responsible stakeholders. | • Ensure no training expiry goes unnoticed.                              |
| <b>1.00 – 1.99<br/>(Basic / Managed)</b>  | • Align planning practices with basic templates across units.         | • Test tablets or rugged laptops for a small team/aircraft type.        | • Introduce a basic digital QMS for findings and corrective actions.                     | • Formalize simple alert thresholds and assign responsible stakeholders. | • Make standard procedures for AOG handling and procurement.      | • Deploy an e-Tech Pubs platform for revision tracking.               | • Deploy and use a simple training management system.                    |
|                                           | • Connect planning tool with MRO/CMMS for automatic flow.             | • Introduce digital job cards in parallel with paper.                   | • Make a standard template for forms and workflows.                                      | • Run pilot tests where PHM alerts adjust maintenance schedules.         | • Implement electronic purchases and order tracking.              | • Create a basic digital configuration list per aircraft type.        | • Start using e-learning for generic topics (safety, security).          |
|                                           | • Make simple planning KPIs and review them monthly.                  | • Train technicians on basic utilization of digital tools.              | • Define closure milestones for corrective actions.                                      | • Document test outcomes (prevented failures, downtime).                 | • Share information of critical spares with maintenance planners. | • Standardize documentation updates and communication.                | • Connect training to role authorizations.                               |
|                                           | • Bond maintenance with logistics for material constraints.           | • Capture defects and findings directly into the system.                | • Monitor closure milestones.                                                            | • Ensure PHM data is saved and accessible.                               | • Define service targets with major suppliers.                    | • Train users on how to access digital documentation.                 |                                                                          |
|                                           |                                                                       |                                                                         | • Make basic courses for QMS applications.                                               |                                                                          |                                                                   |                                                                       |                                                                          |
| <b>2.00 – 2.59<br/>(Defined)</b>          | • Use historical data for workload and capacity forecasts.            | • Develop mobile access for work orders and manuals to all teams.       | • Integrate QMS with MRO/CMMS and configuration data.                                    | • Extend PHM use and document the decision logic.                        | • Integrate logistics systems with MRO planning for visibility.   | • Integrate tech docs and configuration tools with MRO/CMMS.          | • Develop competency matrixes per role and link to courses.              |
|                                           | • Introduce digital workflows for plan approval and change control.   | • Integrate task execution with documentation and configuration.        | • Develop dashboards for key quality and compliance KPIs.                                | • Integrate PHM outputs with planning and ILS systems.                   | • Use usage and failure data to calculate safety stock levels.    | • Implement digital workflows for document/config changes.            | • Develop simulation-based training for difficult tasks.                 |
|                                           | • Train planners in the use of data and scenario analysis.            | • Provide supervisors with digital boards showing task status.          | • Formalize feedback channels from QMS into procedure updates.                           | • Train planners/engineers to interpret PHM/RUL outputs.                 | • Evaluate key logistics KPIs (AOG duration, inventory turns).    | • Ensure access to config status during scheduling/execution.         | • Use maintenance findings to improve training courses.                  |
|                                           | • Ensure plans are accessible to supervisors/technicians.             | • Standardize how deviations and findings are recorded.                 | • Involve quality staff in DT projects from the design phase.                            | • Start evaluating where digital twins could add value.                  | • Align ILS planning cycles with scheduled maintenance.           | • Introduce digital dashboards for documentation currency.            | • Plan training proactively based on future technology.                  |
| <b>2.60 – 3.19<br/>(Integrated)</b>       | • Integrate PHM outputs/KPIs into condition-based planning.           | • Use historical data to improve standard times and resource planning.  | • Apply root-cause and trend analysis systematically.                                    | • Increase PHM coverage to more systems.                                 | • Implement forecasting models for spares demand based on PHM.    | • Make sensitive manuals/config data accessible via QR codes.         | • Align training plans with the DT roadmap (PHM, analytics).             |
|                                           | • Make real-time dashboards to monitor fleet/hangar status.           | • Automate operations (e-approvals, traceability).                      | • Use QMS data to prioritize high-impact changes.                                        | • Use PHM to improve maintenance intervals.                              | • Pilot RFID, barcode, or other tracking for high-value items.    | • Link documentation to real-time PHM data and history.               | • Use maintenance data to identify support equipment training needs.     |
|                                           | • Use planning KPIs for root-cause analysis and improvement.          | • Introduce AR-based guidance for complex tasks.                        | • Align quality objectives with maintenance and DT KPIs.                                 | • Establish a cross-functional PHM board.                                | • Increase online collaboration with suppliers through portals.   | • Align configuration control with PHM and digital twins.             | • Coordinate planning with training to minimize impact.                  |
|                                           | • Form a cross-functional Planning Board.                             | • Use execution data to identify training needs/bottlenecks.            | • Share lessons learned across units in a structured manner.                             | • Begin implementing digital twin models for high-impact systems.        | • Use "what-if" simulations to assess readiness impact.           | • Review and update all documentation processes.                      | • Encourage technical and digital hybrid career paths.                   |
| <b>3.20 – 4.00<br/>(Digital-Oriented)</b> | • Implement advanced optimization (constraint-based, simulations).    | • Move towards full paperless operation with regulator acceptance.      | • Implement risk-based auditing driven by data analysis.                                 | • Use digital twins for scenario analysis and simulations.               | • Introduce advanced analytics for network and supplier risk.     | • Explore and implement model-based engineering systems.              | • Provide on-demand digital education from the workplace.                |
|                                           | • Integrate short-term planning with long-term capacity/investment.   | • Integrate tools/equipment to monitor conditions and reduce risk.      | • Combine safety, reliability, and quality into risk dashboards.                         | • Continuously improve models using maintenance feedback.                | • Move toward more automated replacement for specific items.      | • Integrate digital twins and docs into a "digital thread".           | • Use analytics to personalize and measure training impact.              |
|                                           | • Use forecast models to proactively adjust plans.                    | • Correlate execution parameters with quality/reliability outcomes.     | • Use digital tools for proactive risk identification.                                   | • Integrate digital twin data with life-cycle cost analysis.             | • Integrate logistics measures into high-level dashboards.        | • Use config data for long-term design and obsolescence.              | • Improve practice courses across units and fleets.                      |
|                                           | • Benchmark planning performance externally.                          | • Evaluate and integrate new tech (robots, drones, NDI).                | • Contribute to industry-wide benchmarking.                                              |                                                                          | • Co-develop digital improvements with strategic suppliers.       | • Share best practices with OEMs and partners.                        |                                                                          |

## 6.4. Domain & Dimension Scores Combination Treatment

To organize the next steps of digitalization there is a common course of actions, described as following:

View detailed scores for each domain and dimension at the same time. Domains (Planning, Line/Base, PHM, ILS, Documentation, Training) tell you exactly where in the maintenance chain you are strong or weak.

The dimensions (Strategy, Policies, Backbone, Process Digitalization, Data, Organization, People and Culture) show the skills and resources behind these strengths or weaknesses.

Here is a practical way, the organization can use this information:

### 1. Identify the “red cells.”

Check out the dimension and domain matrix and note the lowest scores (Initial or Basic) of cells. These represent areas where capability is poor in combination with low performance (e.g. Data & Analytics in PHM or People & Skills in Training).

### 2. Decide the level of action.

If there are several domains which are weak in the same dimension (for example Data & Analytics having low scores across all domains) you will need a large-scale initiative. Establish a program to enhance data governance, tools and analytics skills within the maintenance team.

If one domain is low in several dimensions (for instance, PHM is low in strategy, systems and skills), then develop a targeted program which will be able to focus on all these areas.

### 3. Balance quick improvements with structural changes.

Identify the scores that are near the top of a band (e.g., 1.9 or 2.5). Most of the times, these are opportunities. There is the ability to move these scores up to the next level band, with less effort and usually less cost, like the addition of an interface, an instruction, a training course - lecture or a slightly modified routine.

If scores are always low within a specific band, those are likely structural, such as old systems, lack of strategies or huge skill gaps. It will also take a longer, multipurpose effort to fix these.

#### 4. Sequence the roadmap logically.

Align to the dimensions by order of importance: prioritizing steps that meet their own characteristics.

Begin with Strategy & Governance and Policies/Cybersecurity, so that direction and rules are clear and simple.

Next, try to improve the Digital Backbone and Process Digitalization, to support change by the infrastructure and workflows.

Then there's Data & Analytics and People & Skills for transforming the digital infrastructure into helpful insights and better ways to work. Encourage a continuous-improvement, innovative approach so the DT procedure will continue to develop.

#### 5. Re-use and scale good practice.

If a domain is strong on one type or aspect (e.g. Training: has good digital workflows), determine the typical practices. These best practice techniques from “green cells” may often be applied to “yellow” or “red” cells.

Using the model this way, turns it into a conversation tool, not a checklist. It provides maintenance leaders and teams the same language, along with a guide for turning conversations into meaningful plans.

### 6.5. Implementing the Roadmap: An Agile Approach

Getting a low or average score on the maturity matrix can feel overwhelming for a maintenance organization. When management looks at a transformation roadmap filled with recommended actions across multiple domains, the natural instinct is often to try and fix everything at once, through a massive, traditional "waterfall" project. However, experience shows that digital transformation rarely works efficiently that way.

To get the real value out of this assessment tool, organizations need to treat the roadmap as a dynamic backlog, using the principles of Agile PM. Instead of locking into a rigid multi-year plan, the digital transition should be broken down into manageable, iterative cycles, like Agile "Sprints". This approach prevents the organization from taking on too much disruption at once.

Here is how this cyclical methodology practically works with the assessment tool and the recommended actions:

Step 1: Baseline and Sprint 1 Planning.

The process starts with the initial maturity assessment. Let's say a company scores in the "Basic / Managed" band (Level 2). Instead of looking at advanced Level 5 goals, leadership focuses strictly on the immediate "red cells" in the matrix. They select a small, targeted batch of recommended actions from the roadmap specifically aimed at reaching Level 3. These actions become the exclusive goals for Sprint 1, which typically lasts a few months.

Step 2: Execution.

The team spends this first sprint executing only those specific tasks, for instance, digitizing the hangar floor job cards or establishing basic CMMS integrations. By keeping the scope small, the organization can achieve quick wins that build a good momentum and at the same time to improve the confidence of the personnel.

Step 3: Re-assessment (The Sprint Review).

After the first sprint is finished, the organization doesn't just move onto the next thing on a long list. They stop and use the maturity assessment again - this is like an Agile sprint review. This new assessment shows how things really are now, after the improvement actions. Has the score gone up? And did the improvement in specific areas caused other problems? For example, did making things better in Flightline Maintenance accidentally cause a slowdown in getting data through Logistics?

Step 4: Sprint 2 and beyond.

Based on these new, updated scores, the team selects the next set of recommended actions for Sprint 2. If an action from the previous sprint failed to improve the score, they adjust and try a different approach. If it succeeded, they pick the next logical step from the roadmap to push towards Level 4.

Going around with this Assess-Execute-Reassess cycle, the roadmap transforms from a static document into a living management guide. It makes the organization to measure its actual progress all the time instead of just ticking off tasks on a list. This Agile method of doing things and repeating the process helps build a “we always try to improve”



attitude (which is Dimension 8) as the maintenance teams slowly learn to adjust, get more accurate, and develop their digital methods.

## 6.6. Overall Maturity Index (OMI)

The overall maturity index indicates a maintenance organization's general position regarding its digital capabilities. While it does not replace detailed area scores, it helps determine the most appropriate transformation practice, that need to be implemented to the organization's strategy. The following roadmap outlines some generic focus areas and some recommended next steps and actions to be taken for the upgrade to a full digital implementation, according to the OMI score.

### Overall Index 0.00–0.99 – Getting Started

Set the general digital directions and write down a short, clear digital implementation plan for maintenance (why it is important, what you want to improve, what are the advantages) and communicate the plan across the departments.

Stabilize the basic capabilities and applications.

Choose (or develop) one basic system that gives you the capability to record maintenance work, as a minimum requirement and start using it consistently, even if it is simple, ignoring people's reaction to changes.

Start with small steps at the beginning, as the organization is not mature for big changes in short timeframes.

Pick 2–3 low-risk processes (e.g. document access in digital applications, simple computerized forms) and digitalize them to build the initial confidence.

Offer basic training courses for the new applications – methods and short demonstration lectures to people, in order to see the digital tools as a help, not a risk and fully understand the potentials.

Create a small DT core team that will be able to coordinate and track all digital initiatives. Expand the team as the demands are rising.

### Overall Index 1.00–1.99 – Building the Foundations

Turn the ambition into a plan. Translate the high-level vision into a simple, time-phased roadmap for maintenance with a handful of priorities and milestones.

Review the deployed systems.

Map all the existing digital tools, remove the obvious overlaps between them and strengthen all the interfaces between the ones you decide to keep.

Standardize the core processes.

Make sure planning, execution, quality and ILS processes are sufficiently documented and coordinated with the systems that support them.

Improve the data quality and the reporting procedures.

Name all data owners, separate and clean key data sets and automate a small set of standard reports and dynamic dashboards. Structure the desirable digital skills.

Define the basic digital skills that are required for every role and offer a focused training, not just one-time tool introductions or demonstration.

### Overall Index 2.00–2.59 – Structured but Not Yet Fully Integrated

Use the detailed scores and identify which domains and dimensions are consistently weaker and make them weak areas a priority for your plan.

Invest in integration.

Focus on interfaces, shared data models and cross-functional workflows so that the used tools by maintainers and supervisors and monitoring processes work as a single system.

Upgrade the analytics where it is important.

Move from purely descriptive old-fashioned reporting to a diagnostic method by using predictive tools for planning, PHM and ILS.

Align all the digital turn with the desired capacity of the DT core team.

Make sure that training, documentation and support are properly coordinated so that users are not overloaded.

Formalize the learning loops.

Use maturity results and performance data in a regular base, so you will be able to understand what works properly and what needs to be adjusted.

#### Overall Index 2.60–3.19 – Integrated and Data-Driven

Target the remaining weak spots.

Use domain scores to identify where digital maturity is lowest and design tailored programs to improve the recognized weak areas.

Industrialize everything that is digitized and provides value. For business intelligence, PHM or digital workflow solutions that have been deployed, implemented and work properly increasing the value of the organization, put in place proper governance (models, versions, ownership).

Monitor and scale down the complexity by simplifying the procedures where this is possible.

Stop adding tools or features that do not clearly support business outcomes and do not bring clear value to the maintenance.

Strengthen all the external links.

Engage more systematically with the external stakeholders, like OEMs, MRO partners and alliances on data and digital topics and make them part of the digital implementation.

Develop advanced talent.

Monitor KPIs and invest in roles such as data engineers, PHM specialists and product owners who can sustain and evolve the digital ecosystem of the organization.

#### Overall Index 3.20–4.00 – Digital-Oriented Maintenance Organization

Continue to experiment with digital tools and processes, but keep in mind that the cornerstone of the aircraft maintenance is safety.

Set up a structured testing procedure with labs, pilots and innovation partnerships, in order to explore any new ideas without affecting the normal operations.

Periodically review the digital systems and the established processes, remove or simplify elements that are no longer adding value to the maintenance procedure.

Make sure that all the critical digital services have strong backup, incident-response and cyber protection measures.

Try to influence the wider ecosystem of the MRO sector.

Use your experience and digital advantage to determine or change the standards, the best practices and the joint projects within the aviation/defense community.

Look beyond maintenance.

Leverage digital maintenance capabilities in wider strategic discussions (fleet planning, capability development, joint operations) to expand the DT advantages and value to other sectors beyond aircraft MRO.

The following Table 25, represents all the generic focus areas and the recommended actions to be taken, in accordance with the OMI, that an organization scores, after the usage of the DT maturity assessment tool of this thesis.

Table 25. *Generic Focus Areas and Recommended Actions per OMI Score Band (Credit: Own Elaboration)*

| Overall Maturity Index (OMI) | Strategic Focus                              | Generic Recommended Focus Areas and Action Items                                                               |
|------------------------------|----------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| 0.00 – 0.99                  | <b>Establishing the Baseline</b>             | • Define a clear digital implementation plan and communicate it across all departments .                       |
|                              |                                              | • Stabilize basic capabilities by adopting at least one central system for recording maintenance tasks .       |
|                              |                                              | • Select 2–3 low-risk processes for initial digitalization to build organizational confidence.                 |
| 1.00 – 1.99                  | <b>Building the Foundations</b>              | • Translate the high-level vision into a time-phased roadmap with clear priorities and milestones .            |
|                              |                                              | • Map existing digital tools to remove overlaps and strengthen system interfaces .                             |
|                              |                                              | • Standardize core processes (Planning, Execution, Quality, ILS) and automate a small set of standard reports. |
| 2.00 – 2.59                  | <b>System Integration &amp; Data Quality</b> | • Use detailed matrix scores to prioritize improvements in consistently weak domains and dimensions .          |
|                              |                                              | • Invest in shared data models and cross-functional workflows to ensure tools work as a single system .        |
|                              |                                              | • Shift from descriptive reporting to diagnostic analytics for planning, PHM, and ILS.                         |
| 2.60 – 3.19                  | <b>Data-Driven Optimization</b>              | • Design tailored programs to improve specific functional areas where digital maturity remains lowest .        |
|                              |                                              | • Formalize governance for successful business intelligence and PHM solutions to sustain value .               |
|                              |                                              | • Strengthen external links with OEMs and MRO partners through systematic data integration.                    |
| 3.20 – 4.00                  | <b>Continuous Innovation</b>                 | • Establish structured testing procedures and innovation partnerships to explore new technologies safely .     |
|                              |                                              | • Regularly review and prune digital systems to remove elements that no longer add operational value .         |
|                              |                                              | • Leverage digital maturity to influence industry standards and best practices within the aviation community.  |

## **Chapter 7.** Case Study: Application of the Maturity Model

### **7.1. Purpose and Design of the Case Study**

In this chapter, the model is tested in a real-world setting. After covering the theory, literature review and design, the main question is whether the model works in practice.

Can the questionnaire provide meaningful results when completed by actual maintenance staff?

Do the scores reflect the organization's reality?

Most importantly, can they help create a practical roadmap for digital transformation?

To answer these questions, the full assessment tool has been used, including the questionnaire, scoring logic and roadmap framework, in a real aircraft maintenance organization. **For confidentiality reasons, the name of the organization is not disclosed.**

The case study had three clear goals:

1. To test if the tool is practical. Are the 62 questions clear and relevant? Has the survey the right length? Do participants understand the 0 to 4 scale and feel comfortable to answer?
2. To check if the model produces useful results. Do the cell, dimension, and domain scores make sense? Do they highlight the right priorities? Can the results be explained and justified to management?
3. To show how the model generates a roadmap. Using the actual scores, can the model create a realistic set of priorities and actions that the maintenance organization can implement?

#### **7.1.1. Case Study Process**

The case study followed this simple process:

- The Google Forms questionnaire was sent to a representative group of the aircraft maintenance organization.  
<https://forms.gle/9vjqDyVTbaMRZZRW7>
- Responses were collected and processed using the scoring logic described in Chapter 5.5.
- The results were analyzed with Excel.
- The organization scoring was translated on what worked well and what could be improved.
- A tailored roadmap was created based on the organization's actual maturity profile.

To ensure the validity of this pilot application, the research design was governed by specific methodological justifications:

- Company Selection: The selected highly regulated aviation MRO represents a typical "hybrid" operational state. While utilizing core IT software (CMMS and ERP platforms), it still relies heavily on legacy paper-based workflows. This transitional environment makes it the ideal setting to test the diagnostic capabilities of the developed framework.
- Sampling Method: A purposive (expert) sampling approach was utilized. The survey strictly targeted 28 Subject Matter Experts (SMEs) representing both the horizontal breadth of MRO domains (Planning, Execution, QA, Logistics, and Training) and the vertical organizational hierarchy (frontline technicians to senior directors), ensuring a balanced, 360-degree assessment.
- Bias Mitigation: To control subjective bias inherent in self-assessments, three strategies were applied: (i) complete participant anonymity to encourage honest feedback, (ii) cross-departmental triangulation of scores to neutralize localized over-optimism, and (iii) concrete operational scenarios anchoring each 0–4 scoring option in the questionnaire.

- Roadmap Criteria: Roadmap prioritization was based on: (i) Criticality, addressing the lowest-scoring "red cells" first, (ii) Feasibility, targeting "quick wins" near threshold bands, (iii) Logical Dependencies, stabilizing foundational digital infrastructure before deploying advanced tools, and (iv) Resource Alignment, leveraging high workforce readiness to drive gradual cultural change.

The Case Study of this thesis is not a large-scale survey or a long-term study. It is a focused trial meant to show that the model can deliver value right away, even with limited resources.

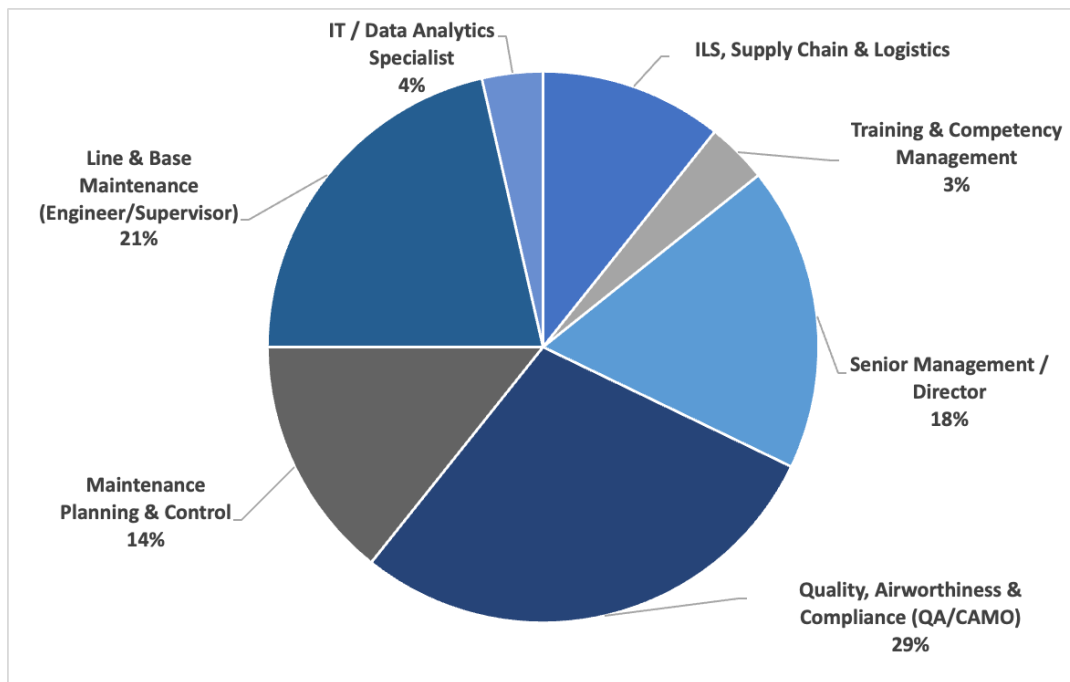
The survey was distributed to a broad range of stakeholders at multiple functional levels and through the organization's hierarchy, to secure a comprehensive view of the digital landscape. Inputs were obtained from 28 SMEs, representing the full vertical and horizontal structure of the maintenance operation.

By including technicians, IT and logistics specialists, department heads, and directors, the study covered all aspects of aircraft maintenance. This approach connected technical work with management and administrative workload, giving a full view of the organization's digital maturity.

The following pie chart shows the participants' professional backgrounds. The largest groups are personnel from Quality, Airworthiness & Compliance (28.6%) and FlightLine & Hangar Maintenance (21.4%), making sure that the model's findings are grounded within technical, safety and operational realities.

Furthermore, including Senior Management (17.9%), Planning (14.3%), and Logistics (10.7%) to the survey, provides the perspective of the supply-chain area and the organization's strategy, in order to validate the holistic nature of the DT assessment.





*Chart 1 Case Study, Participants' Professional Background Pie Chart (Credit: Own Elaboration)*

## 7.2. Score Analysis

The main result of this case study is the Digital Maturity Assessment Matrix, shown in the following Table 26.

Instead of just being a table of numbers, this matrix acts as a flexible “digital blueprint”. It shows how the eight key transformation areas (dimensions) interact with the seven main domains of aircraft maintenance.

The values in this matrix come from the combined insights and real-world experience of the participating 28 SMEs, shown in Chart 1. By bringing these views together, the matrix offers a detailed look inside the organization, shifting the focus from theory to real-world evidence.

This view is important because it shows where digital adoption is strong and also points out areas where technology is moving faster than the organization’s culture or skills.

In the end, this matrix is a key part of the thesis, for the simple reason, that turns raw field data into a clear strategic map, giving the evidence needed to go from identifying problems to creating a focused, practical plan for the organization’s digital future.

Table 26. Case Study Digital Maturity SCORE Matrix (Credit: Own Elaboration)

|                            |                                                         | Maintenance Domain                |                                      |                                        |                                                 |                                          |                                                       |                                     | Dimension Score |
|----------------------------|---------------------------------------------------------|-----------------------------------|--------------------------------------|----------------------------------------|-------------------------------------------------|------------------------------------------|-------------------------------------------------------|-------------------------------------|-----------------|
|                            |                                                         | A. Maintenance Planning & Control | B. Line & Base Maintenance Execution | C. Quality, Airworthiness & Compliance | D. PHM / Predictive Maintenance & Digital Twins | E. ILS, Supply Chain & Logistics Support | F. Technical Documentation & Configuration Management | G. Training & Competency Management |                 |
| Digital Maturity Dimension | 1. Strategy & Governance                                | 1,93                              | 1,57                                 | 2                                      | 1,21                                            | 2,14                                     | 2,14                                                  | 1,54                                | 1,79            |
|                            | 2. Policies, Compliance & Cybersecurity                 | 1,89                              | 2,14                                 | 2,05                                   | 2,04                                            | 1,79                                     | 2,39                                                  | 1,68                                | 2,00            |
|                            | 3. Information Systems & Digital Backbone               | 1,89                              | 1,96                                 | 2,25                                   | 1,57                                            | 1,96                                     | 2,25                                                  | 1,61                                | 1,93            |
|                            | 4. Process Digitalisation & Workflow Automation         | 1,86                              | 1,38                                 | 1,79                                   | 1,86                                            | 1,79                                     | 2,36                                                  | 1,43                                | 1,78            |
|                            | 5. Data & Analytics                                     | 2,18                              | 1,96                                 | 1,82                                   | 1,36                                            | 1,86                                     | 2,07                                                  | 1,64                                | 1,84            |
|                            | 6. Organisation, Roles & Cross-Functional Collaboration | 1,86                              | 1,54                                 | 2                                      | 1,29                                            | 1,64                                     | 2,14                                                  | 1,68                                | 1,74            |
|                            | 7. People & Digital Skills                              | 2,14                              | 2,25                                 | 2,32                                   | 1,57                                            | 1,93                                     | 2,43                                                  | 1,8                                 | 2,06            |
|                            | 8. Culture of Continuous Improvement & Innovation       | 1,89                              | 1,54                                 | 1,82                                   | 1,07                                            | 1,46                                     | 2,04                                                  | 1,68                                | 1,64            |
|                            | Domain Score                                            | 1,96                              | 1,79                                 | 2,01                                   | 1,50                                            | 1,82                                     | 2,23                                                  | 1,63                                | 1,85            |

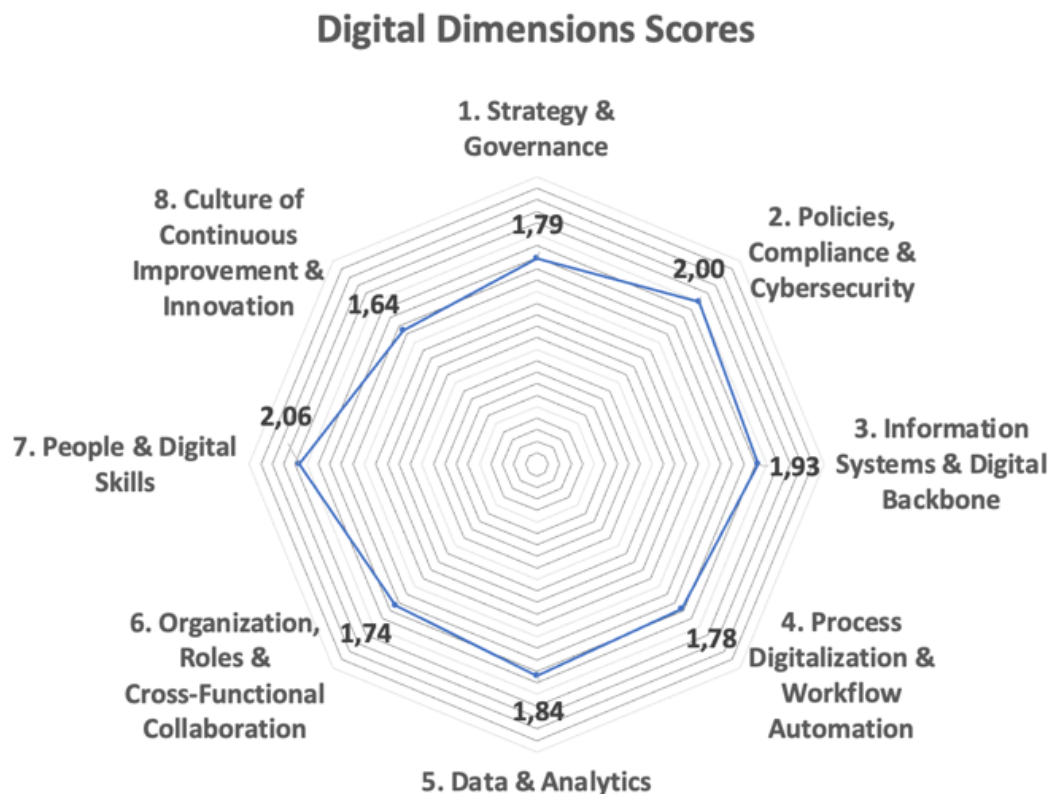
### 7.2.1. Scoring and Index Calculation

To provide a clear and measurable assessment of the organization's digital status, we calculated maturity levels in the matrix using a layered averaging method. This approach delivers a detailed view of the organization's operations.

1. Individual Cell Scores: Each cell in the matrix shows where a Digital Dimension, like Data & Analytics, meets a maintenance Domain, such as Line Maintenance. We averaged responses from 28 subject matter experts for each cell (according to Section 5.5.2 methodology), so each score reflects their combined knowledge.

2. Domain and Dimension Maturity Scores: The model also gives two main summary views besides the individual cell scores:

- **Dimension Maturity Scores (Row Averages)**: These scores highlight digital strengths across the organization. For example, consistently high People & Skills scores indicate workforce readiness for change, even if Process Digitalization lags behind.



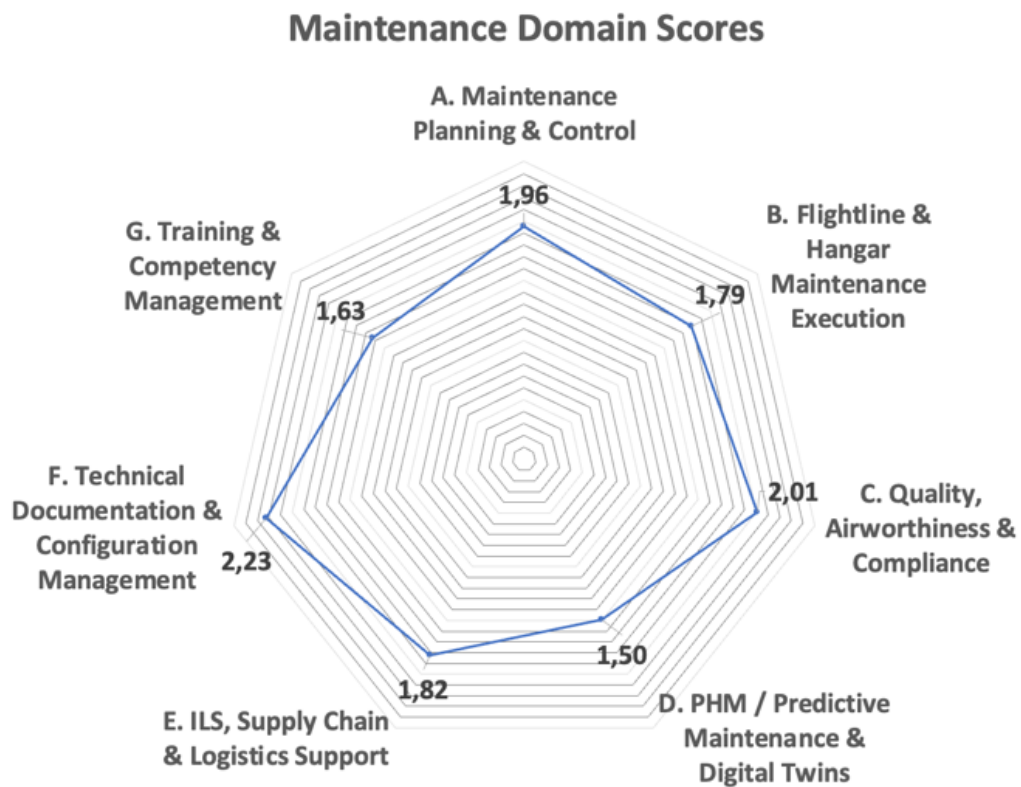
*Chart 2 Case Study, Digital Dimensions Scores, Radar Chart (Credit: Own Elaboration)*

The scores for every Dimension (calculated according to Section 5.5.3 methodology), as shown in Chart 3, are the following:

1. Strategy & Governance – Score: 1,79 (Basic/Managed).
2. Policies, Compliance & Cybersecurity – Score: 2,00 (Defined).
3. Information Systems & Digital Backbone – Score: 1,93 (Basic/Managed).
4. Process Digitalization & Workflow Automation – Score: 1,78 (Basic/Managed).
5. Data & Analytics – Score: 1,84 (Basic/Managed)

6. Organization, Roles & Cross-Functional Collaboration – Score: 1,74 (Basic/Managed).
7. People & Digital Skills – Score: 2,06 (Defined)
8. Culture of Continuous Improvement & Innovation – Score: 1,64 (Basic/Managed)

- **Domain Maturity Scores (Column Averages):** These scores indicate the digital maturity of each maintenance sector. They help identify departments, such as Technical Documentation, that are leading in digital progress and those, like PHM, that require additional support.



*Chart 3 Case Study, Maintenance (MRO) Domain Scores, Radar Chart (Credit: Own Elaboration)*

The scores for every Domain (calculated according to Section 5.5.4 methodology), as shown in Chart 2, are the following:

- A. Maintenance Planning & Control – Score: 1,96 (Basic/Managed).
- B. FlightLine & Hangar Maintenance Execution – Score: 1,79 (Basic/Managed).

- C. Quality, Airworthiness & Compliance – Score: 2,01 (Defined).
- D. PHM / Predictive Maintenance & Digital Twins – Score 1,50 (Basic/Managed).
- E. ILS, Supply Chain & Logistics Support – Score: 1,82 (Basic/Managed).
- F. Technical Documentation & Configuration Management – Score: 2,23 (Defined).
- G. Training & Competency Management – Score: 1,63 (Basic/Managed).

3. The Overall Maturity Index (OMI): The final OMI score is 1.85, which is the average of all cell scores. On the 5-level scale, it places the organization at Level 2 – Basic/Managed (Score 1.00-1.99).

This score is nothing more than a high-level indicator, that takes the general pulse of the current situation, but it does not actually dictate the transformation strategy.

#### 7.2.2. Digital Maturity Matrix Results Analysis

Using the matrix, the organization's digital maturity was assessed through both quantitative and qualitative methods. The analysis looks at results across three levels: the overall index, functional domains, and digital dimensions.

##### Overall Maturity Index Analysis

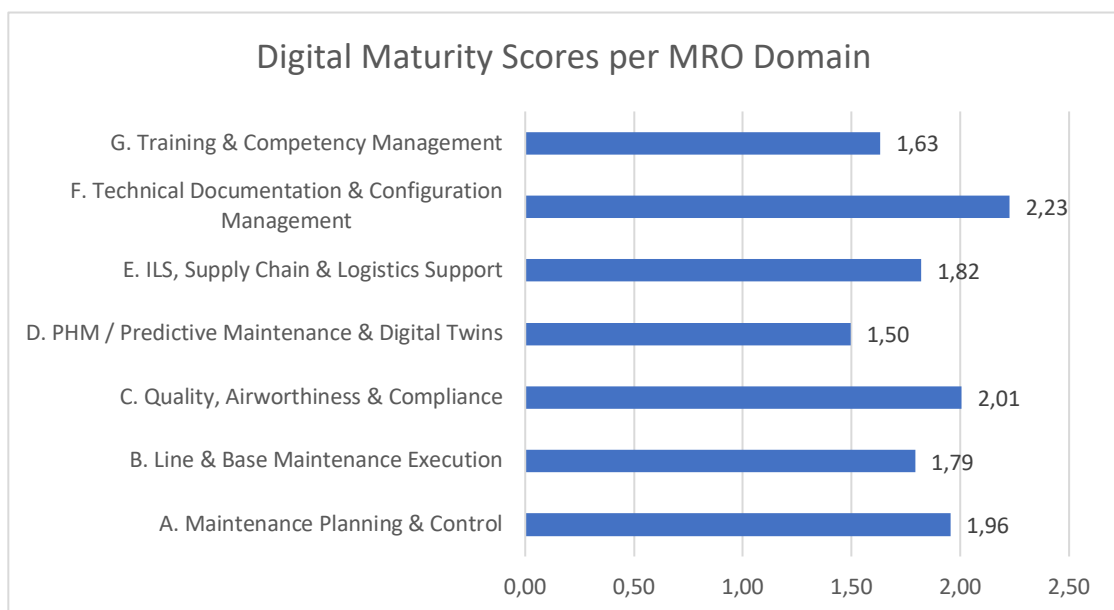
The organization scored 1.85 out of 4.00 on the Overall Maturity Index. On the score scale, this means the organization is at Level 2 (Basic/Managed).

This shows a move from paper-based processes to a basic digital setup. The organization has moved beyond old, isolated ways of working and now manages digital tools, but these tools are not yet fully connected or optimized everywhere. However, since the score is below 2.00, digital tools remain isolated and not yet sufficiently integrated to reach Level 3 (Defined).

##### Functional Domain Performance Analysis

Looking at the functional domains, as shown in the bar chart of Digital Maturity Scores per maintenance Domain, there are clear differences in performance.

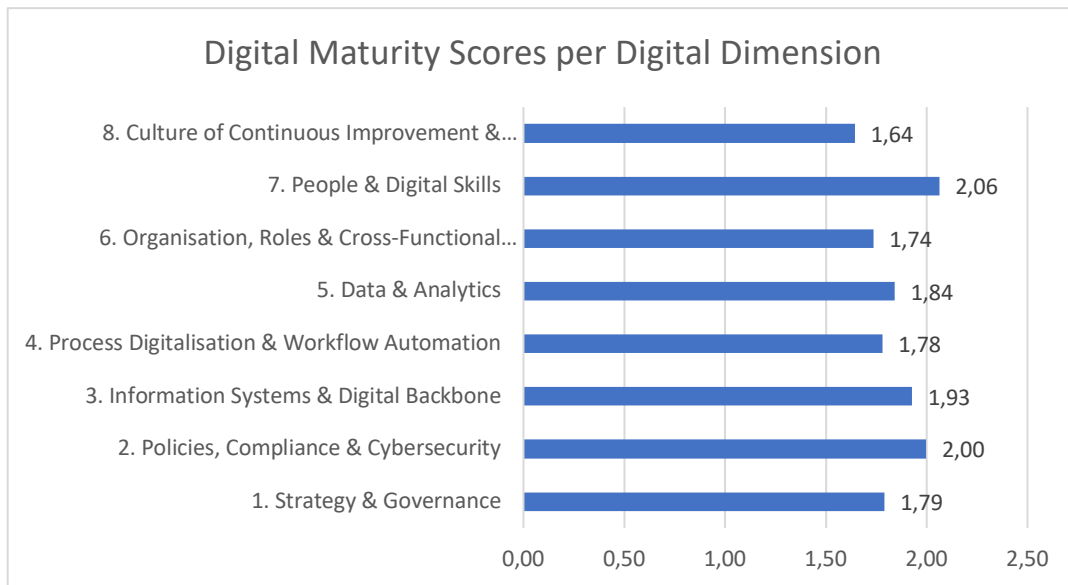
- Domain F (Technical Documentation) had the highest score at 2.23, making it the only domain clearly above Level 3. This shows that managing technical orders and manuals digitally is both mature and standardized in the organization.
- Domain C (Quality & Compliance) was next with a score of 2.01. This reflects a strong focus on airworthiness, with digital audit trails and compliance records now standard practice. The score of this domain is marginally above Level 3 maturity, that means that a big amount of effort and resources are needed to pass the digitalization to the next level.
- Domain D (PHM & Predictive Maintenance) had the lowest score at 1.50, showing a significant technological gap. While modern aircraft produce a lot of sensor data, the organization has not yet set up the analysis processes or predictive culture needed to use this data for proactive maintenance. Priority focus to this domain is essential in order for the organization to be able to implement the digital transformation and improve the overall maturity index.



*Chart 4 Case Study, Digital Maturity Scores per Maintenance Domain Chart (Credit: Own Elaboration)*

#### Digital Dimension Score Analysis

The analysis of digital dimensions, shown in the Digital Maturity Scores per Digital Dimension chart, highlights human-related challenges.



*Chart 5 Case Study, Digital Maturity Scores per Digital Dimension Chart (Credit: Own Elaboration)*

- Dimension 7 (People & Skills) scored highest at 2.06. This means staff have the digital skills needed for a more advanced system. The main bottleneck is not people, but the systems and processes supporting them.
- Dimension 8 (Culture of Continuous Improvement) had the lowest score at 1.64. This indicates that the digital tools are used most of the times to keep records and not to drive innovation. The organization tends to react to events and not to foresee them, and uses technology to document the past results, rather than to improve future procedures.

### Heatmap Synthesis

In modern data analytics, heatmaps are simple visualization methods that turn big, complicated numerical tables into a grid of colors. Each number gets a color from a scale, and usually that scale goes from a deep red for the very worst results, through orange and yellow, and then up to a dark green for the best results and strengths.

For this assessment of how far along in digital improvement the organization is, the heatmap compares the different areas of digital use (DT dimensions) with the different parts of aircraft maintenance (maintenance domains). Using the heatmap, researchers and managers can instantly find the areas where digital teams are working in isolation or don't have the skills they need. It turns a table of score numbers into a clear picture of what is

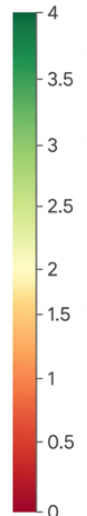
going on, and that clarity provides a starting point for decisions and processes improvement.

Specifically, for the current Case Study analysis, there is the Absolute Scale Heatmap, using a set color scheme from dark red (for score: 0) to dark green (for score: 4). This is a very objective look at how far the company is from being totally ‘Digital-Oriented’.

For the organization of the Case Study, most of the scores are in the lower middle area. As a picture, this means nearly everything on the map is in pale yellows and light oranges. It’s perfectly correct as a calculation, but this lack of different shades makes it oddly difficult to see the small differences in ability between the different parts of maintenance and the different digital aspects.

*Table 27 Case Study, Digital Maturity Matrix Absolute Scale Heatmap (Credit: Own Elaboration)*

|                            |                                                         | Maintenance Domain                |                                      |                                        |                                                 |                                          |                                                       |                                     | Dimension Score |
|----------------------------|---------------------------------------------------------|-----------------------------------|--------------------------------------|----------------------------------------|-------------------------------------------------|------------------------------------------|-------------------------------------------------------|-------------------------------------|-----------------|
|                            |                                                         | A. Maintenance Planning & Control | B. Line & Base Maintenance Execution | C. Quality, Airworthiness & Compliance | D. PHM / Predictive Maintenance & Digital Twins | E. ILS, Supply Chain & Logistics Support | F. Technical Documentation & Configuration Management | G. Training & Competency Management |                 |
| Digital Maturity Dimension | 1. Strategy & Governance                                | 1,93                              | 1,57                                 | 2                                      | 1,21                                            | 2,14                                     | 2,14                                                  | 1,54                                | 1,79            |
|                            | 2. Policies, Compliance & Cybersecurity                 | 1,89                              | 2,14                                 | 2,05                                   | 2,04                                            | 1,79                                     | 2,39                                                  | 1,68                                | 2,00            |
|                            | 3. Information Systems & Digital Backbone               | 1,89                              | 1,96                                 | 2,25                                   | 1,57                                            | 1,96                                     | 2,25                                                  | 1,61                                | 1,93            |
|                            | 4. Process Digitalisation & Workflow Automation         | 1,86                              | 1,38                                 | 1,79                                   | 1,86                                            | 1,79                                     | 2,36                                                  | 1,43                                | 1,78            |
|                            | 5. Data & Analytics                                     | 2,18                              | 1,96                                 | 1,82                                   | 1,36                                            | 1,86                                     | 2,07                                                  | 1,64                                | 1,84            |
|                            | 6. Organisation, Roles & Cross-Functional Collaboration | 1,86                              | 1,54                                 | 2                                      | 1,29                                            | 1,64                                     | 2,14                                                  | 1,68                                | 1,74            |
|                            | 7. People & Digital Skills                              | 2,14                              | 2,25                                 | 2,32                                   | 1,57                                            | 1,93                                     | 2,43                                                  | 1,8                                 | 2,06            |
|                            | 8. Culture of Continuous Improvement & Innovation       | 1,89                              | 1,54                                 | 1,82                                   | 1,07                                            | 1,46                                     | 2,04                                                  | 1,68                                | 1,64            |
|                            | Domain Score                                            | 1,96                              | 1,79                                 | 2,01                                   | 1,50                                            | 1,82                                     | 2,23                                                  | 1,63                                | 1,85            |



To get around this visualization issue, the use of a 'Normalized' heatmap is necessary. With the Normalized Heatmap, the scale of the colors that are used, covers only the range of scores that the organization really got.

Dark green now represents the maximum score (2,43 of cell F7), and dark red shows the absolute lowest (1,07 of cell D8).



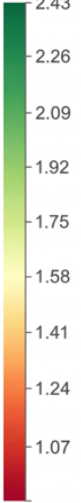
This 'normalization' of the figures essentially expands the colors to their maximum, and makes the internal differences within the company more obvious, as it immediately brings into focus the digital and operational problems and strengths.

The Absolute Scale heatmap is ideal for comparing the company to others in the industry, but the Normalized heatmap is a very accurate diagnostic method for the maturity level of the organization.

It provides the exact basis for creating the step-by-step transformation plan and tells managers specifically which areas (DT dimensions and MRO domains) are most important to improve immediately.

*Table 28 Case Study, Digital Maturity Matrix Normalized Heatmap (Credit: Own Elaboration)*

|                            |                                                         | Maintenance Domain                |                                      |                                        |                                                 |                                          |                                                       |                                     | Dimension Score |
|----------------------------|---------------------------------------------------------|-----------------------------------|--------------------------------------|----------------------------------------|-------------------------------------------------|------------------------------------------|-------------------------------------------------------|-------------------------------------|-----------------|
|                            |                                                         | A. Maintenance Planning & Control | B. Line & Base Maintenance Execution | C. Quality, Airworthiness & Compliance | D. PHM / Predictive Maintenance & Digital Twins | E. ILS, Supply Chain & Logistics Support | F. Technical Documentation & Configuration Management | G. Training & Competency Management |                 |
| Digital Maturity Dimension | 1. Strategy & Governance                                | 1,93                              | 1,57                                 | 2                                      | 1,21                                            | 2,14                                     | 2,14                                                  | 1,54                                | 1,79            |
|                            | 2. Policies, Compliance & Cybersecurity                 | 1,89                              | 2,14                                 | 2,05                                   | 2,04                                            | 1,79                                     | 2,39                                                  | 1,68                                | 2,00            |
|                            | 3. Information Systems & Digital Backbone               | 1,89                              | 1,96                                 | 2,25                                   | 1,57                                            | 1,96                                     | 2,25                                                  | 1,61                                | 1,93            |
|                            | 4. Process Digitalisation & Workflow Automation         | 1,86                              | 1,38                                 | 1,79                                   | 1,86                                            | 1,79                                     | 2,36                                                  | 1,43                                | 1,78            |
|                            | 5. Data & Analytics                                     | 2,18                              | 1,96                                 | 1,82                                   | 1,36                                            | 1,86                                     | 2,07                                                  | 1,64                                | 1,84            |
|                            | 6. Organisation, Roles & Cross-Functional Collaboration | 1,86                              | 1,54                                 | 2                                      | 1,29                                            | 1,64                                     | 2,14                                                  | 1,68                                | 1,74            |
|                            | 7. People & Digital Skills                              | 2,14                              | 2,25                                 | 2,32                                   | 1,57                                            | 1,93                                     | 2,43                                                  | 1,8                                 | 2,06            |
|                            | 8. Culture of Continuous Improvement & Innovation       | 1,89                              | 1,54                                 | 1,82                                   | 1,07                                            | 1,46                                     | 2,04                                                  | 1,68                                | 1,64            |
|                            | Domain Score                                            | 1,96                              | 1,79                                 | 2,01                                   | 1,50                                            | 1,82                                     | 2,23                                                  | 1,63                                | 1,85            |



### Heatmap Analysis

Looking at the heatmap more carefully, Technical Documentation & Configuration Management (Domain F) has the best score, with a rating of 2.23 for the whole area. That's especially true for the DT dimension 7: "People & Digital Skills" (with a dimension score: 2.43, which is the best cell score of the whole matrix), that shows that the technicians in this area have both the skills and are using digital tools as a daily routine to their work.

On the other hand, PHM / Predictive Maintenance & Digital Twins (Domain D) is the most problematic area, only getting 1.50. Within that, the "Culture of Continuous

Improvement & Innovation” only gets 1.07 (which is the lowest cell score of the matrix), showing a general unwillingness of the organization or a lack in tools-equipment-resources to move to the predictive maintenance.

Looking at the different aspects, “People & Digital Skills” (Dimension 7) is highest at 2.06. So, the staff’s abilities are further ahead of the current technical systems. This is good because it means employees could use more sophisticated tools, if the organization spends money on the appropriate systems for the digital transformation and the cost for training will be limited.

### Cell Score Analysis

Looking closely at the maturity matrix results, we can pinpoint the top-ten areas (presented in Chart 6) and the ten that are falling furthest behind (presented in Chart 7), giving a detailed picture of digital abilities throughout the company.

The top-score results indicate the organization's digital strengths lie within Technical Documentation and Configuration Management (Domain F), and Quality, Airworthiness and Compliance (Domain C).

The best single score across all areas was 2.43 in cell F7, for People and Digital Skills in Technical Documentation, and 2.41 in cell F3, for Information Systems in Technical Documentation, was almost as good. From this, we can say the organization has reached a ‘Defined’ level of maturity in the reliability of its data, and has personnel who are skilled in the necessary technology, as well as using consistent methods for controlling and changing documents.

Also, the good scores in areas related to quality suggest that digital records of checks and keeping records to meet legal requirements are now an important, normal element of how the organization operates, and provide a dependable and protected basis for handling important information about safety.

These areas of strength, indicated by the ‘green cells’, mean the organization has successfully completed the digitization process, turning paper records into organized digital files.

This high standard of documentation and adherence to regulations is a benefit to the organization as it means technicians doing the work have the newest, officially approved information, which is essential for flight safety.

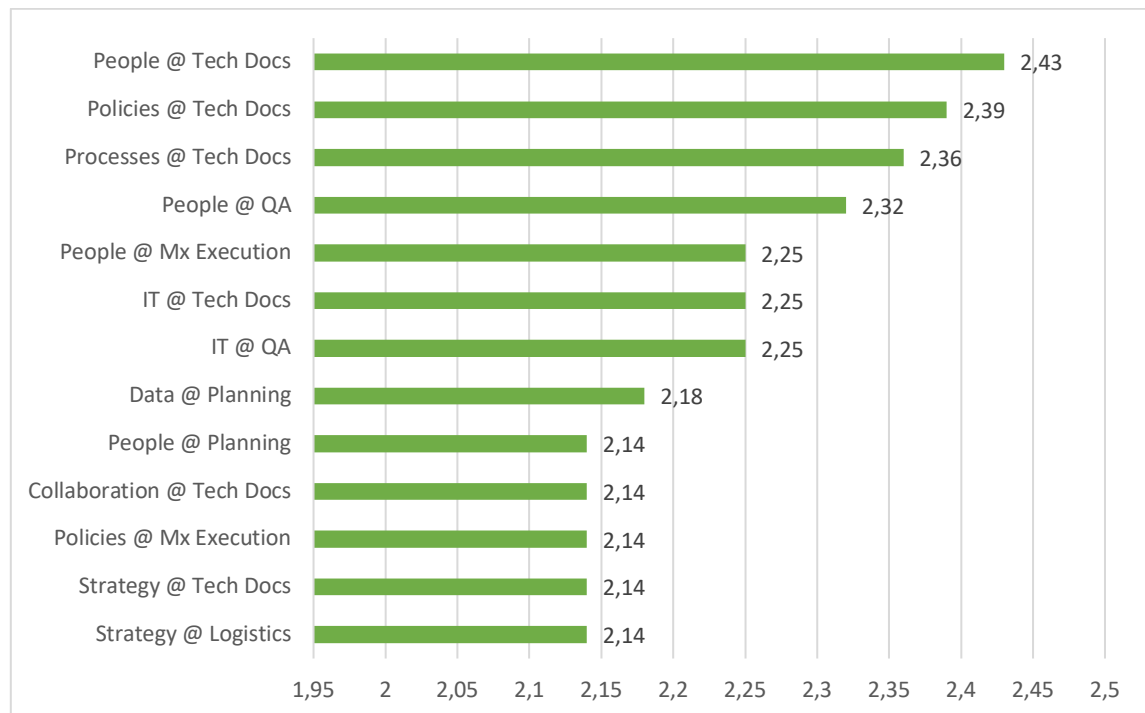


Chart 6 Top-10 Digital Maturity Matrix Cell Scores (Credit: Own Elaboration)

The assessment does also suggest that although the organization is very good at recording what has happened and keeping to current standards, these abilities are currently used only by administrative and regulatory departments and are ready to be used to improve general operations.

Reviewing the ten lowest scores on the assessment reveals a considerable standstill in areas needing sophisticated data use and forward-looking judgements. This clustering of particularly low scores, or “red cells”, demonstrates the organization’s success in recording what has been done, but a deficiency in the technical systems and willingness to see what maintenance will be needed in the future.

The very lowest levels of development were found in Domain D, Prognostics and Health Management / Predictive Maintenance and Digital Twins. Specifically, cell D8 (Prognostics and Health Management Innovation) received a score of 1.07, a very significant deficiency.

Cell D1 (The Strategic Importance of Predictive Maintenance) was a close second at 1.21, and cell D5 (The Application of Data Analysis in Prognostics and Health Management) scored 1.14. These results mean predictive maintenance is at the moment considered as a theoretical idea instead of being done in practice, predominantly because of the absence of a clear plan and appropriate analytical resources.

Another significant collection of low results is apparent in Domain G, Training and Competency Management, specifically in how it is connected to maintenance data in real time and with the use of more realistic technology. The score of 1.32 for cell G3 (Linking Training to Maintenance Data) is a sign that training is a separate, bureaucratic process and does not change as maintenance work and technology evolve.

Moreover, the consistent lack of high scores in Dimension 8 (A System for Constant Development), and its frequent appearance in the bottom ten, points to a firm, “we’ve always done it this way” attitude. This creates a “digital paradox”, where the workforce has the inherent ability to progress, but is hampered by a way of working that reacts to problems, and by disconnected processes that prioritize the present position over improvements using digital approaches.

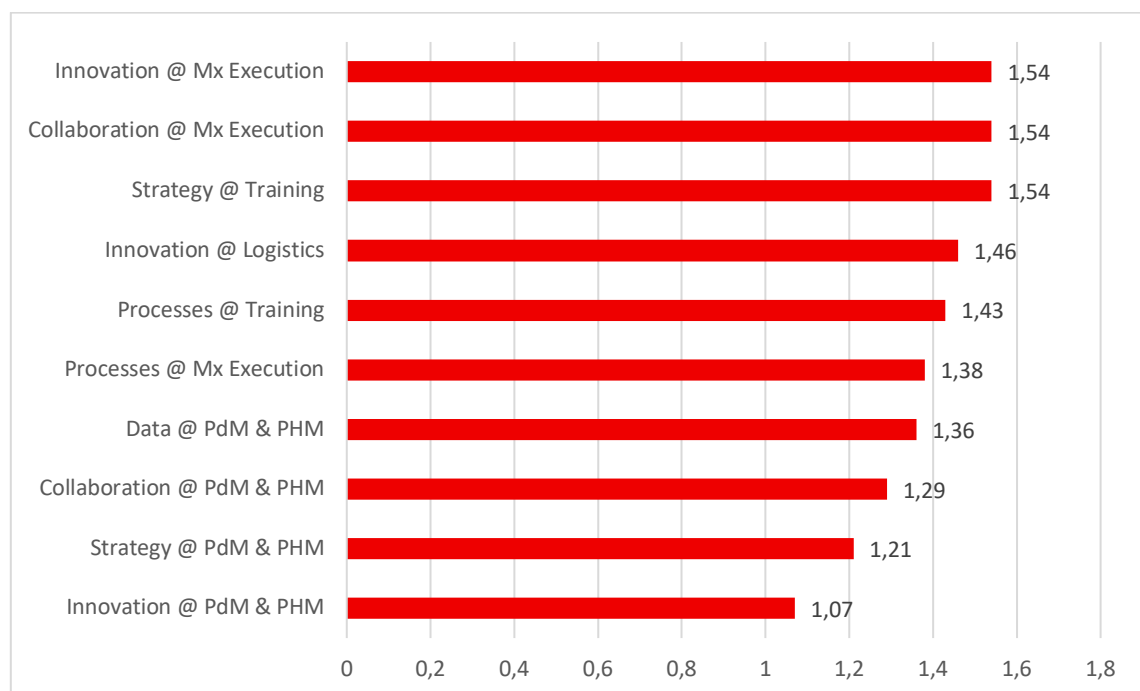


Chart 7 Bottom – 10 Digital Maturity Matrix Cell Scores (Credit: Own Elaboration)

This big difference between the strongest (“green”) and weakest (“red”) sections of the matrix emphasizes that digital transformation isn't happening at the same rate

everywhere, and therefore leadership needs to move funding and support to the departments with the biggest technological shortcomings.

#### 7.2.1. SWOT Analysis

Based on the quantitative data from the heatmap, the following SWOT<sup>10</sup> analysis outlines the strategic position of the organization, while it translates findings of the heatmap into actionable insights for digital maintenance maturity.

- Strengths

**Strong Documentation Foundation:** The high performance in Technical Documentation (Domain F) provides a reliable "data truth" which is essential for any further digitalization.

**Digital Readiness of Personnel:** The workforce (Dimension 7) shows higher-than-average maturity, meaning training programs are working and employees are open to digital shift.

**Solid Compliance & Cybersecurity:** With a score of 2.00, the organization has established a safe environment for digital operations, minimizing the risks of data breaches.

- Weaknesses

**Predictive Maintenance Lag:** The very low scores in PHM (Domain D) show that the organization is still heavily reliant on traditional, time-based, or reactive maintenance.

**Cultural Bottlenecks:** The "Culture of Innovation" (Dimension 8) is the weakest link (1.64), suggesting a "this is how we've always done it" mentality that delays the adoption of new technologies.

**Siloed Automation:** Workflow automation (Dimension 4) remains inconsistent, with significant gaps between different maintenance departments.

- Opportunities

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<sup>10</sup> SWOT analysis is a strategic framework used to evaluate an organization's internal Strengths and Weaknesses, alongside external Opportunities and Threats.

Scaling Best Practices: The success of the Technical Documentation domain can serve as a guide for the digitalization of other, less mature domains like Supply Chain (Domain E) or Flightline Maintenance (Domain B).

Transitioning to Predictive Models: Since the staff is already digitally capable, there is a massive opportunity to implement IoT and AI-driven PHM tools to reduce long-term operational costs.

Standardizing Workflows: Bridging the gap between the high-performing and low-performing domains could lead to a more synchronized and efficient maintenance lifecycle.

- Threats

Technological Debt: If the organization continues to lag in Predictive Maintenance (PHM), there is the risk for the organization to become obsolete compared to competitors who utilize Digital Twins to optimize fleet availability.

Inactivity of Talent: If the digitally skilled workforce is not provided with advanced tools (as seen in the gap between skills and PHM tools), there is a risk of losing high-value personnel to more technologically advanced competitors.

In real life, according to high-level managers of the specific organization, the biggest problem of the company is that skilled employees are increasingly leaving for firms that offer higher salary and a more sophisticated digital environment, creating a continuous "brain drain". In this case, the threat identified by the heatmap SWOT analysis is becoming a serious problem for the firm and immediate actions should be taken by the leadership.

Operational Inefficiencies: The low innovation culture might lead to rising maintenance costs over time, as reactive methods are much more expensive than automatic, data-driven processes.

### 7.3. Maturity Analysis and Recommended Actions (Roadmap)

With an Overall Digital Maturity Index of **1.85**, the organization falls into the **“Building the Foundations” maturity band (Level 2 – Basic/Managed)**. As defined in Chapter 6 (Section 6.1), this scoring shows that while the organization has pass the ad-

hoc digital experiments phase and recognizes the necessity of transformation, the efforts for digital transformation remain fragmented. The digital domain is characterized by isolated actions rather than an integrated ecosystem.

Although the OMI simply provides a general indication, regarding the level of the digital maturity of the organization, a more detailed review of the matrix reveals a unique strategic opportunity that a simple average score would hide. The organization possesses a rare asset: its workforce is digitally more mature than its processes. The People & Skills dimension scored 2.06 (Level 3 - Defined), notably outperforming Organization Roles & Cross-Functional Collaboration (1.74) and Culture of Continuous Improvement & Innovation (1.64).

This difference indicates that the maintenance staff is ready and capable of adopting advanced tools, but they are currently held back by legacy workflows and disconnected systems. The roadmap, therefore, should not focus on “convincing” the staff, but rather on releasing their potentials by improving the infrastructure.

According to the recommended actions roadmap, included in Tables 16 and 24, the priorities for the case study organization, in order to proceed to digital maturity, are summarized but not limited to the following actions (for the corresponding focus areas):

- Make a simple documented DT maintenance roadmap with 3–5 objectives according to the general vision. (Strategy & Governance)
- Establish a simple governance structure/team with specific roles and a meeting calendar. (Strategy & Governance)
- Introduce a small set of KPIs for DT (e.g., % paperless work orders, % data-driven planning). (Strategy & Governance)
- Conduct a gap analysis to identify areas where digital policies are not fully applied and clarify responsibilities. (Policies)
- Improve technical security controls (e.g., multi-factor authentication, automated system logging, and encryption). (Cybersecurity)
- Prioritize a small number of key integrations, such as CMMS to ERP or CMMS to planning tools. (IT)
- Clean up master data (aircraft IDs, part numbers) and define clear data ownership. (IT)
- Provide basic support and training to improve the way systems are used. (Digital Backbone)
- Review digitalized processes to reject unnecessary steps and approvals. (Process Digitalization)

- Introduce simple workflow tools for approvals and notifications. (Workflow Automation)
- Specify clear ownership for each process and its digital representation. (Process Digitalization & Workflow Automation)
- Automate key reports using AI tools where possible. (Data & Analytics)
- Standardize definitions of core metrics (e.g., TAT, MTBUR, AOG rate). (Data & Analytics)
- Define formal working groups for key areas such as planning, PHM, and quality. (Organization, Roles & Cross-Functional Collaboration)
- Introduce combined learning methods (classroom, e-learning, and hands-on coaching). (People & Digital Skills)
- Introduce regular Continuous Improvement (CI) meetings at the team level with simple action logs. (Culture of CI & Innovation)
- Align all the planning practices with the basic templates across the units or departments. (Maintenance Planning)
- Test the use of tablets or rugged laptops for a small team or aircraft type. (Flightline Maintenance)
- Involve quality/airworthiness staff in DT projects from the design phase. (QA & Airworthiness)
- Formalize simple alert thresholds and clearly assign responsible stakeholders for their monitor and review. (PHM)
- Make standard procedures for AOG handling and procurement of critical items. (Logistics)
- Integrate all tech documents and configuration tools with MRO/CMMS and other engineering systems. (Technical Documentation)
- Deploy and use a simple training management system or LMS across all departments. (Training & Competency Management)

Based on the specific “red” and “yellow” cells identified in the heatmap, the following proposed transformation roadmap, organizes the above - mentioned actions into a real, measurable and executable strategic plan. This roadmap is structured into three distinct horizons, performed into three consecutive sprints, in accordance with the agile PM philosophy.

#### Sprint 1: Standardization and Connectivity

Goal: Move from Level 2 (Basic/Managed) to Level 3 (Defined) by fixing the “Digital Backbone”.



The immediate priority is to address the low scores in Dimension 3 (Information Systems & Digital Backbone) and Dimension 4 (Process Digitalization & Workflow Automation). The current score of 1.79 in the Flightline & Hangar Maintenance domain indicates that technicians on the floor are likely struggling with manual workarounds.

**Action 1.1**     Close the “Hangar Floor” Gap: The heatmap shows weakness where Process Digitalization meets Execution. The organization must deploy mobile devices (personal tablets) that allow technicians to access the mature Technical Documentation (Score 2.23) directly at the aircraft. The goal is to eliminate paper printing and manual data entry.

**Action 1.2**     Integrate Disconnected Domains: Currently, Logistics (Domain E) and Maintenance (Domain B) function independently. The priority should be the deployment of an application that works as an interface between the supply chain software and the maintenance planning system. This interface will give the capability to planners to view spare parts availability in real time without accessing multiple systems.

**Action 1.3**     Standardize Data Entry: To prepare for future predictive abilities, the organization must stop entering free-text descriptions. Standardized fault codes must be enforced in the MRO software to improve data quality (Dimension 5).

### Sprint 2: Data-Driven Optimization

Goal: Move towards Level 4 (Integrated) by activating the data.

Once the systems are connected, attention turns to Domain D (PHM), which is currently the weakest link with a score of 1.50.

**Action 2.1**     Test PHM on Critical Fleets: Do not attempt to roll out predictive maintenance everywhere. Select one specific fleet (type of aircraft or squadron) or type of systems (e.g. engines) and establish a “data lab.” Use the existing data from the sensors to create simple notifications for particular failure modes. The goal is to increase value and raise the PHM maturity score to at least 2.50.

**Action 2.2**     Digitize Quality & Compliance: Using the well-established foundation in Domain C (score 2.01), the organization should move from digital record-keeping to digital auditing. Deploy automated workflows for non-conformance reports in

order to reduce administrative overhead and at the same time to speed up decision-making.

Action 2.3     Formalize Digital Governance: The organization needs to move from ad-hoc projects to a managed portfolio. A “Digital Maintenance Committee” should be established to ensure that IT investments correspond to operational capability goals.

### Sprint 3: Innovation and Prediction

Goal: Reach Level 5 (Digital-Oriented).

Only after the foundation is solid, the organization will implement the advanced technologies, as presented in the literature review, increasing the low Culture of Continuous Improvement score (1.64).

Action 3.1     Deployment of Digital Twins: With reliable data now flowing from Strikes 1 and 2, the organization can begin feeding it into structural Digital Twins to support airframe life-extension decisions.

Action 3.2     Prescriptive Analytics: Move from “predicting failure” to “prescriptive solutions”. The systems should suggest the optimal maintenance practices based on mission requirements and logistics constraints.

Action 3.3     Augmented Reality (AR) Integration: Since the workforce has high digital skills, introducing AR for complex troubleshooting can now be done effectively, provided the underlying technical data is fully digital and linked.

### Summary of Strategic Direction

The organization does not need a cultural revolution; its people are ready. It needs a structural development. By focusing the first strike on fixing the broken links in processes and systems (Dimensions 3 and 4), the organization can quickly unlock the value of its skilled workforce, turning the current “Basic/Managed” status into a fully “Integrated” digital maintenance operation.

## The Feedback Loop

At the end of every sprint, the organization will re-assess its digital maturity using the maturity model. This "Sprint Review" ensures that the roadmap stays accurate. If a certain action didn't improve the score as expected, the team can pivot and adjust the backlog for the next cycle.

By following this Assess-Execute-Reassess loop, the roadmap stays relevant to the organization's real-time needs. This repeating process prevents the disruption of trying to change everything at once and helps build a permanent culture of continuous improvement.

*Table 29 Digital Transformation Strategic Roadmap (Credit: Own Elaboration)*

| Sprint                                            | Goal                                                                                         | Key Actions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Expected Outcome                                                                                                                           |
|---------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Sprint 1: Standardization and Connectivity</b> | Move from Level 2 (Basic/Managed) to Level 3 (Defined) by strengthening the Digital Backbone | <b>1.1 Close the "Hangar Floor" Gap:</b> Deploy mobile devices (personal tablets) for technicians to access technical documentation directly at the aircraft, eliminating paper printing and manual data entry.<br><b>1.2 Integrate Disconnected Domains:</b> Implement an interface between supply chain software and maintenance planning systems to provide real-time spare parts visibility.<br><b>1.3 Standardize Data Entry:</b> Enforce standardized fault codes in MRO software instead of free-text descriptions to improve data quality. | Improved workflow efficiency, reduced manual workarounds, better system connectivity, and higher-quality maintenance data.                 |
| <b>Sprint 2: Data-Driven Optimization</b>         | Move towards Level 4 (Integrated) by activating and utilizing data effectively               | <b>2.1 Test PHM on Critical Fleets:</b> Apply predictive maintenance on one selected fleet or system (e.g. engines) using sensor data and simple failure notifications.<br><b>2.2 Digitize Quality &amp; Compliance:</b> Introduce automated workflows for non-conformance reports and digital auditing processes.<br><b>2.3 Formalize Digital Governance:</b> Establish a Digital Maintenance Committee to align IT investments with operational capability goals.                                                                                | Increased PHM maturity, faster decision-making, reduced administrative burden, and stronger governance of digital transformation projects. |
| <b>Sprint 3: Innovation and Prediction</b>        | Reach Level 5 (Digital-Oriented) through advanced technologies and continuous improvement    | <b>3.1 Deployment of Digital Twins:</b> Use reliable maintenance data to support airframe life-extension decisions through Digital Twin technology.<br><b>3.2 Prescriptive Analytics:</b> Enable systems to recommend optimal maintenance actions based on mission and logistics requirements.<br><b>3.3 AR Integration:</b> Introduce Augmented Reality (AR) for complex troubleshooting supported by fully digital technical data.                                                                                                               | Transition from predictive to prescriptive maintenance, enhanced innovation capability, and a sustainable digital maintenance ecosystem.   |
| <b>Feedback Loop</b>                              | Maintain continuous improvement and roadmap accuracy                                         | Reassess digital maturity at the end of each sprint using the maturity model ("Sprint Review"), adjust priorities, and refine the backlog for the next cycle.                                                                                                                                                                                                                                                                                                                                                                                      | Adaptive roadmap, reduced transformation risk, and development of a permanent culture of continuous improvement.                           |

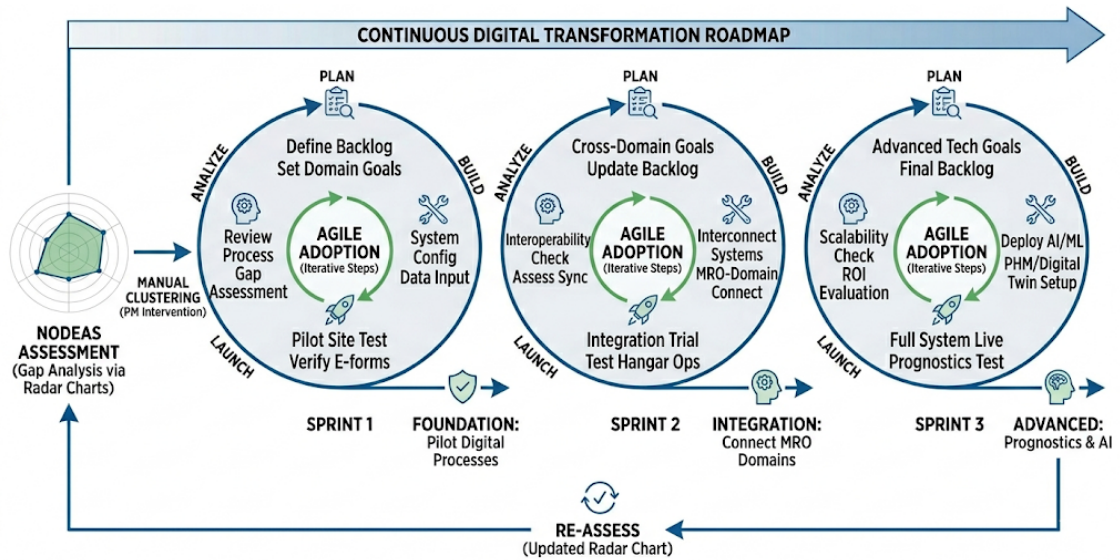


Figure 10. *The NODEAS Framework Digital Transformation Strategic Roadmap. (Credit: Own Elaboration. Generated by Gemini AI - Google, May 2026)*

#### 7.4. Maturity Tool Evaluation

In addition to generating a maturity score for the case study organization, the case study was essential for testing the assessment instrument. The evaluation addressed two main criteria: usability and diagnostic validity.

The high response rate confirmed that the questions were relevant and clear to staff at all levels. However, feedback indicated that the 62-question, 20-minute format is challenging in a fast-paced maintenance environment. Reformation of the future versions will support more frequent assessments.

The tool demonstrated strong diagnostic effectiveness by capturing important indications that generic models missed. It identified the organization's "digital paradox": a workforce with high digital maturity (Level 3 in People & Skills) limited by low-maturity infrastructure (Level 2 in Digital Backbone). A one-dimensional survey would likely have ignored this issue.

A great conclusion, driven by the maturity assessment model, that was verified by high-level managers of the case study organization, was the high experienced and skilled personnel leakage to other (more digital advanced) companies. This leakage was recognized as a threat during the SWOT analysis of Chapter 7.2.1 and proved that the maturity model of this thesis is more than a theoretical tool, but it can be used to gain value and guide organizations to modernization.

## **Chapter 8. Conclusions and Future Research**

### **8.1. Summary Conclusions**

This thesis started with a practical question: how can an aircraft maintenance organization measure its digital maturity and use that information to plan? Although digital technologies are already part of aviation, maintenance units often operate at different speeds, use various tools, and lack a common way to see where they stand.

To answer this question, a digital maturity model designed for aircraft maintenance was developed. The model combines eight key dimensions, such as strategy, cybersecurity, digital backbone, process digitalization, data and analytics, organization and alliance, people and digital skills, and a culture of improvement, with seven main maintenance domains. These domains include planning, line and base execution, quality and airworthiness, PHM or predictive maintenance, ILS, technical documentation and configuration, and training and competency. This (DT dimension) x (MRO domain) matrix helps organizations assess digital maturity both across the company and within essential parts of the maintenance system.

Building on this structure, it was created a survey-based assessment tool using a simple 0-4 scale. This tool turns the daily experience of planners, engineers, technicians, quality staff, and others into maturity scores for each question, each cell (dimension by domain), each dimension, each domain, and an overall index.

In Chapter 7, this tool was applied in a real case study, and the results have been analyzed and showed how the model can reveal specific weaknesses, such as low data and analytics capability in PHM or limited digital skills in line maintenance, as well as strengths. Another key part of the thesis is the set of maturity-based roadmaps.

For every dimension and domain, each score band (Initial, Basic, Defined, Integrated, Digital-Oriented) has been matched with a short description of what the situation usually looks like and a list of practical actions a maintenance organization can take at that level. The case study in Chapter 7 demonstrates how an organization can use these roadmaps to decide where to focus first, using both the overall index and the detailed domain and dimension scores.

Even with some limitations, this thesis offers something practical and valuable: a structured, aviation-focused way for maintenance organizations to discuss digital transformation, assess where they are now, and plan their next steps more clearly and sincerely.

## 8.2. Limitations of the Present Study

Like any model, the maturity assessment framework developed in this thesis has certain limitations, both in terms of its practical implementation and its broader conceptual scope. Most fundamentally, the developed model is designed to evaluate digital processes, systems, and skills rather than physical maintenance execution maturity.

This introduces a critical boundary between digital and manual execution fidelity: an organization might achieve a high digital score through paperless tracking and electronic signatures, yet the mechanical workmanship and physical precision on the hangar floor still rely entirely on manual technician competence.

Consequently, while the framework highlights the strategic importance of the operational feedback loop—where floor-level execution results inform planning—it does not resolve the complex, real-time data integration challenges required to seamlessly capture manual hangar-floor adjustments and feed them back into CMMS or ERP scheduling systems. Beyond this core conceptual boundary, the main empirical and structural constraints of the study are detailed below.

In addition to these core conceptual boundaries, the developed framework exhibits several practical and methodological limitations, as detailed below:

### 1. Limited Testing

The model was created by reviewing existing literature and tested in just one case study organization. While the results matched known challenges and led to helpful conclusions, the model has not yet been used in civil MROs, airline maintenance departments, OEM service centers, or other military settings. Each of these areas has its own challenges, such as different rules, types of fleets and work speeds.

### 2. Bias of Self-Assessment

All the data comes from how participants view their own digital maturity. For example, a planner might rate "Data & Analytics" as Defined, even if there are still

problems with turnaround time (TAT). In this way, the model collects opinions, not actual results and measured performances. To check the model completely, the scores should be compared with real outcomes, such as KPIs for availability, cost, or safety indicators.

### 3. Questionnaire Length

The questionnaire includes 62 questions and lasts approximately 20 to 25 minutes. This is suitable for a pilot study, but it maybe it is too long for regular use, like the annual assessments. Maintenance staff with limited time may not want to fill out lengthy surveys. A shorter version with 35 to 40 questions that still covers all key areas would likely be more practical.

### 4. Generic Roadmap Actions

The recommended actions for each maturity level are based on industry best practices, but they are not adjusted for each organization's specific situation, like fleet age, rules, budget limits, or maintenance issues. What works for a military squadron might not suit a civil MRO company. Future versions of the model could give more options for customization.

These limitations are typical for models developed in a master's thesis. They show both the progress made and the areas that need more work. The model is a good starting point for practical use, but organizations should adjust it to their own needs and compare it with their own performance data.

## 8.3. Suggestions for Future Research

The model provided clear and useful insights in the case study. However, there are still many ways to make it more useful and relevant to specific needs and environments. The following steps are the main priorities for future development:

### 1. Test it over several maintenance organizations

The questionnaire should be used in civil MRO organizations, airline maintenance departments, OEM service centers and military units. Each setting has its own rules, fleet types, work pace and budget limits. This will help determine whether the 62 questions need changes and whether the maturity levels work well in different situations.

### 2. Link maturity scores to hard performance parameters

A key research question is whether higher maturity scores consistently predict improved outcomes. It is necessary to correlate dimension and domain scores with established key performance indicators (KPIs):

- Fleet availability / mission readiness.
- Turnaround time (TAT) and AOG duration.
- Rework rates and findings per specific amount of flight hours.
- Maintenance cost per flight hour.

### 3. Build a web-based assessment platform

Move from using Google Forms to a dedicated assessment platform designed to:

- Auto-calculates all scores and generates dashboards instantly, that can be used during assessment debriefings and progress monitoring.
- Provides customized roadmaps based on organization type (military/civil, fleet size).
- Store anonymous benchmark data to allow comparisons, such as showing an organization's maturity level in PHM compared to the industry average.
- Support follow-up assessments to facilitate progress assessment over time.

### 4. Sector-specific customizations

Different variants of the questionnaire, tailored to assess different types of aviation maintenance organizations, can be deployed, in order to cover specific areas of interest in details. Types of variants that can be developed and the specific areas of focus, are the following:

- Continuing Airworthiness Management Organizations (CAMO), focusing on reliability, and continuous airworthiness.
- Engine shops (specific tools and equipment, processes, OEM dependencies).
- Drones/UAVs (different regulatory environment, different maintenance philosophy).

### 5. Long-Term Studies

Track three to five organizations over a period of two to three years. The process should involve measuring maturity, implementing the recommended roadmap, conducting subsequent assessments and evaluating business outcomes.

This longitudinal approach will demonstrate that the model does not only describe the current practices but also produces measurable improvement.



## Epilogue

The model of this thesis was built to serve as a clear "**norm**" for the aviation industry, setting a standard for what a digital maintenance unit should actually look like.

To achieve this, it uses a process of "**digital evaluation**" that looks at real data and everyday workflows rather than just theoretical ideas, and ensures that digital transformation practices will be smoothly implemented to the organization's culture.

This method is specifically designed for "**aircraft**" maintenance organizations, where safety and reliability are top priorities.

The ultimate goal of the model is to provide the guidance for improving "**sustainment**", ensuring that maintenance is no longer a reactive procedure, but a proactive operation, that anticipates risks and ensures optimal performance.

Bringing all these parts together, we have a tool that explains how to manage the digital transformation of aircraft maintenance in a feasible way.

This model is what we call NOrmative Digital Evaluation for Aircraft Sustainment, or simply NO.D.E.A.S.

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