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NATIONAL AVIATION UNIVERSIT
FACULTY OF AIR NAVIGATION, ELECTRONICS AND TELECOMMUNICATIONS
DEPARTMENT OF AVIONICS

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QUALIFICATION PAPER

(EXPLANATORY NOTES)

FOR THE DEGREE OF «BACHELOR»

SPECIALITY 173 ‘AVIONICS’

Theme: Model of transition from MSG2 to MSG3 maintenance logic for airlines

Done by: ___________AV-410Ba ,Orel Vitalii Volodymirovich_____
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Kyiv 2024

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TASK

for qualification paper

Orel Vitalii Volodymirovich

1. Theme: ‘Model of transition from MSG2 to MSG3 maintenance logic for airlines’, approved by order 355/ст of the Rector of the National Aviation University of 13March 2024.

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4. Content of explanatory notes: List of conditional terms and abbreviations, Introduction, Chapter 1, Chapter 2, Chapter 3, Conclusions, References

5. The list of mandatory graphic materials: figures, charts, and graphs.

№	Task	Duration	Signature of supervisor
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ABSTRACT

Explanatory notes to graduation work “Model of transition from MSG2 to MSG3 maintenance logic for airlines”: 62 pages, 6 figure, 2 tables, 29 references

Keywords: Maintenance, Maintenance steering group, Logic, Methodology.

The object of the research - the process of transition from MSG-2 to MSG-3 logic.

The subject of the research – maintenance steering group logic.

Purpose of graduation work - investigation of the transition process from MSG-2 to MSG-3 logic in airlines

Research Method - Methods of decision theory, reliability theory, statistics theory, information theory, and expert judgment method were used to solve this goal.

CONTENTS

LIST OF ABBREVIATIONS

MSG – Maintenance steering group

AIDS – Airborne Indicating Detection Systems

AMOC – Alternative Method of Compliance

AMP – Aircraft Maintenance Program

AMS – Approved Maintenance Schedule

AOG – aircraft is on the ground

APU – auxiliary power unit

ATA – American Translators Association

BITE – Built-in Test Equipment

CA – Competent Authority

CAA – Civil Aviation Authority

CBM – Condition-based maintenance

CM – Condition Monitoring

CPCP – Corrosion Prevention Corrosion Protection

DI – Detail Inspection

EASA – The European Aviation Safety Agency

ECAC – The European Civil Aviation Conference

FAA– Federal Aviation Administration

FC – Flight Cycle

FH – Flight Hour

FMEA – Failure Modes Effect Analysis

GVI – General Visual Inspection

HT – Hard Time

ICA – Instructions for Continued Airworthiness

ICAO – The International Civil Aviation Organization

ISC – Industry Steering Committee

IWG – Industry Working Groups

JAA – Joint Aviation Authorities

L/HIRF – Lightning/High Intensity Radio Frequency

LLP – Life Limited Parts

MPD – Maintenance Planning Document

MRB – Maintenance Review Board

MRBR – Maintenance Review Board Report

MSG – maintenance steering group

MSI – maintenance significant items

MTBF – mean time between failure

MTBR – mean time between removal

NBAA – National Business Aviation Association

OC – On-Condition

PSE – Principal Structural Elements

PBP&L – Performance-based. Planning & Logistics

PC – Personal computer

PMI – Principal maintenance inspectors

SDI – Special Detail Inspection

SSI – structurally significant items

SB – Service bulletins

ZIP – Zonal Inspection Program

TR – Transit Check

INTRODUCTION

During the era which the aircraft and aviation industry largely growth up, the aircraft manufacturer, and selected industry participants form groups called Maintenance Steering Groups (MSG). The objective of this Maintenance Steering Group (MSG) is to establish the optimal timing for overhauling all components, without consideration for whether they actually require it or not. Prior to the creation of the MSG methodology, there were various approaches to aircraft maintenance planning in aviation. Most of these were based on maintenance schedules that set regular intervals of time or flight hours for maintenance and repairs.

However, this approach did not always take into account the real state of aircraft components, which can change depending on operating conditions. This often resulted in either excessive or insufficient maintenance, which could affect the safety and efficiency of flights.

During the development of the aviation industry in the middle of the 20th century, the first maintenance programs for airliners had the main goal of ensuring flight safety and increasing the service life of aircraft. Since this period was characterized by intensive development of the aviation industry, it was time to establish systematic approaches to maintenance, which became a guarantee of the reliability and safety of aviation flights.

At that time, maintenance programs were based on manual methods and extensive experience of mechanics and engineers. They included inspections of various systems, engines, structural components and other key elements of aircraft. Maintenance schedules were established according to standard procedures that included periodic inspections during regular maintenance stops or when components were replaced in accordance with manufacturer standards.

The creation of MSG was aimed at improving these approaches. The MSG methodology is based on an analysis of the actual maintenance requirements of the components, taking into account their actual condition and history of operation. This allows you to optimize the maintenance schedule, taking into account the real needs of a specific aircraft, which contributes to increasing the safety and efficiency of aviation operations.

In 1962, research into reliability began within the US airline industry. With the initial findings, they successfully engaged the aviation authorities of the USA, namely the FAA, to initiate sponsorship for further development. By 1966, the FAA released a document outlining recommendations for establishing reliability programs, designated as AC120-17A, which served as the framework for crafting systematic approaches to maintenance programs.

The foundational logic of MSG-1 was first formulated and implemented in 1968 during the development of the B747-100/200 aircraft. Collaboratively, representatives from customer airlines and Boeing Inc. devised the MSG-1 manual, titled "Assessment of Maintenance and Development of Maintenance Programs."

The primary objective of the document was to devise methodologies for constructing Maintenance and Repair (M&R) programs that would meet the demands and preferences of regulatory agencies, operators, and manufacturers of JSC (the developer and manufacturer). The MSG-1 document outlined the overall framework and decision-making processes involved in establishing the initial maintenance requirements for a new aircraft or engine. The benefits of the systems approach applied to the aircraft were seen as a rationale for general solutions that could be applied to other new types of aircraft. This led to the release of MSG2 in a few years later, which was applied to the L-1011 and DC-10 aircraft. Thus, the logic of MSG1 and MSG2 was very similar. In particular, a European version of the same concepts called EMSG2 was developed on the same principle in 1972 and was used for the Concorde and A300 aircraft. However, the main difference between these philosophies was the concepts of "by condition" and "condition monitoring" that were introduced, which allowed a drastic reduction in the number of planned overhauls of components. Representations of the maintenance logic allow to reduce the number of components that needed overhaul several times, namely from 400 to 10.

Soon after these developments, the US Army became interested. Their main interest was not cost efficiency, but rather reducing the downtime of their machinery during maintenance. Maintenance programs based on MSG logic greatly reduce this downtime. As a result, a new version of logic was developed, which is based on product reliability control. This program became the basis for the development of the third version of MSG-3. A task force of the Air Transport Association of America ATA thoroughly studied MSG-2 and identified areas for its improvement. First of all, the decision-making logic was clarified, economy and safety were clearly distinguished, and hidden functional failures were noticed. A working group of the Air Transport Association of America ATA conducted an analysis of MSG-2 and identified areas for its improvement. First of all, the decision-making process was clarified, the difference between economy and safety was clearly defined, and special attention was paid to hidden functional failures.

The ATA Association's Working Group conducted an assessment of MSG-2 and pinpointed several aspects requiring enhancement. These encompassed the precision of decision-making logic, the distinction between economics and safety, and the effectiveness in addressing hidden functional failures (FO). Additionally, it is important to note:

- The development of the new-generation aircraft provided attraction and motivation for the evolutionary development of the MSG concept.

- New aviation regulations impacting maintenance programs were enacted, necessitating corresponding adjustments in MSG procedures. These included updated guidelines concerning damage-resistant structures and the implementation of a Supplemental Structural Inspection Program tailored for long-lasting aircraft.

- The escalating expenses associated with fuel and the increasing costs of spare parts and materials prompted detailed assessments of budgets, significantly influencing the evolution of maintenance programs. Consequently, maintenance programs demanded comprehensive evaluations to validate the selection of tasks that truly uphold the safety and reliability standards inherent in the design, or contribute to economic benefits.

Given the information provided, the ATA-affiliated airlines have concluded that re-evaluation of MSG-2 is timely and important. The attempt to develop and revise the document was a joint effort involving the FAA, CAA/UK (Civil Aviation Regulatory Authority in the US and UK), AEA (Association of European Airlines), US and European engine manufacturers. , airlines from various countries, including the US, and the US Navy. This collective effort contributed to the MSG-3 document. Consequently, several disparities emerged between the MSG-2 and MSG-3 documents, evident in both the structuring and delivery of content as well as the specifics of methodology. Nonetheless, MSG-3 did not feature fundamental discrepancies from its predecessor; it was constructed upon sections of MSG-2, the efficacy of which was validated by ten years of dependable aircraft operation employing a maintenance regimen rooted in these principles.

In MSG-3, the route for searching and making logical decisions has been improved to provide a more rational procedure for selecting works AND greater focus on advancing the logical scheme. The MSG-3 logic implemented a top-down approach or failure sequence analysis. At the output of the fault sequence there was a functional fault, which was assigned one of the main categories:

- Safety

- Economy

Each segment encompasses a methodology alongside specific decision logic flowcharts. For instance, the 'Systems & Powerplant' section necessitates the identification of Maintenance Significant Items (MSI) before employing logic diagrams to ascertain maintenance tasks and intervals.

Similarly, within the 'Aircraft Structures' section, the initial phase involves subdividing the aircraft structure into manageable areas or zones. Within these divisions, Structural Significant Items (SSIs) are selected, within which Principal Structural Elements (PSEs) can be pinpointed. A malfunctioning PSE possesses the potential to induce catastrophic consequences. The remaining portion of the structure is denoted as Other Structure (OS).

MSG-3 further furnishes methodologies and logic diagrams for formulating structural inspection tasks. Regulatory directives concerning damage tolerance and the fatigue assessment of structures are also outlined in (FAR/CS 25.571).

Apart from the tasks and intervals delineated by MSG-3, there will be supplementary concerns linked to Certification Maintenance Requirements (CMR). These will be unveiled during an aircraft's Systems Safety Assessment, usually arising from latent failures or concurrent events. These could necessitate extra tasks at varying intervals beyond those outlined in the MRB report.

This thesis examines the model of the transition from MSG2 to MSG3 of airline service logic. Which will allow you to understand the differences between them, namely the logic and the common concept. Which fundamentally affect the safety, economy and overall reliability of airline aircraft.

Chapter 1

Main maintenance steering groups *MSG2,MSG3*

1.1 Review of Maintenance steering group 2

The MSG-1 initiative showcased the airlines' strong desire for a Boeing 747 program aimed at reducing both maintenance-related downtime and associated costs, while also enhancing flight safety. These objectives were not exclusive to the Boeing 747. Motivated by the aspiration to develop universal procedures applicable to all aircraft, a second Maintenance Steering Group (MSG-2) was established.

Building on the experience gained from MSG-1 and removing details specific to the 747, the group developed a maintenance program decision logic suitable for any aircraft system. The results were published in 1970 by the Air Transport Association (ATA) as the “Airline/Manufacturer Maintenance Program Planning Document (MSG-2).” Subsequently, the FAA approved MSG-2 as a reasonable and practical method for establishing new aircraft maintenance requirements, and ATA adopted MSG-2 as a standard for any aircraft under development.

At its core, MSG-2 represents a decision-making logic: a structured, systematic procedure for establishing requirements for scheduled maintenance that ensure a safe, economical, and reliable aviation environment. For unspecified reasons, it is generally assumed that the final maintenance program will be more refined (involving fewer tasks and longer intervals) compared to any previously used procedures.

Essentially, the MSG-2 approach relies more on logic and reliability data rather than personal judgment to determine the necessary maintenance tasks and their timing. Equipment reliability is a crucial aspect of MSG-2 logic, though several traditional concepts related to reliability, age, and maintenance were re-evaluated. These concepts are discussed in greater detail in the following section, but overall, aviation experience and recent research have concluded that relatively few components exhibit a negative relationship between age and reliability within their typical lifespan, although the potential for service-induced failures clearly exists.

MSG-2 is based on the principle that an effective maintenance program must acknowledge these phenomena, which it achieves through decision analysis.

The basic MSG-2 procedure starts by identifying all maintenance-significant components, their functions, failure modes, consequences, and probabilities of failure. Once these components are identified, maintenance tasks are defined that could potentially enhance inherent reliability or detect reliability degradation. Finally, the desirability of performing these maintenance tasks is evaluated concerning the impact on safety, operational performance, or economics resulting from the failure of such components.

A critical assessment of the MSG-2 concept might lead one to prematurely dismiss it as merely systematic common sense. While it certainly embodies that, the real challenge lies in effectively implementing the logic early in the design phase. It has been estimated that fully testing equipment for an entire life cycle under completely representative environments before service entry would require that the design (and thus the technology) be at least 30 years old. In an era when the half-life of much technology is likely less than six years, this is unacceptable in terms of both performance and economics. Therefore, when developing an initial maintenance program, there is often little more than analogous information available to optimize maintenance costs. The MSG-2 concept aims to provide a maintenance strategy that addresses the problem of decision-making with limited information directly.

1.1.2 Categories of Maintenance steering group 2

-Hard Time. A life limit or maximum interval is assigned to a component before maintenance tasks are performed on a part or unit. These intervals apply not only to overhauls but also to the total lifespan of the part or unit

-On Condition. This means we do not wait for the component to fail; instead, throughout its lifespan, we conduct regular inspections, tests, and analyses to assess its integrity and determine its condition. This allows us to make informed decisions and take appropriate actions. Thus, we can define the maintenance process as one involving repetitive inspections or tests to assess the condition of units, systems, or structural components to ensure continued serviceability, with corrective actions taken as necessary based on the condition of the item.

-Condition Monitoring. This means the component or part is left until it fails, without regular inspections, tests, or other monitoring. Simply put, it is a maintenance process that allows a unit to operate until failure. Condition monitoring is not allowed for units whose failure would adversely affect operational safety.

1.1.3 MSG-2 Logic structure

MSG-2 is organized around a sequence of questions and answers designed to identify the necessary scheduled maintenance tasks. This question-answer-default process is conducive to forming a decision tree, as illustrated in Figure 1.

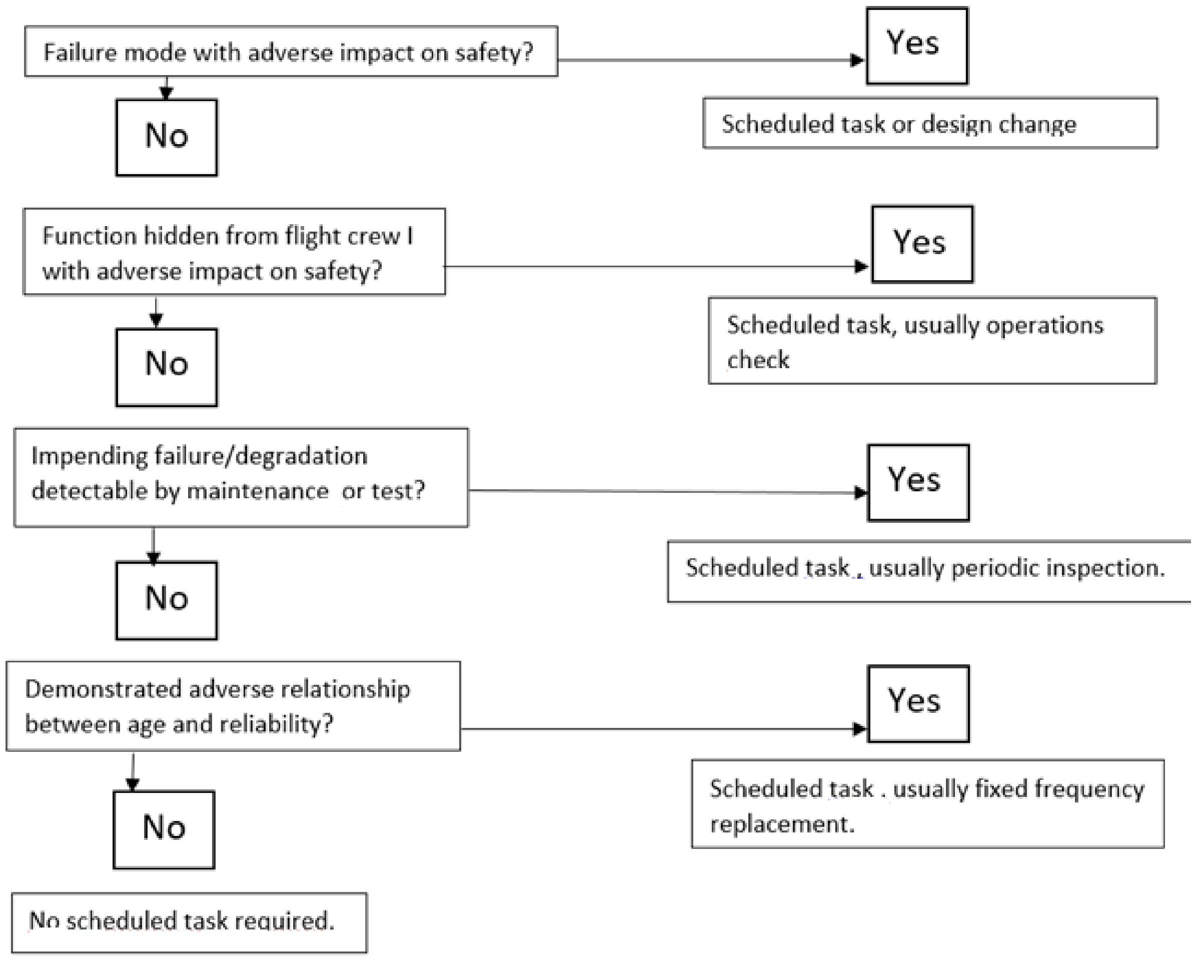

Figure 1: MSG-2 Logic Tree

Question 1 inquires if a failure condition adversely affects operational safety. If the analysis yields a "yes," an effective maintenance task is required, or the component must be redesigned if no suitable task can be identified. A "no" answer leads to the next question.

Question 2 aims to determine if the failure of backup systems providing safety protection might be hidden from the flight crew. If so, a scheduled maintenance task or operational check is needed to ensure the function's availability. If the failure is observable by the flight crew, the next question is addressed.

Question #3 is to determine whether incipient failures can be easily detected. If they can, a periodic preventive maintenance task should be scheduled if it is economically justified. If not, the final question is considered.

The final question seeks to ascertain if there is a specific time limit before failure that can be reliably predicted. If such a time limit exists, a fixed interval replacement task is generally appropriate. If not, no tasks are required for the particular unit under consideration.

It is important to note that the first two questions address the crucial issue of flight safety. The last two questions involve economics and require the judgment of the maintenance planner. Tasks of questionable effectiveness should likely be avoided for economic reasons. However, these tasks could be selectively added later if in-service experience suggests their necessity. Figure 2 provides a conceptual model summarizing the safety and economic implications of failure versus maintenance effectiveness, which encapsulates the objectives of the MSG-2 decision logic tree.

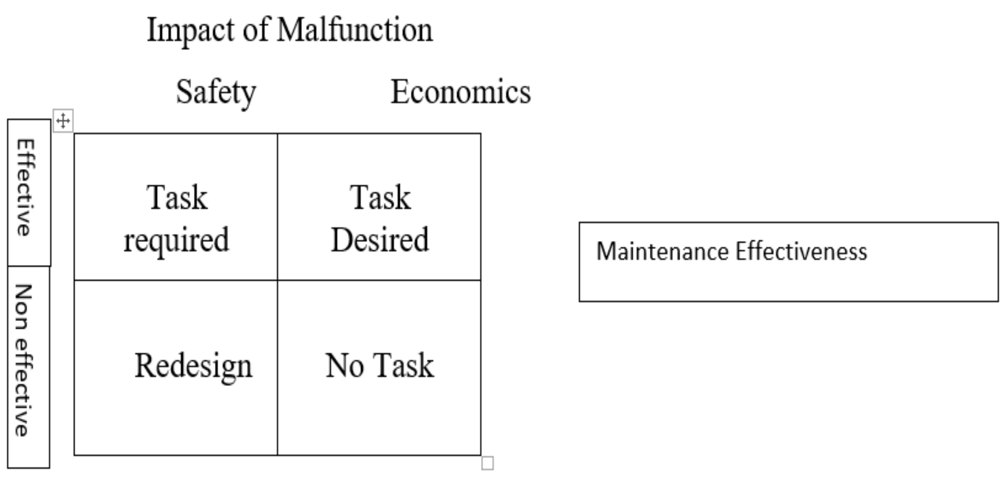

Figure 1.2: MSG-2 Conceptual Model

In essence, the logic tree seeks to identify all tasks that "can" be performed and have potential effectiveness. It then separates those that "must" be done for safety from those that "should" be done for economic reasons. This process results in three categories of maintenance: Hard Time Limit, On condition, Condition Monitoring. This categories was shown in the previous unit.

1.1.4 Revision and changes to MSG2

The MSG-2 approach is "systematic common sense" and more. Upon closer examination, it becomes clear that it is founded on principles that challenge some long-held assumptions and beliefs in the field of maintenance. Industry, airline, and defense participants in the development of MSG-2 identified several former assumptions that were reviewed and essentially reversed under the MSG-2 philosophy. Some of these are outlined below.

1.Former Assumption. Poor maintenance is the cause of safety/reliability problems .

Result of Review. While inadequate maintenance can contribute to equipment failure, the design is of greater importance. If a design is fundamentally unreliable, no amount of maintenance can rectify the problem. At best, effective maintenance can ensure that the equipment operates up to the level of reliability inherent in its design.

2.Former Assumption. More maintenance is better

Result of Review. Any maintenance action has the potential to decrease, rather than increase, resistance to failure. Consequently, reducing unnecessary maintenance can enhance operational reliability. Each potential maintenance task should be thoroughly evaluated to ensure it is more likely to benefit than harm before being implemented. One Air Force study revealed that 40% of the work needed to restore a sample of F-4 aircraft to operational condition was directly caused by failures induced by prior maintenance.

3.Former Assumption. Equipments wear out.

Result of Review. Mr. Tom Matteson , of United Airlines , and partauthor of the MSG-2 concept , points out that in some ways the “bathtub curve doesn’t hold water” for complex equipment.

It is true that many single-component pieces of equipment, such as tires, hoses, and brake pads, do wear out. However, complex systems composed of numerous single-component items, such as radios and hydraulic systems, may never "wear out" as long as the individual elements within the system can be repaired, renewed, or replaced as needed.

The crucial point to consider here revolves around two key facts: (a) any maintenance action carries some inherent risk of damage, and (b) there are issues related to the failure of overhauled equipment when returned to service. Consequently, selective staggered replacement, rather than comprehensive overhaul (where almost every component is replaced simultaneously), becomes more justifiable for reasons of both reliability and economics.

Airlines used MSG-2 on both new and existing aircraft their fleet. Comparing the percentage of hard time limit items prescribed when aircraft initially enter service to the increased reliance on on-condition and condition monitoring today, significant differences are evident. Airlines have reported substantial savings in maintenance man-hours and costs. For example, airframe maintenance costs for the 707, which averaged $56 per flight hour in 1963, dropped to $40 per flight hour in 1971 (both measured in 1963 dollars), despite considerable increases in labor pay scales and material costs. Additionally, during the same period, the aircraft accident rate decreased.

United Airlines, a staunch advocate of the MSG-2 concept, applied this approach to revamp the maintenance program for its DC-8 fleet, yielding equally remarkable outcomes. The depot interval for the DC-8 was extended from 1200 to

2300 hours, significantly reducing the number of time change items from 280 to just 10. Few years later , United Airlines reported that, on average, only one engine was undergoing overhaul for every 100 engines installed on its operational DC-8 fleet.

1.1.5 MSG2 in military sphere

The Department of Defense (DOD) has long been focused on mitigating the operational and support costs linked to its aircraft systems. Therefore, it's unsurprising that the favorable outcomes of the MSG-2 concept in commercial airlines garnered attention. Indeed, both Congressional staff inquiries and interest from the Office of the Secretary of Defense (OSD) contributed to the inception of MSG-2 within the DOD.

Despite the appealing results of MSG-2 in the commercial sphere, there was initially some reluctance to adopt the approach for military aircraft. One contention from the military services was that aviation operations in the military context differed significantly from those in commercial aviation, suggesting that the practices yielding success for airlines might not be directly applicable in military settings.

The Congressional budget hearings marked the legislature's increasing impatience with the escalating maintenance expenses of military aircraft. They highlighted that each year, the military was overhauling and repairing fewer aircraft than initially projected, yet at a higher cost.

Fortunately, studies within the Department of Defense were already in progress, showing that with slight adjustments, MSG-2 procedures could be applied in the military context. The military anticipated that adopting decision logic based on reliability in maintenance would enhance efficiency for at least two reasons:

Firstly, it will validate calculations grounded in real operational experiences, aiding maintenance personnel in decision-making scenarios where there may be a bias toward performing excessive maintenance.

Secondly, by decreasing the duration aircraft remain in depots, it will lower the overall aircraft procurement requirement necessary to sustain a specific number of aircraft in operation. This could either increase the effective force size for a set procurement level or allow aircraft to spend more of their operational lifespan actively deployed.

Therefore, in the same year, the Department of Defense embraced the MSG-2 methodology as the foundation for a reliability-centered maintenance initiative for military aircraft systems. The Defense Policy and Planning Guidance (DPPG) for that year advocated for a restructuring of maintenance schedules for existing aircraft and outlined plans to develop requirements for all new aircraft using a reliability-centered maintenance approach, along with the decision-making logic central to MSG-2. Deputy Secretary of Defense Clements explicitly highlighted the implementation of MSG-2 within the DOD as a specific goal in his Management by Objectives tracking system.

Since then, the OSD has consistently reaffirmed the MSG-2 policy on an annual basis. In the 1977 Defense Guidance document, it directed the Services to begin identifying the costs of implementing MSG-2 for specific aircraft systems in their Program Objective Memorandum (POM) submissions to the OSD:

The Services are encouraged to persist in the development and execution of reliability-centered maintenance strategies for both new and existing aircraft. Program Objective Memorandums (POMs) should allocate funds specifically for the analysis needed to develop and implement these new maintenance strategies, along with a projected timeline for implementation.

The strategies implemented by the Services thus far in adopting MSG-2 serve as the foundation for several subsequent chapters in this report.

1.2. Review of Maintenance steering group 3

Building on the experience and identified shortcomings of MSG-2, the original version of MSG-3 was first published in 1980. It introduced a top-down approach that focused on the 'consequences of failure.' MSG-3 required the assessment of functional failures and classified the consequences into two basic categories: 'SAFETY' and 'ECONOMIC'. Unlike MSG-2, MSG-3 is task-oriented, eliminating confusion related to the various interpretations of 'Condition Monitoring,' 'On-condition,' and 'Hard time.' Another significant improvement was the inclusion of 'damage tolerance rules' and the 'supplemental inspection programs.'

Since 1980, regular amendments have been made to MSG-3, the most recent in 2015 but, as yet MSG-4 has not followed. The latest version of MSG-3 introduced some elements related to Structural Health Monitoring Systems (SHMS), which was the result of issue papers published by the International Maintenance Review Board Policy Board (IMRBPB).

In MSG-3, the process for logical decision-making was enhanced to offer a more rational procedure for selecting tasks, with a greater emphasis on advancing the logical framework. The MSG-3 logic adopted a top-down approach or failure sequence analysis. At the conclusion of the failure sequence, a functional failure was categorized into one of the main categories.

With the introduction of MSG-3 this process was refined to ensure the correct treatment of both “Safety Related” and “Economic Related” as well as including the Corrosion Protection Corrosion Prevention CPCP and Structural Integrity Program considerations including:

-Consequences of failure approach – either safety or economics;

-Distinction between failure evident to or hidden from operating crew;

-Customised task selection in each category;

-Develops an applicability and effectiveness criteria for each task;

-Task selection arranged in preferred task sequence;

1.2.1 Logic of MSG-3

Under MSG-3 logic, activities are assessed at the system level rather than the component level. In other words, if it can be demonstrated that the functional failure of a particular system has no effect on operational safety or that the economic repercussions are not significant, routine maintenance activity is not required.

Although there is no actual in-service operational data available when the MSG-3 process begins for a new aircraft, extensive historical data on the performance of similar components and systems used in earlier designs, along with test data from the manufacturer and component vendors, is available. It is this in-service reliability data of similar components and systems that informs task and interval decisions.

Another principal benefit of the MSG-3 process is that it generally leads to higher safety standards. This is primarily due to a more intelligent approach to maintenance, which involves selecting tasks that are effective. As a result, there are far fewer maintenance tasks, minimizing the infant mortality effect associated with excessive maintenance. Studies in human factors have clearly identified a correlation between excessive maintenance and induced incidents or accidents resulting from preventive maintenance through the replacement and overhaul of components.

Prior to MSG-3, the Corrosion Prevention and Control Program (CPCP) was mandated by Airworthiness Directives. Under MSG-3, the CPCP has been integrated into the baseline Maintenance Review Board (MRB) program and included as part of the structures maintenance program. This integration significantly reduces duplicative tasks.

According to Advisory Circular AC-121-22A, FAA policy requires the use of the latest MSG analysis procedures to develop scheduled maintenance targets for all new or derivative aircraft. This methodology is the only approach accepted by airworthiness authorities. An MSG-3 analysis consists of three primary separate analysis. Systems Analysis, Structural Analysis and Zonal Analysis. Zonal Analysis also includes Enhanced Zonal Analysis (EZAP) and EWIS (Electrical Wiring Interconnection System).

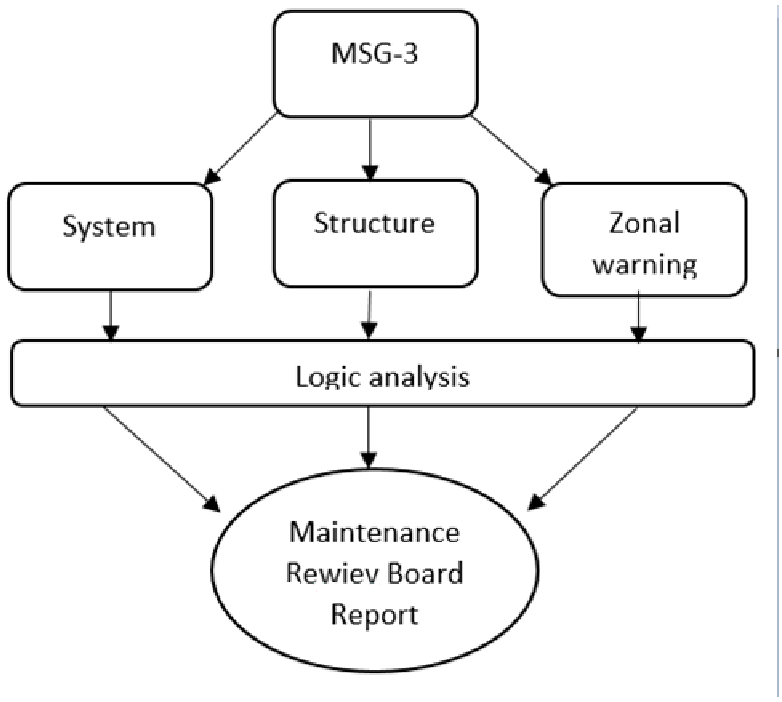

Figure 1.3. Primary Elements of an MSG-3 ananlysis

The Systems analysis consists of the following steps:

1.Identification of Maintenance Significant Items (MSI) – This employs a top-down approach, beginning at the ATA level and progressing to sub-ATA and individual system levels to identify all functional areas. Each identified item is referred to as a candidate MSI.

2.MSI Definition: From the pool of candidate MSIs, the final MSIs are selected. Each chosen MSI must answer "YES" to at least one of the following questions:

-Could failure be undetectable by crew as part of their normal duties?

-Could failure affect safety?

-Could Failure have an Operational impact?

-Could Failure have an Economic Impact?

Once an MSI has been selected, its detailed functional characteristics and descriptions are documented. This documentation includes a system description, interfaces, component details, high-level block diagrams, protective features, and crew alerting systems associated with the function.

3.Functional Failure analysis: Initiated with an exhaustive examination of the MSI function, an assessment is conducted to ascertain whether the function is apparent or concealed, and whether the ensuing functional failure will be apparent or concealed. Subsequently, the impact of the functional failure is established. The failure effect analysis evaluates the consequences of the functional failure through a sequence of inquiries guided by a logic diagram.

4.Failure Cause Analysis and Task Definition. Following the identification of failure causes, the subsequent step involves selecting task(s) to address the failure effect. Utilizing a set of questions derived from the MSG-3 logic diagram, tasks that are both Applicable and Effective are determined. In cases where risk remains unabated by available tasks or their combination, system redesign becomes imperative. The choice of logic diagram type hinges on the FEC Category.

Depending on the result of the analysis one of the following or a combination of the tasks is possible:

-Lubrication/Servicing (All categories)

-Operational/Visual Check (FEC 8 or 9) – Hidden Failure Related.

-Inspection/Functional Check (All Categories)

-Restoration (All Categories)

-Discard (All Categories)

-Combination (FEC 5 and 8 only)- Safety related

5.Task Interval Determination: After identifying a task, the last phase involves establishing its interval. The interval is denoted in Flight Hours/Flight Cycles/Calendar-based metrics such as Days, Months, Years, or, in certain instances, individual component life such as Engine Hours/Engine Cycles/APU Hours/APU Cycles.

Determining the interval entails considering numerous factors, including but not limited to consequences of failure, capability to detect degradation, potential failure to functional failure curves, historical or projected reliability, design maintenance and engineering judgment, vendor recommendations, and manufacturer/operator experience.

1.2.2 Structural Analysis

Structural analysis encompasses fatigue, corrosion, environmental degradation, and accidental damage. It acknowledges new damage tolerance principles, multiple failures, effects on adjacent structures, crack propagation, and supplementary fatigue-related inspections. The MSG-3 methodology ensures the incorporation of the Corrosion Prevention Control Program (CPCP) as part of the structural analysis.

Each structural component undergoes assessment for its importance to ongoing airworthiness, susceptibility to damage, and ease of inspection. These components are referred to as Structural Significant Items (SSIs). An SSI is defined as any element or assembly that significantly contributes to bearing flight loads, ground loads, pressure loads, or control loads, where failure could compromise the structural integrity of the aircraft.

For SSIs there are three proposed Inspection Levels

-GVI stands for General Visual Inspection, which involves visually examining both interior and exterior areas, installations, or assemblies to identify any evident damage, failure, or irregularity. Typically, this inspection is conducted from a close distance without the need for additional aids, except when specified otherwise, and under standard lighting conditions.

-DET/DVI stands for Detailed Visual Inspection, which involves a thorough examination of a particular item, installation, or assembly to identify any damage, failure, or irregularity. This inspection typically requires adequate lighting, which may be supplemented with a direct and appropriately intense light source. Inspection aids like mirrors and magnifying lenses might be necessary for a comprehensive assessment. Additionally, surface cleaning and complex access procedures may be needed to conduct this inspection effectively.

-SDI, or Special Detailed Inspection, involves inspecting a particular item, installation, or assembly using specialized techniques such as Non-Destructive Testing (NDT) or specialized equipment like boroscopes, videoscopes, or tap tests to identify any damage, failure, or irregularity. This type of inspection may require intricate cleaning and substantial access or disassembly procedures to ensure a thorough examination.

During the structural analysis, each Structural Significant Item (SSI) undergoes evaluation for Accidental Damage and Environmental Damage, and a corresponding rating is assigned. The rating and the intervals associated with it are determined using a rating table.

The assessment of Accidental Damage considers factors such as the type of damage, the likelihood of damage occurrence, and the likelihood of detecting damage. On the other hand, the assessment of Environmental Damage considers the exposure of an SSI to unfavorable environmental conditions and the visibility of any damage. Additionally, the review of environmental damage includes an assessment of the Corrosion Prevention Control Program (CPCP).

1.2.3 Zonal Inspection

Zonal requirements are established by evaluating each aircraft zone for accidental damage, operational environment, and accessibility. These evaluations are summarized using a rating system that can be translated into specific inspection task intervals. Furthermore, General Visual Inspection (GVI) tasks from other Industry Working Groups (IWGs) are incorporated into the zonal program.

Chapter 2

Development of scheduled maintenance

2.1 Creating a scheduled maintenance program

In aviation, it is standard practice for initial scheduled maintenance tasks and intervals to be specified in Maintenance Review Board (MRB) Reports (MRBR). The MRBR details the initial minimum scheduled maintenance and inspection requirements necessary for developing an approved continuous airworthiness maintenance program for an aircraft's airframe, engines, systems, and components. The MRBR is created to efficiently comply with the maintenance instruction requirements for developing Instructions for Continued Airworthiness. Through the MRB process, manufacturers, regulatory authorities, vendors, operators, and industry collaborate to develop the initial scheduled maintenance and inspection requirements for new aircraft and on-wing powerplants. The MRBR is intended to serve as a foundation for each operator to develop its own continuous airworthiness maintenance program, subject to approval by its regulatory authority.

Once approved, the requirements outlined in the MRBR serve as a foundation for each air carrier to develop its own maintenance program. In the commercial aviation industry, there is an increasing emphasis on using the MSG-3 methodology to create an initial scheduled maintenance program for the purpose of developing an MRB report. This methodology is widely adopted as it provides a common means of compliance for establishing minimum scheduled maintenance requirements within the framework of instructions for continued airworthiness set by most regulatory authorities. MSG-3 represents a collaborative effort among manufacturers, regulatory authorities, operators, and the Air Transport Association of the USA. The methodology incorporates the principles of Reliability-Centered Maintenance (RCM) to justify task development, though it does not fully implement RCM criteria to audit and validate the initial tasks defined.

MSG-3 outlines the general organization and decision-making process for determining the scheduled maintenance requirements aimed at preserving the lifespan of aircraft and/or powerplants, while maintaining the inherent safety and reliability levels of the aircraft. The tasks and intervals developed serve as the foundation for the initial maintenance requirements issued by each airline, guiding their initial maintenance policies. As airlines accumulate operating experience, they may make further adjustments to optimize scheduled maintenance (ATA MSG-3, 2007). According to ATA MSG-3 (2007), the objectives of efficient scheduled maintenance for aircraft are:

-To ensure the aircraft maintains its inherent safety and reliability levels.

-To restore safety and reliability to their original levels when deterioration occurs.

-To gather information needed for design improvements of items whose inherent reliability is found to be insufficient.

-To achieve these objectives at the lowest total cost, including both maintenance expenses and the costs associated with failures.

The analysis process determines all scheduled tasks and intervals based on the aircraft's certified operating capabilities. The steps in this analysis include (ATA MSG-3, 2007):

-Selection of Maintenance-Significant Items (MSI),

-Analysis of MSIs (identifying functions, functional failures, failure effects, and failure causes),

-Choosing maintenance actions through decision logic.

Example of maintenance check periods and nomenclature:

-A check – every 500 FH. Now known as a P1 check

-B check – every 6 months. Often incorporated into A or C checks

-C check – every 4-6,000 FH / 2-3 years. Now P8, P10 or P12 checks

-D check – every 24-40,000 FH / 9-12 years. Typically a P48 check

2.1.2 Maintenance Review Board

The management of planned maintenance development should be overseen by the Industry Steering Committee (ISC), which includes members representing a diverse group of airlines, as well as representatives from aircraft and engine manufacturers and suppliers. This committee should have the authority to set policies, establish initial maintenance interval objectives, guide working groups and other tasks, and maintain communication between the aircraft manufacturer and airlines not represented on the ISC.

The Maintenance Review Board was initially associated with a group of regulatory inspectors, each with specialized skills, who were charged with the responsibility of approving the initial maintenance program for new commercial aircraft.

Presently, MRB approval is still in the hands of the regulators, but the process is a joint venture between the manufacturer, vendors, operators and regulators. The process entails an Industry Steering Committee (ISC) assembled with representation from manufacturer-vendors, operators and regulatory authorities. An operator chairs the ISC. The ISC delegates the MSG-3 analysis work to the Industry Working Groups (IWGs) that have similar participation to the ISC and are chaired by an operator. Normally, there are five IWGs (Systems, Structures, Avionics-Electrical, Propulsion and Zonal). The working groups analyze the aircraft using the MSG-3 method and the MSG-3 analysis reports are then submitted to the ISC for approval. The end result of this effort is an initial scheduled maintenance program. The initial scheduled maintenance program is submitted by the ISC to the MRB as the draft MRB Report. Upon MRB approval, the MRB Report forms the initial minimum scheduled maintenance requirements. The MRB Report can be used on its own or as part of the Maintenance Planning Document (MPD). It is important to mention that both the ISC and the Working Groups membership consist of a selected elite of the most qualified personnel in terms of knowledge and experience. Participation in the ISC and the IWGs process is recognized as a great privilege. Furthermore, this unique partnership between the Manufacturer-Supplier Operator and Regulator is extremely beneficial to all the parties involved. It improves communication and understanding of each other's needs. It is a reflection of a democratic system where objectives and goals can be achieved in a free and friendly way.

The ISC should advise the MWG to fully consider the needs of suppliers and accept them only if accepted effectively in accordance with MSG-3.

The Maintenance Review Board (MRB) initially comprised a group of specialized regulatory inspectors responsible for approving the initial maintenance program for new commercial aircraft. Today, MRB approval remains with the regulators but now involves a collaborative process between manufacturers, vendors, operators, and regulators. This process is overseen by an Industry Steering Committee (ISC), which includes representatives from manufacturers, vendors, operators, and regulatory authorities, and is chaired by an operator. The ISC assigns the MSG-3 analysis work to Industry Working Groups (IWGs), which have similar representation and are also chaired by an operator. Typically, there are five IWGs (Systems, Structures, Avionics-Electrical, Propulsion, and Zonal). These groups use the MSG-3 method to analyze the aircraft and submit their reports to the ISC for approval. The final product is an initial scheduled maintenance program, which the ISC submits to the MRB as the draft MRB Report. Upon MRB approval, this report establishes the initial minimum scheduled maintenance requirements and can be used independently or as part of the

Maintenance Planning Document (MPD). Notably, both the ISC and IWGs consist of highly qualified and experienced personnel. Participation in these groups is considered a privilege. This collaboration between manufacturers, suppliers, operators, and regulators fosters better communication and understanding, reflecting a democratic system where objectives are met in a cooperative and amicable manner.

One or more working groups may be established, comprising specialists who represent participating airlines, aircraft manufacturers, suppliers, and certification bodies. The ISC can also provide methods for obtaining the detailed technical information necessary to formulate maintenance plan recommendations. Regardless of the organizational structure, the technical data from the analysis, which supports the recommendations, must be presented to the ISC. Once approved by the ISC, these materials should be compiled into a comprehensive report for submission to the certification body.

2.1.3 Selection of maintenance in MSG-2 and MSG-3

The table outlines the maintenance methods employed based on the classification of potential failures. For instance, if a product's failure negatively impacts operational economics, MSG-3 logic assigns SV (servicing) and LU (lubrication) maintenance tasks in addition to scheduled repairs and serviceability checks. In contrast, MSG-2 logic is inadequate in addressing economic conditions, relying solely on standard methods such as component removal at specified intervals and performance checks.

	MSG-1/2	HT	OC	CM	-	-
	MSG-3	DS/RS	IN/OP/FC	-	SV	LU
Impact on security	MSG	X	X			
Availability hidden functions		X	X			
Affects on economy		X	X		X	X
Effects of exploitation		X	X		X	X
Government requirements		X	X			
Term limits exploitation		X				

Table 2.1. The Maintenance methods

2.1.4 Life cycle of systems

The life cycle encompasses all activities for a given system or product, starting with identifying a consumer need and extending through system design and development, production and/or construction, operational use, sustaining maintenance and support, and ultimately, system retirement and phase-out. Given the significant interactions between activities in each phase, it is crucial to consider the entire life cycle when addressing maintainability or any other system characteristic.

Various approaches to life cycle perspectives often focus on specific system properties during its lifetime, such as technical reliability or life cycle cost (LCC) and economic analysis. A comprehensive life cycle perspective must also address the importance of the support system and continuous improvements for systems expected to operate over several decades.

When discussing costs, there's often a tendency to focus solely on short-term expenses, such as those linked to the initial procurement of a system or product. Design development and manufacturing costs are typically well understood, as historical data can inform predictions in these areas. However, the long-term costs associated with system operation and support are often overlooked, despite evidence showing that they can make up a significant portion of the total life cycle cost for a given system.

For instance, while the purchase of a commercial aircraft may amount to $200 million, an additional $2 billion may be needed for its operation, maintenance, and support throughout its economic life, which typically spans 20 to 25 years.

Moreover, when examining the cause-and-effect relationship, it becomes evident that a significant portion of the anticipated life cycle cost for a system arises from decisions made during the early stages of planning and conceptual design. Choices regarding the incorporation of new technologies, the selection of components and materials, the determination of equipment packaging schemes, diagnostic routines, and similar factors exert considerable influence on the life cycle cost.

Illustrated in Figure 2.1 are three generalized projections that depict a substantial commitment to the life cycle cost during the initial phases of system or product development, although these projections may vary depending on the specific system under consideration. While actual expenditures for a project may accrue gradually in the early stages and escalate during later design phases and production, the commitment to the life cycle cost is notably greater during the early stages of system development. For certain systems, as much as 60 to 70% of the projected life cycle cost is essentially "locked in" by the conclusion of the preliminary design phase. In essence, the decisions made during early design stages can significantly influence the maintenance and support costs of a system, which often represent a substantial portion of the overall expenditure.

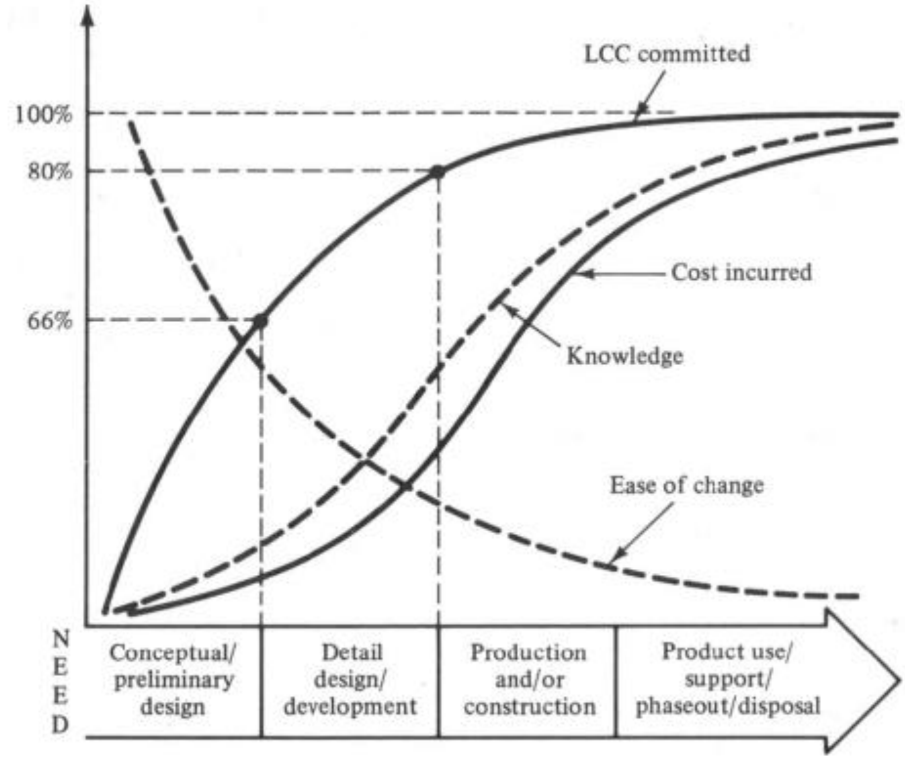

Figure 2.1. Generalized projections

While system performance's technical aspects have been heavily emphasized in design and construction, relatively little attention has been paid to design characteristics like reliability, maintainability, serviceability, supportability, human factors, and environmental factors. Neglecting reliability and maintainability considerations during design often leads to high downstream maintenance and support costs. Moreover, extensive maintenance and support requirements can significantly degrade overall system effectiveness or productivity.

Furthermore, inadequate or erroneous maintenance efforts can result in reduced quality, incidents, and accidents. Therefore, it's crucial to correctly design maintenance and support concepts during the initial phase of a system's life cycle. Additionally, since the maintenance and support system should compensate for any deficiencies in the design of the system of interest, insufficient reliability and maintainability performance necessitate costly logistical resources such as spares, manpower, information and communication technology (ICT), and facilities, all of which contribute to increased Life Support Cost (LSC) and Life Cycle Cost (LCC).

Designing maintenance correctly during the initial phase is critical for complex systems, not only to ensure their performance but also because maintenance significantly impacts the complex system's Life Cycle Cost (LCC).

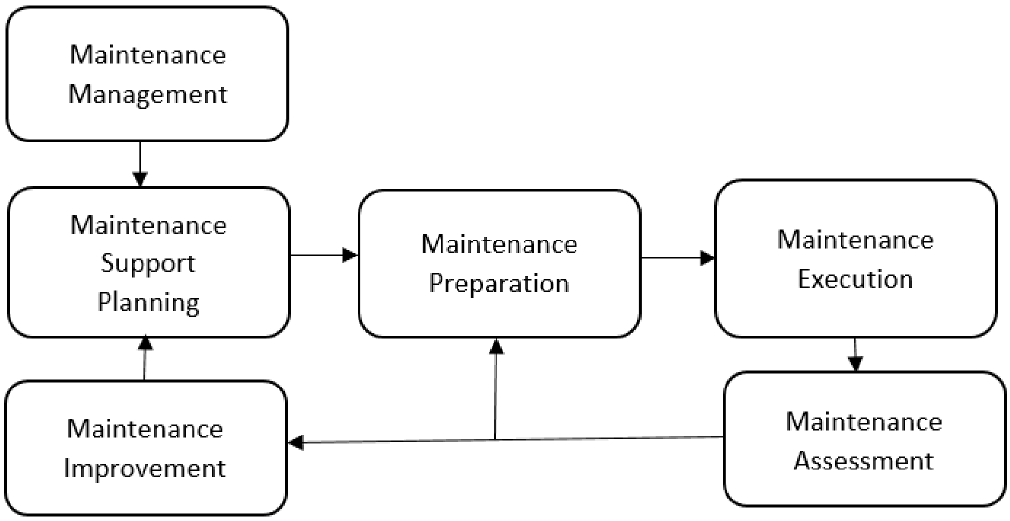

Figure 2.2. A generic maintenance process

Looking from another perspective, the aim of the maintenance process is to ensure a system's capability to meet demand for deliveries, ultimately leading to customer satisfaction. Achieving this goal requires that the maintenance process be efficiently and effectively aligned horizontally with operational and modification processes and vertically with the needs of external stakeholders. As depicted in Figure 2.2, the maintenance process encompasses various activities such as management, support planning, preparation, execution, assessment, and improvement. This portrayal underscores the significance of continuous improvement within the maintenance realm, a concept elaborated upon by Nowlan and Heap (1978), Coetzee (1999), Campbell and Jardine (2001), Murthy (2002), and also outlined in NAVAIR 403 (2005).

According to Murthy (2002), maintenance is perceived as a multidisciplinary endeavor encompassing several key elements: comprehending degradation mechanisms and correlating them with data collection and analysis, furnishing quantitative models for predicting the effects of various maintenance actions, and strategic maintenance management. Furthermore, Murthy identifies three primary steps integral to maintenance management: understanding the system-of-interest, planning optimal maintenance actions, and executing these actions.

There exist two primary maintenance strategies: preventive and corrective maintenance. Preventive maintenance involves proactive measures aimed at preempting potential future issues. Figure 2.3 illustrates these strategies.

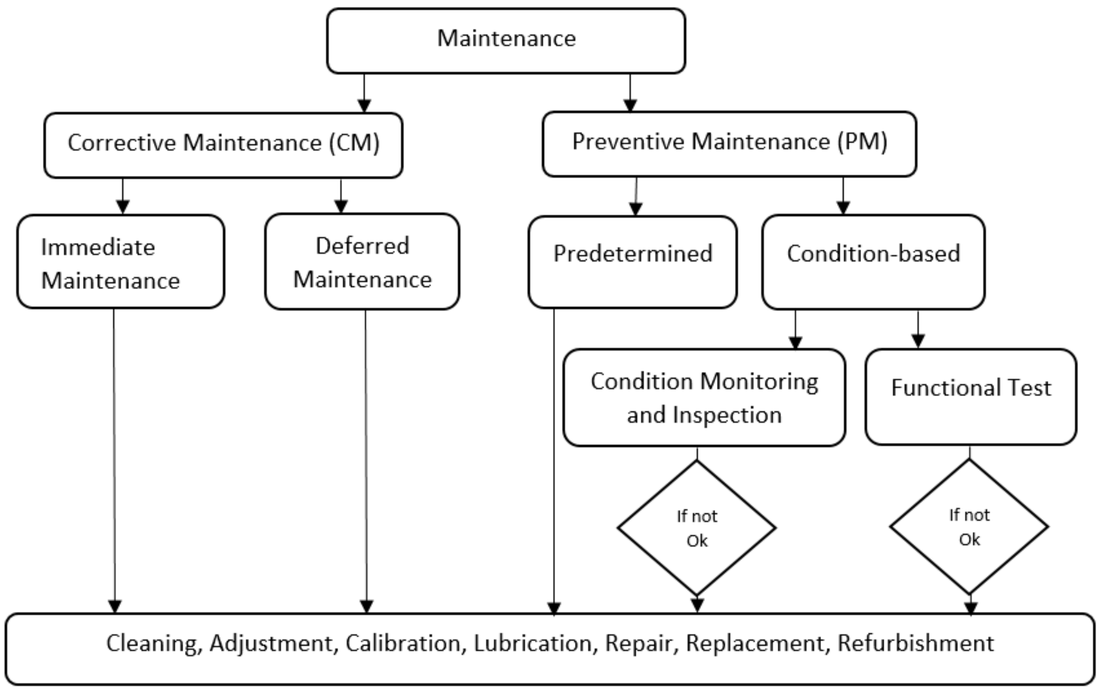

Figure 2.3 Types of maintenance task, adopted from IEC

Conversely, corrective maintenance entails reactive measures undertaken to rectify faults. Examples of corrective and preventive activities include adjustment, calibration, cleaning, lubrication, refurbishment, repair, and replacement.

2.1.5 Certification requirements (CRM)

In addition to the scheduled maintenance intervals determined through MSG-3 analysis, planned work on maintenance (TO) may arise during the certification process as per paragraph 25.1309 of FAR-25. Continuous Maintenance Requirements (CMRs) are mandatory periodic tasks established during the certification process as operational limitations of the type certificate. Typically, they are identified through quantitative analysis conducted to ensure compliance with requirements concerning catastrophic and emergency situations resulting from failures. CMRs are designed to identify significant latent failures that could compromise safety, as the occurrence of one or more such failures could potentially lead to an emergency or catastrophic scenario during flight.

It's crucial to highlight that Continuous Maintenance Requirements (CMRs) are derived from a distinct analysis process compared to the maintenance tasks and intervals justified by MSG-3 analysis. The procedure for aligning maintenance tasks chosen based on MSG-3 analysis with CMRs is extensively outlined in Circular AS 25-19 and is overseen by the Certification Maintenance Coordination Committee (CMCC). This coordination process can impact the established intervals of work adopted by the Maintenance Working Group (MWG).

2.1.6 Methodology for the analysis of the aircraft structure

Every structural component is evaluated based on its significance for the aircraft's airworthiness, the resilience to various types of damage, and the level of complexity associated with detecting each type of damage. Once these relationships are established, a program for scheduled structural inspections (TO) can be devised. This program aims to confirm its efficacy in terms of detecting and preventing structural degradation throughout the aircraft's operational lifespan, whether due to environmental exposure (e.g., corrosion, aging, biodamage) or accidental damage.

The maintenance regimen for the airframe structure, established as part of the scheduled maintenance plan for the airframe, must adhere to the requirements outlined in the aircraft type certification and within the parameters set by the Maintenance Review Board (MRB). Mandatory replacement intervals (resource and service life) for structural components operated within the "safe limits" are incorporated into the Airworthiness Limitations. These limitations are mandated by certification authorities as a component of the Instructions for Continued Airworthiness.

Certain items necessitating instability assessments may also be encompassed, along with specific Corrosion Prevention and Control Program (CPCP) tasks, which are further substantiated by practical in-service observations. Requirements for detecting accidental damage (AD), environmental damage (ED), and fatigue damage (FD), as well as protocols for preventing and/or managing corrosion levels, serve as the foundation for the design of the maintenance program developed under the auspices of the MRB.

Nevertheless, the specifications for the extent of fatigue damage (FD) detection assessments might not be completely defined prior to the aircraft's entry into service. In such instances, the aircraft manufacturer is tasked with establishing mutually agreed upon deadlines for fulfilling the FD requirements—specifically, structural inspections—prior to commencement of operations. Additionally, if deemed necessary, specialized procedures should be devised for other novel materials (such as composites) fundamental to the airframe structure, as their damage characteristics may not align with the procedures outlined in existing documentation.

Important and other elements of construction:

-A Structurally Significant Element (SSI) refers to any component, part, or assembly unit that significantly contributes to the structural integrity essential for ensuring the safety of the aircraft, bearing the impact of air or ground loads, pressure differentials, or control forces and potential failures. An SSI may encompass a Primary Structural Element (PSE), which denotes any component crucial for sustaining air or ground loads, pressure variations, or controlled forces, and whose failure would result in catastrophic consequences. All PSEs are vital design components.

-Another design pertains to elements that are not categorized as structurally significant. These elements are primarily allocated to both the outer sections of the structures and the inner ones within the confines of the zone.

This statement aims to ensure the operator's compliance and should be incorporated into the overall MSG-3 documentation for this product. Subsequently, questions are posed regarding selected crucial items:

-Could the malfunction of this component (or subsystem) compromise safety during ground or airborne operations?

-Would the malfunction of this component (or subsystem) be detectable during regular operations?

-Might the malfunction of this component (or subsystem) impact operation?

-Could the malfunction of this component (or subsystem) influence operational costs?

For products where all four questions receive a negative answer, MSG-3 analysis is unnecessary, and further analysis at lower levels of MSI selection is not required. Additionally, to prevent future reanalysis, lower-level products should be identified to exclude them from evaluation. This exclusion list should be submitted by the manufacturer to the Industry Coordinating Committee (ISC) for review and approval.

2.1.7 Selection of value candidates for the maintenance of MSI objects

Prior to the application of MSG-3 logic to any asset, it is essential to identify Maintenance Significant Items (MSIs) within the aircraft's systems and components. The process of identifying these crucial items for maintenance is methodical and cautious, relying on engineering assessments of the anticipated consequences of failure.

The developer systematically categorizes the aircraft into its primary functional units, such as systems and subsystems, based on ATA sections. This classification also encompasses structural components and emergency equipment. This categorization process continues until all replaceable elements within the aircraft are identified. Subsequently, utilizing the "top-down" analysis approach, the developer compiles a comprehensive list of items to which the MSI selection criteria will be applied.

Before implementing MSG-3 logic circuits for a product, an initial ATA report must be completed, which includes the following details:

-Clearly identifying the product as an MSI (Maintenance Significant Item).

-Specifying product functions, functional failures, and the consequences of failures, along with the reasons for refusals.

-Including any additional relevant information about the product, such as its reference to the ATA section, applicability within the fleet, manufacturer designation, a brief description of the product, expected failure rates, and any hidden functions that need to be listed in the Minimum Equipment List (MEL) for operational aircraft, as well as unit and system reservations. For products that receive a positive response to at least one of the four questions, MSG-3 analysis is required, and the appropriate level for consideration must be determined and approved. It's important to carefully select the optimal level for consideration, ensuring that the product is part of the most suitable systems for evaluation.

An MSI product typically represents a system or subsystem one level higher than the lowest level identified in Step 1. This level is deemed optimal for consideration, as it strikes a balance: it's sufficiently high to prevent unnecessary analysis yet low enough to ensure comprehensive coverage of all functions, functional failures, and their causes.

The working groups evaluate potential candidates for MSI inclusion and, through the MSG-3 analysis, evaluate the most suitable level for subsequent review. Any necessary changes to the MSI list can be suggested by the working groups and forwarded to the Industry Coordinating Committee. The primary objective of this process for the working groups is to ensure that no crucial maintenance item is overlooked and to identify the appropriate level for further examination. It's essential to understand that while a product may be designated as an MSI and undergo analysis, it does not automatically imply that maintenance work will be conducted on that product.

2.1.8 Scheduled technical maintenance

The primary objective of scheduled maintenance for the airframe structure is to sustain the established level of airworthiness throughout the aircraft's lifespan in the most economical manner. To accomplish this, inspections outlined in the maintenance program must fulfill requirements for detecting damage, based on assessments for accidental damage (AD), environmental damage (ED), and fatigue damage (FD). All applicable types of inspections for the specific aircraft fleet must be thoroughly considered.

Additional maintenance tasks related to the Environmental Damage (ED) prevention program, aimed at maintaining corrosion damage at Level 1 or better, are implemented starting from a specified service life threshold established during the aircraft certification process. This decision is based on the combined experience of the manufacturer and the operator with similar airframe designs, considering differences in key design elements such as material selection, assembly processes, corrosion protection systems, and the design of areas like galleys and lavatories.

Non-metallic structures, which may include damage or defects such as delamination, are classified as Structurally Significant Elements (SSI) and require assurance of their strength throughout the aircraft's lifespan. The maintenance of these components is assessed based on operational conditions. Key areas such as primary joints, connections with metal elements, and regions subjected to high stress are considered likely candidates for inspection.

Inspections aimed at detecting fatigue damage (FD) in metals are initiated once the service life threshold established during the aircraft certification process is reached. A selective control program may be employed during these inspections if it is deemed acceptable and effective. Inspections of fixed connections are based directly on the manufacturer's approved assessment results regarding the integrity of the connections. Any modifications or repairs made by the operator must follow mutually agreed-upon and approved procedures.

Tests and inspections for detecting fatigue damage (FD) in non-metallic components may not be necessary, as their design adheres to a "no damage growth" philosophy, confirmed through testing. In the absence of operational experience with similar structures, maintenance requirements should follow the airframe manufacturer's recommendations. The proposed initial scheduled maintenance, intended as a baseline for service design, is established by the Industry Steering Committee (ISC) for each aircraft based on:

- Operating experience;
- Offers by the Manufacturer;
- Considerations of the requirements formed by the input of the analysis system

2.2 Bridging check

During a typical lease transition, the Aircraft Maintenance Program (AMP) may be updated to reflect a different maintenance plan with varying thresholds and intervals, such as those driven by the Maintenance Planning Document (MPD). This transition from one AMP to another is commonly referred to as a "Bridging Check."

When an aircraft is returned at the end of a lease period, the maintenance plan will have evolved from what it was at the lease's commencement. This is normal as the MPD changes over time, and the AMP adjusts accordingly.

A transition plan will assess the various elements of the programs related to the airframe and engine. These elements include:

-Certification Maintenance Requirements

-Airworthiness Limitation Items

-Instructions for Continued Airworthiness

-Airworthiness Directives / Service Bulletins

-Corrosion Prevention and Control Program

-Major Repairs and Alterations

Additionally, based on an operator’s requirements, task intervals may change (increase or decrease). These changes are typically driven by factors such as reliability data or the specific operating environment. Local regulatory requirements may also apply.

It is important to note that lease agreements usually specify return requirements concerning the maintenance plan and thresholds, which must be adhered to.

The aircraft lease may stipulate that the aircraft must be returned in accordance with MPD thresholds, or it may allow for AMP thresholds. It is crucial to understand the return conditions regarding threshold requirements.

A lease statement might include terms such as “pursuant to the MPD”; given that the AMP and MPD can differ, this distinction is significant.

When considering trend analysis and aircraft reliability, a complex and extensive range of metrics, data collection, and decision-making processes is involved. Factors considered include engine/APU trend data, aircraft defect rates, component defect and failure rates, and aircraft technical delay/diversion rates, among many others.

The analysis of reliability information can be utilized not only to enhance the reliability of systems and components but also to improve the overall reliability of the aircraft.

Trends and analysis may reveal issues related to service providers or external entities, in addition to individual components. It is not always necessary to take action on the aircraft's maintenance plan to address the root cause.

Aircraft capabilities, such as ETOPS, are another reliability consideration based on the operating fleet and scope of operations. Special attention should be given to capabilities like ETOPS, where findings that affect or could influence ETOPS capability are collected and considered.

The collected analysis and information should be reviewed and analyzed, with appropriate actions considered based on their impact. These actions may include changing the maintenance program or adjusting thresholds, for example.

It is important to recognize that an AMP (Aircraft Maintenance Program) is specific to an aircraft and, while influenced by many factors, reliability programs can result in changes to thresholds or intervals and the addition of tasks.

Managing an aircraft lease can be complex, involving multiple tasks and considerations related to the return conditions specified in the lease agreement.

Reviewing these conditions against the aircraft and its associated records is crucial to protect the asset's value and ensure a known standard for the next transition.

Depending on your role in a transition, you may also be involved in a "bridging check."

An aircraft can operate under only one AMP at a time, so different operators or a lessor receiving an aircraft will often have different requirements from the current AMP. This necessitates moving the aircraft from one maintenance plan to another, a process known as the "bridging check," which "bridges" the different maintenance plans together.

For instance, a lessee might reduce intervals on some maintenance tasks for reliability, extend others, or add specific operator tasks.

The "bridging check" involves evaluating the tasks, thresholds, and intervals currently used to maintain the aircraft against those required by the next maintenance plan. Any differences, shortfalls, or additional tasks are addressed as necessary.

Maintenance changes and requirements can be influenced by various factors. For example, a lessor receiving an aircraft typically prefers not to have additional tasks or reduced intervals/thresholds, as these could lead to extra maintenance and costs.

The lessor might refer back to MPD thresholds and intervals. It's essential to always check the lease for specific return requirements.

Is the aircraft on an MSG-3 program? Some earlier aircraft may be on MSG-2, resulting in significantly different maintenance programs.

ETOPS: If you lease an aircraft in an ETOPS configuration, it may need to be returned in this configuration, even if you are not an ETOPS operator.

Once the entirety of the task is understood, a bridging check work package may be produced, considering various options to perform the required bridging program.

Remember that the aircraft bridging maintenance obligation rests with the new owner or operator, who must ensure the new maintenance program is fully compliant with all necessary requirements.

2.2.2 Safety

Safety is central to the maintenance philosophy of today’s air carriers. Both MSG-2 and MSG-3 analysis procedures and logic have been used to develop the majority of routine scheduled maintenance and inspection programs for Transport Category Air Carriers operating under 14 CFR 121 (FAR 121). MSG-3 represents a significant shift from MSG-2, offering a more comprehensive decision logic flow, a "top-down" approach to failure consequences, separation of evident and hidden functional failures, and a clear distinction between safety-related and economic/operational consequences. This results in a more straightforward, task-oriented program. This paper does not replace formal MSG-3 training or fully details the transition of maintenance programs but focuses on the safety benefits of converting an existing MSG-2-derived program to MSG-3.

In MSG-3 analysis, a fail-safe system is defined as a system with spare elements that, if they fail, impact safety and operability. In other words, reserve elements can be out of order without the system being complete. The failure of these elements will not be apparent to the flight crew, but the aircraft can still operate in accordance with the airline's requirements. This means the manufacturer's design of the fail-safe system permits ongoing maintenance.

MSG-3 analysis is applied to each failure and cause of failure of each Maintenance-Significant Item (MSI) to maintain the established levels of safety and reliability of the aircraft, without using the extended service system. Extended maintenance tasks can be used to define a fail-safe system for the operator's operational or economic benefit. Such tasks are not processed using MSG-3 and should not be included in the subsequent MRB report.

2.2.3 Economic advantages of MSG logic 3

The basis for creating a new maintenance logic is an increase in the economic component. Improvement of technical maintenance makes it possible to reduce costs and increase the safety component of the aircraft fleet.

The creation of a maintenance program relies on specific information, such as historical and projected aircraft utilization (flight hours per day and flight hours per cycle), whether the current program is a locked program or a phased program, and the details of the old MSG and new MSG programs. MSG-3 offers lower maintenance costs, typically saving 15% to 25% for the same aircraft type when transitioning from MSG-2 to MSG-3. MSG-3 significantly cuts the expenses related to the removal and replacement of complex components. While MSG-3 reduces the number of maintenance tasks, it does not diminish the importance of competency management. Some MSG-3 tasks are economically motivated, while others are implemented to enhance safety. Over a year and a half, the man-hour savings are approximately 12,000 hours per aircraft

- MSG2 - 42,598 hours
- MSG3 - 30,242 years

The primary parameter when planning maintenance is the number of man-hours required by an individual or a team to complete an aircraft maintenance or defect repair task typically expressed as a whole number or a fraction.

The starting point, of course, is to understand the workload, which combines scheduled and unscheduled tasks.

The scheduled workload consists of tasks derived from the Aircraft Maintenance Program (AMP) and additional works, whether generated by the company or driven by regulations.

The Maintenance Planning Document (MPD) is dynamic, and continuously revised to include all changes resulting from STCs, customer requirements, SBs, ADs, etc.

The standard cost is usually indicated in the OEM MPD corresponding to each task under "A," "B," "C" checks, etc.

This forms the baseline for understanding our manpower requirements, enabling airlines, operators, or MROs to plan for maintenance manpower and associated parts requirements. Consequently, it helps determine the ground time required for the relevant work scope of an aircraft, whether for phased or blocked checks, depending on the operator's customized MPD.

Depending on the efficiency of each crew, these costs may deviate from the OEM MPD recommendations.

OEMs estimate the number of man-hours required to perform various maintenance tasks on their products through "time and motion" studies, determining these values for the "average" mechanic equipped with the correct tools and workshop support.

Operators typically set a factor based on their crew efficiency, such as 1.25, 1.5, or 2 times the recommended OEM MPD man-hours. Therefore, to plan effectively, operators must monitor trends and set average costs based on the specific model of each aircraft and/or fleet.

In the context of an MRO or facility with various challenges, such as manpower constraints and material or logistic issues, these OEM estimates may be overly optimistic.

The transition from MSG2 to MSG3 was a solution to the problem of reducing economic costs during maintenance. The logic of MSG3 is considered systemic, structural and zonal. It is this clear and ergonomic approach that creates the economy of this logic. Compared to MSG2, where tasks can be duplicated, disappear, as they are recognized as redundant, some tasks are duplicated. Tasks that are performed in MSG2 can be performed as one in MSG3. Therefore, this logic has optimal advantages for its use in the present.

The cost of an airplane flight hour depends on:

− product maintenance frequency;

- the frequency of planned shooting of products;

- intensity of product failures;

- the cost of repairing the failed product;

− maintenance of product cost;

- the cost of product replacement work.

All versions of the MSG logic are justified by the fact that the probability of failure does not necessarily increase with the operation of the unit. In fact, approximately 95% of all components have failure distribution laws, such as random failures and wear-in. From this, it follows that the operation of products according to the resource in 95% of cases is unsuitable, after that the cost of maintenance is unreasonable and can lead to a decrease in the level of reliability of the products.

During the formation of the list of tasks required for maintenance forms (A-check, C-check, etc.), the intervals for these tasks must be established, as well as the total labor costs for their implementation. Table 6 provides the calculation of labor costs for performing each "A-check" form based on the tasks included in it.

	A1	A2	A3	A4
1A Task	60	60	60	60
2A Task		50		50
4A Task				110
Summary	60	110	60	220

Table 2.2. Forms of “A” check

Example of labor costs for the execution of the "A-cheque" form

- Works provided by 1A can be divided only by one method (they are provided by the skin form and cannot be transferred).

- Works provided under 2A can be divided in 2 ways.

- Works provided under 4A can be divided in 4 ways.

The number of methods for the entire "A-check" form is:

N = 1!*2!*4! = 1*2*24 = 48

Therefore, you can select various options to achieve an optimal distribution of labor costs among forms A1, A2, A3, and A4.

Example of the economic benefit of MSG-3 over MSG-2:

Consider a Boeing 737-400 aircraft using MSG 2 and MSG 3 logic.

This aircraft is used as short-haul/medium-haul. Its usage is 4 flight cycles per day or 8 flight hours per day.

The evaluation period is 5,000 flight hours.

The comparison of these logics is impractical, since the tasks that the MSG-2 logic has in itself may not be present in the MSG-3 due to a more ergonomic approach. With the help of information sources, we can find information on how many man-hours it takes to check all systems. In the case of MSG-2 is 33,955 M/H, while MSG-3 is 25,422 M/H. This information allows you to see the difference in the use of these approaches.

The number of people who use the selected system for maintenance can be calculated using the following formulas:

$$A = FH_p / FH_{t*} MH_t \quad (2.1)$$

A-how many man/ hours required for task by FH_p;

FH_p-period of Flight Hours of aircraft;

MH_t-how many man/hour the task requires;

The average cost per person hour is $32, according to Boeing. Using the formula, we can determine the difference in economic costs when using each of the above logics.

$$B = M/H_A * M/H_{one} \quad (2.2)$$

B= costs of maintenance of all aircraft systems;

M/H_A-all Man/Hours needs for performed tasks;

M/H_{one}-cost of one Man/Hour;

For MSG2 by formula: 33955 *32 =1 086 560$

For MSG3 by formula: 25422*32= 813 504$

Based on the obtained data, we see that the use of MSG-3 logic reduces the company's economic waste by 20%-25%, which plays a very important role for large aircraft fleets and confirms the feasibility of the transition of airlines to MSG-3 logic.

Chapter 3

Perspectives of MSG3 logic

3.1 Adopting the MSG-3 logic

Only recently have other corporate aircraft manufacturers begun to embrace and apply MSG-3 in crafting their maintenance programs. This shift can be attributed, in part, to Bombardier's adoption of MSG-3, prompting the broader corporate and general aviation sector to follow suit. Credit is also due to the NBAA Maintenance Committee for endorsing MSG-3 as the preferred approach for developing scheduled maintenance programs.

Concluding this historical and conceptual overview of aircraft maintenance program development would be incomplete without offering some definitive insights into MSG-3. These remarks aim to inspire others and encourage further dialogue on this topic.

• The progression of preventive maintenance has transitioned from rigid time-based practices with limited reliability to a contemporary era characterized by high-reliability, task-oriented approaches.

• MSG-3 analysis bolsters safety by furnishing justified, lucid, and comprehensive coverage of aircraft systems.

• It enhances design proficiency by upholding safety criticality, mandating detection tasks for safety consequences, thereby necessitating redesign if such tasks are absent.

• Components lacking critical failure modes can now be addressed under the task-oriented paradigm, primarily on economic grounds.

• MSG-3's targeted intelligent maintenance diminishes human error through its precision and minimal intervention.

• Intelligently targeted maintenance, applicable and effective, reduces operational expenses and boosts aircraft availability.

• The amalgamation of MSG-3 analysis with the MRB process yields a user-centric (operator), regulatory-approved, and manufacturer-accepted program.

• The synergy between MSG-3 and the MRB process expedites program approval and facilitates future program modifications (e.g., escalations, deletions, or additions of tasks).

Sustaining effective maintenance programs and enhancing reliability hinge on maintaining a close, ongoing collaboration among maintenance organizations (operators), manufacturers (designers), and regulatory bodies (FAA, JAA, DOT, etc.). This relationship entails empathy, understanding, and acknowledgment of each other's challenges, objectives, and capabilities.

3.2 Future maintenance and MSG-3

The MSG-3 process offers two primary advantages: cost-effectiveness and elevated safety standards. It can be regarded as an intelligent maintenance approach due to its meticulous selection of maintenance tasks that are both relevant and efficient. This approach substantially reduces the number of maintenance tasks, thereby intelligently mitigating the risk of excessive maintenance-related issues, commonly known as the infant mortality effect. Human Factors studies have empirically demonstrated a correlation between excessive maintenance and increased incidents or accidents. Intelligent MSG-3 maintenance can be likened to medical practices. While chemotherapy and radiation treatments may be less effective and can sometimes result in patient harm, a vaccine or antidote approach could offer a more targeted and efficient solution. Similarly, MSG-3's focused maintenance strategy acts as a preventive "vaccine," contrasting with the traditional method of preventive maintenance involving component replacement and overhaul.

MSG-3, characterized by its adaptive and forward-thinking nature, is not a static methodology but rather an evolving framework that responds to emerging technologies and evolving user requirements. In the development of next-generation aircraft, designers are incorporating MSG-3 principles from the outset to prioritize safety and efficiency. Key engineering designers actively participate in Integrated Working Groups (IWGs) to ensure that MSG-3 considerations are integral to the aircraft's design process. The tangible results of this approach can be observed in next-generation aircraft such as Boeing's 777, Airbus' A340, and Bombardier's Global Express and CRJ series, which demonstrate high safety standards, increased uptime, and reduced maintenance costs.

The ATA's Maintenance Subcommittee is presently updating MSG-3 to align with the latest technological advancements. The forthcoming revision of MSG-3 is anticipated to be released in early 2001.

It is noteworthy that corporate and general aviation sectors have traditionally lagged behind commercial airlines and military organizations in adopting maintenance practices. However, there are exceptions to this trend, exemplified by Bombardier's Challenger and Global Express business jets, which adopt a maintenance approach distinct from the broader corporate aviation sector.

Conclusion

In my thesis, was considered the transition model from MSG-2 logic to MSG-3 logic in airlines. The main issue was the approach of MSG logicians to the creation of perfect maintenance. During the implementation, we considered the pros and cons of MSG-2 and MSG-3 logics and their impact on the history of technical operation of aircraft fleets of various companies. The shift from MSG-2 to MSG-3 maintenance logic marks a pivotal stage in the evolution of aircraft maintenance systems. Studies indicate that adopting MSG-3 logic provides substantial benefits over earlier methods, such as reduced maintenance costs and enhanced safety.

The implementation of MSG-3 standards requires close cooperation between manufacturers, operators and regulatory authorities, which ensures a more coordinated and efficient maintenance process. Such cooperation at all stages of the development and implementation of maintenance programs allows for faster approval of programs and the introduction of necessary changes, which increases the efficiency of aviation operations.

Overall, the transition to MSG-3 logic represents a significant step forward in ensuring the safety and efficiency of aircraft maintenance. This benefits all participants in the aviation industry, helping to improve the quality of service, reduce costs and increase the level of flight safety. MSG-3 logic sets new standards in aircraft maintenance that meet the modern requirements and challenges of the aviation industry.

In conclusion, I would like to point out why companies still choose a newer logic for creating a maintenance plan:

1. Cost Reduction: MSG-3 focuses on performing maintenance tasks efficiently, targeting only those that are necessary, thus preventing unnecessary spending on inspections and repairs of components that are not faulty.

2. Enhancing aviation safety: MSG-3 prioritizes identifying and preventing critical failures, thereby enhancing the safety of aviation operations. Through the identification of potentially hazardous failures and the implementation of necessary precautions, the MSG-3 system plays a crucial role in mitigating risks and bolstering the reliability of aviation operations.

3. Work scope optimization: MSG-3 facilitates the efficient allocation of resources and time across a range of maintenance tasks, ensuring that maintenance efforts are focused on areas of greatest need. By doing so, it enhances the effectiveness of maintenance programs while simultaneously reducing unnecessary workload and related costs.

4. Industry stakeholders need to collaborate closely to implement MSG-3 effectively. This collaboration involves manufacturers, operators, and regulatory bodies working together to streamline the approval process for maintenance programs and make necessary adjustments. Through this joint effort, stakeholders can ensure that maintenance practices adhere to regulatory standards and industry best practices, leading to improved safety and efficiency throughout the aviation sector.

5. Introduction of fresh benchmarks: The migration towards MSG-3 marks a notable advancement in guaranteeing the safety and efficacy of aircraft upkeep, in resonance with contemporary requisites and complexities in the aviation sector. This transition towards MSG-3 benchmarks symbolizes a fundamental change towards maintenance practices that are more efficient and fine-tuned, spurred by technological advancements, operational needs, and regulatory standards.

6. Streamlining program approval processes: MSG-3 facilitates the swift approval of maintenance programs and necessary modifications through close collaboration among all stakeholders involved. This entails fostering strong synergy among manufacturers, operators, and regulatory authorities, ensuring efficient communication and alignment of objectives. Such collaboration expedites

decision-making processes, enhances transparency, and fosters a culture of continuous improvement within the aviation maintenance ecosystem.

7. Maximizing resource utilization: The adoption of MSG-3 facilitates the efficient allocation of resources to enhance the effectiveness and safety of aviation operations. This entails strategically distributing manpower, materials, and financial resources to address maintenance requirements while minimizing inefficiencies and maximizing productivity. Leveraging data-driven insights and predictive maintenance approaches enables organizations to anticipate maintenance needs, allocate resources appropriately, and address issues preemptively. This comprehensive approach to resource management optimizes operational efficiency, lowers expenses, and bolsters safety and reliability across aviation operations.

The transition from MSG-2 to MSG-3 maintenance logic represents a significant advancement in the development of aircraft maintenance systems. Originally designed for large passenger aircraft, MSG-3 has proven to be effective not only for this category of aircraft but also for a wide range of aviation assets, including corporate and general aviation sectors. Overall, the transition to MSG-3 logic represents a significant advance in the safety and efficiency of aircraft maintenance, benefiting aviation industry participants.

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