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DEFINITION OF MSG-4: DEVELOPMENT OF THE OVERARCHING STRUCTURE.

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Abstract

In order to meet the challenges envisioned by the introduction of emerging and future technologies, changes to MSG logic and methodologies are required. This document lays out the proposed outline structure for MSG-4, aligning with industry guidelines for the development of Civil Aircraft.

Recommendations for the Development of MSG-4

Table of Contents

1.0 Exec Summary 2
2.0 Introduction 3
2.1 Background 3
2.2 Mission statement 4
2.3 Value Proposition 4
3.0 Design Phase and Requirements 4
3.1 Co-dependency of Structures and Systems 5
4.0 MSG-4 Process Flow 6
4.1 Aircraft Function Flow 7
4.1.1 Alignment of Aircraft Function to Systems and Sub-systems. 8
4.1.2 Physical Breakdown 8
4.1.3 Allocation of applicable analysis methodology to each function 8
4.1.4 Aircraft Structural Analysis 9
4.2 Aircraft Zones Flow 10
4.2.1 Accidental and Environmental Damage Assessment 10
5.0 Conclusion 10
Appendix 1 – Abbreviations 12
Appendix 2 - References 12
Appendix 3 – MSG-4 Working Group Members 13
Appendix 4 – Case Study 14
Background: 14
Case Study for MSG-4 Development 14
LHS of Flowchart: 15
RHS of Flowchart: 19
Conclusion: 21

Recommendations for the Development of MSG-4

1.0 Exec Summary

Since its introduction in the 1980s, aviation technology has significantly advanced, and the MSG (Maintenance Steering Group) methodology has evolved. However, emerging technologies like new aircraft designs, drones, advanced diagnostics, novel materials, and alternative fuels present new challenges. The MSG-4 Working Group believes a revised MSG methodology is necessary to address these. This paper outlines the initial structure for MSG-4 analysis and the reasoning behind it. This is not the complete solution but comprises the first step, establishing the overarching structure following the initial recommendation for MSG-4's development.

MSG-4 will consider the following:

- Retain what works with MSG-3. MSG-3 is the Reliability Centered Maintenance (RCM) process used throughout Civil Aviation; it has been in place since the 1980s. RCM processes are used across all industries to define preventive maintenance for complex assets. The intention is to maintain MSG methodology as an RCM process, but to introduce best practice including a move towards Condition Based Maintenance (CBM) and the alleviation of some of the existing challenges with MSG-3.
- Remove the independent and simultaneous starts for MSG analysis methods. Currently under MSG-3, Structures, Systems, Zonal and L/HIRF analyses start independently and concurrently, with examples of limited interaction between them, although a transfer process does exist. This has been found to result in gaps within the analyses, with some functions missing from the analysis and in some cases whole sub-systems missing from the analysis.
- Introduction of a fully functional approach to the start of the analysis. Functions are not limited to Systems analysis. Valid functions can include carrying loads, transmitting loads, and providing L/HIRF protection. When defining the start of the analysis, focus should be on the functions of the complete asset, before assigning those functions to the system and sub-system. Only after this is resolved should the relevant MSG methodology (i.e. Structural, Systems, L/HIRF, Zonal) analysis be launched.
- Continue to undertake all analyses at the highest manageable level.
- Uses concepts available in SAE ARP4754B which provides Guidelines for the Development of Civil Aircraft and Systems at the start of MSG methodology.

It is determined that the proposed approach for MSG-4 could result in the realization of further benefits:

- Earlier Integration of MSG: Encourage the application of MSG principles earlier in the product design phase.
- Refocusing industry’s attention on maintenance and safety by highlighting the importance of scheduled maintenance concepts from a functional point of view.
- Aligning definitions across the industry, specifically when relating to Condition Based Maintenance.
- Stronger Industry Collaboration: Improve connections with organizations like IATA and SAE through aligned guidance.

Recommendations for the Development of MSG-4

2.0 Introduction

Since the introduction of Maintenance Steering Group 3 (MSG-3) in the 1980s, there have been numerous technological advances within aviation; and Maintenance Steering Group (MSG) methodology has continually evolved over this time. Now though we are facing a step change in emerging technologies and materials, with cutting edge technology including unmanned aircraft innovations, alternative fuels, hydrogen powered and electric aircraft, and integral ground-based systems helping with aircraft operations and safety.

In recent years, there have been increased moves towards off – aircraft data monitoring and the analysis of health and trend data on ground. As we see a progression towards 'digital twin' solutions, it becomes increasingly relevant that off aircraft analysis forms part of the MSG analysis. This inclusion could also extend to the consideration of data transmission and security. Similarly, the move towards autonomous flight and on-ground operations leads to a change in how we consider the terminology of existing workflows.

The drive towards sustainable aviation and reduction in fuel burn has led to a focus on new materials that are both lightweight and strong, including exotic alloys, composites, ceramic matrix composites (CMC) structures. This introduction of materials with both metallic and non-metallic properties requires the introduction of new workflows to account for these material combinations, which fall outside the current MSG-3 structural analysis methodology. The focus on sustainable aviation has also led to a focus on alternative fuels, namely Sustainable Aviation Fuel (SAF) and Hydrogen as well as electric propulsion. While SAF is considered unlikely to lead to any change required to MSG policy, the introduction of hydrogen and electric propulsion require a greater integration of system monitoring and overlap between Systems and Structural analysis methods. The introduction of IAHM for these technologies would require the expansion of IAHM to include safety, as well as non- safety FEC tasks one the monitoring system is certified for credit application. The aviation industry is looking at significant increase in the use of automated systems to control aircraft operations in the future. While many of these changes would not necessarily directly impact MSG practices, the increased use of ground support infrastructure may, which in turn is a driver for change to maintenance practice.

Additionally, a need for an updated approach was identified to eliminate risks of missing, or not analyzing items appropriately and to eliminate gaps between different methodologies; as well as standardizing volumes 1 and 2 to approach aircraft analysis in a type-agnostic manner. Existing differences between Volumes 1 and 2 will be evaluated, and where it is considered to be applicable and effective these differences will be maintained in the final publication.

The MSG-4 Working Group strongly believes that changes are required to MSG logic and methodologies for MSG to remain current and to meet the challenges envisioned by the introduction of emerging and future technologies. This white paper lays out the foundation and top-level structure for the proposed MSG-4 and describes the intent behind the new process.

2.1 Background

The International MRB Policy Board (IMRBPB) voted during the 2022 Policy Meeting to form an MSG-4 Working Group. This Working Group was subsequently created and opened to regulators and members of Maintenance Program Industry Group (MPIG) and Rotor Maintenance Program Industry Group (RMPIG), with a total membership of 30. A smaller task force of 9 was selected to define the scope and whether a move to MSG-4, or whether an iteration of MSG-3, would be warranted. The resulting white

Paper [1] concluded that a new MSG methodology is required to meet the challenges envisioned by the introduction of emerging and future technologies.

2.2 Mission statement

An A4A Task Force was formed to review MSG-3 and identify various areas that are likely candidates for improvement. Some of these areas are the emergence of new technology, impact of aircraft systems and maintenance activities on the environment, and reliability of the aircraft operations across all mission types for the evaluated fleet. Additionally:

a) New generation aircraft (rotorcraft, drones, eVTOL, etc..) and emerging technologies provide a focus, as well as motivation, for an evolutionary advancement in the development of the MSG concept.
b) Extended use of condition-based maintenance should be considered and the impact on the development of scheduled maintenance, including the availability of digital solutions and ground-based capabilities.
c) In order to fully utilize the benefits of this MSG concept we encourage the incorporation of MSG methodology during the requirements phase in order to influence the design solutions.
d) Maintenance programs require careful analysis to ensure that only those tasks are selected which provide genuine retention of the inherent designed level of safety and reliability or provide economic benefit, taking into account all parameters influencing aircraft integrity.
e) Harmonize the development of new MSG documentation and standards with existing and emerging guidance and policies.

2.3 Value Proposition

MSG-4 will provide a clearly defined process to determine the minimum scheduled maintenance for safe and reliable flight, while optimizing aircraft availability and reducing cost of maintenance. This will apply for all aircraft types, creating a platform for development and future innovation.

MSG-4 will remove gaps identified within the current MSG-3 methodologies and enable analysis of future and emerging aircraft technologies. While allowing seamless integration with design processes with simplified traceability to design requirements and clear guidance and best practices on how to properly start the analysis procedures.

3.0 Design Phase and Requirements

Modern aircraft consist of a large number of integrated systems, many of which are designed and developed by different organisations and original equipment manufacturers (OEM). These have an increasing level of integration and dependencies among them. This also leads to increased integration between the aircraft functions and the systems which implement them, in addition to having functions being performed jointly across multiple systems. The complex integration of these systems requires careful development and design discipline to ensure that safety and operation requirements can be achieved and subsequently maintained.

While MSG-3 Systems analysis has always focused on system integration and the performance of function within systems, the same cannot be said for other MSG-3 analysis streams. Traditionally MSG-3 has assumed that systems engineering principles are purely applied to ‘systems’, when in fact systems engineering concepts apply throughout the aircraft architecture. This integrated approach to systems engineering is reflected in SAE ARP4754B[2] which lays out the Guidelines for Civil Aircraft and Systems which are widely used across Civil Aviation.

Recommendations for the Development of MSG-4

A good systems engineer will consider a complex system in a holistic way, designed to deliver a set of functions, paying special attention to the interactions within various subsystems, understanding that everything interacts with everything else. As aircraft design becomes increasingly reliant on systems of systems, the introduction of future and emerging technologies requires a greater integration of system monitoring. There is an increasing overlap between, what has been traditionally viewed within MSG-3 as 'system' and 'structures' analysis methods. It is clear, therefore, that a new approach is required to define how and when the MSG-3 analysis streams are used, in addition to reviewing the process flows within those analysis streams.

The purpose of MSG is to prevent deterioration of the inherent safety and reliability levels of the aircraft and to restore safety and reliability to their inherent levels throughout its operational life. This is achieved by putting in place maintenance tasks that are both applicable and effective at preventing or detecting functional failures and doing so at the minimum total cost. To do this it is necessary to understand the integrated nature of modern aircraft design; by aligning MSG methodology with the systems engineering approach used to design aircraft and aligning with the process steps introduced through ARP4754B we can ensure that the integrated nature of modern aircraft systems is fully accounted for.

3.1 Co-dependency of Structures and Systems

The White paper: Recommendations for development of MSG-4 [1] indicated that a co-dependency of structures and systems is necessary to enable successful hydrogen, and potentially also large all-electric propulsion, concepts. This crossover of systems and structures is considered to be outside the capability of the existing MSG-3 methodology, and new methodology would be required for MSG-4. In addition some new aircraft designs will depend on the use of ground-based control and analysis systems which will be critical to the operation and safety of the aircraft. This too requires a new look at MSG guidance.

The current MSG-3 Systems, Structural, L/HIRF, and Zonal analysis streams initiate independently and concurrently, allowing for the possibility that some analysis items may be overlooked. Anecdotal evidence has revealed numerous instances of items of analysis and specific functions falling between the gaps of the Structural Significant Item (SSI) and Maintenance Significant Item (MSI) methodologies. Examples where functions have been missed today include the function of the security clip on top of the wing to allow a life raft to be tied off. Another example is structural components within an engine, while engine mounts are Principle Structural Elements (PSE) and therefore must have structural analysis carried out, the same is not true for the engine hardware that attaches to the engine mount, with examples of system analysis but no structural analysis being performed. With no overarching analysis and structure there is effectively no check to ensure that all possible failures, whether under structural, system or L/HIRF have been considered and, where appropriate, assessed against the relevant MSG-3 analysis stream.

Re-evaluating the co-dependency between structures and systems will also promote the integration of the MSG-3 Volume 2 methodologies that require supplemental Accidental Damage (AD), Environmental Damage (ED) analyses for the rotor systems components.

4.0 MSG-4 Process Flow

The proposed MSG-4 process develops scheduled maintenance tasks via use of a guided logic approach, and as with MSG-3, will result in a task-oriented program. The proposed process flow for MSG-4, shown in figure 1, builds on the foundations of MSG-3 and its top-down approach, but has two fundamental differences. Firstly, it introduces a guided logic flow with common starting points for all MSG-3 Analysis methodologies. In doing so, it removes the independent, concurrent starts for MSG-3 methodologies and introduces an overarching structure to the whole analysis. Secondly it introduces systems engineering principles to the complete analysis, thereby aligning with industry standard guidelines for the development of Civil Aircraft and Civil Aircraft systems.

The detail provided in this white paper consists of the first phase of the analysis and stops at the start of each MSG-4 analysis procedure (Systems, Structural, L/HIRF, Zonal and Electrical Wiring Interconnection Systems (EWIS)). These analysis streams themselves will be the subject of further work and will be defined in future white papers. While the intention is to retain Structural, Systems, Zonal and L/HIRF analysis streams, it should be noted that EWIS is currently a placeholder and may be merged with other analysis streams if deemed appropriate. It is also noted that at this stage it is assumed that Stand-Alone Emergency Equipment is a sub-category of Systems analysis. This too is a place holder and may change if deemed appropriate.

The proposed process for MSG-4 features two flows, one starting with the aircraft functions, the other starting with the aircraft zones. Between them they provide the starting point for all MSG-4 Analysis Methodologies, creating an over-arching structure for the complete analysis which is missing from MSG-3.

- The Aircraft Functions flow is a true top-down analysis and aligns with the initial steps from ARP4754B Guidelines for Development of Civil Aircraft and Systems, which starts with the need to define and identify Aircraft Functions.
- The Zonal flow concentrates on the physical hardware and provides the starting point for Zonal and EWIS analysis methods, while additionally acting as 'catch all' for the other MSG Analysis Methodologies.

Following each analysis procedure, the task list and requirements are prepared. This is then assessed through a Task Consolidation exercise to ensure that where practicable the tasks and task intervals within an individual system, subsystem and LRU are aligned. While it may not always be possible to align maintenance, the intent is to minimize maintenance burden where practicable by aligning tasking and task intervals with maintenance being performed in the same area or on the same LRU where practicable.

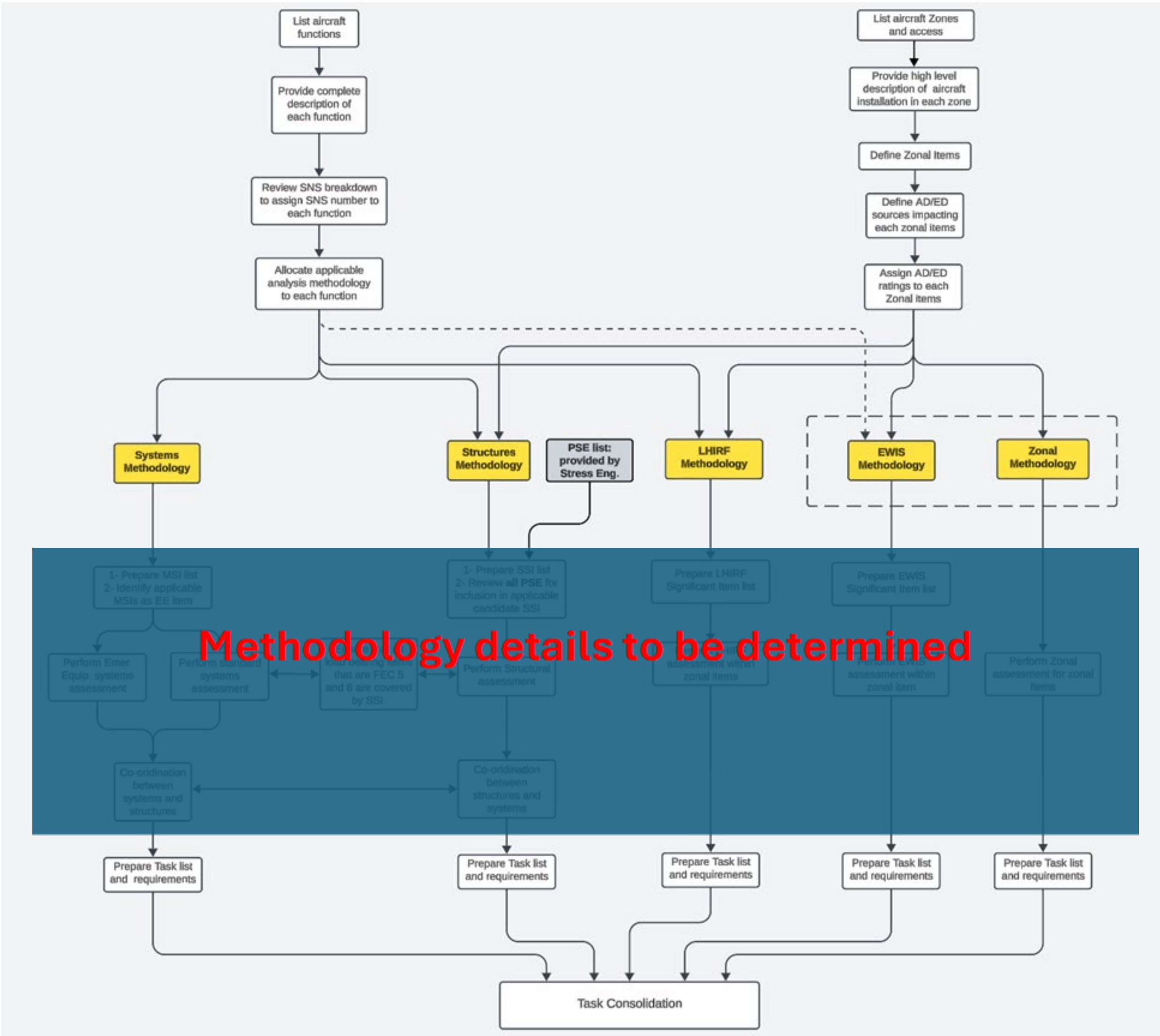

Figure 1: Proposed MSG-4 Process flow.

4.1 Aircraft Function Flow

In order to ensure that all functions are accounted for, and that preventative maintenance can be put in place to prevent or detect the corresponding functional failures, it is necessary to understand what those functions are. The starting point for MSG-4 is therefore considered to be the list of functions that the aircraft is performing. This is typically derived from the list of Aircraft Requirements.

The Aircraft Functions flow is a true top-down analysis and aligns with the initial steps of ARP4754B which starts with the need to define and identify Aircraft Functions. The output of the defined activity 'Aircraft Function and Requirement Development' is a list of aircraft requirements, a subset of which is the aircraft functions. This output may be considered the input for the MSG-4 analysis. By utilising the same output, we are also able to eliminate additional workload within OEMs at the early stage of MSG while aligning with Industry standard guidelines and processes. For those OEMs which are not following ARP4754B, the same approach is followed – starting with the Aircraft Requirements and the Aircraft Functions.

This understanding of aircraft functions should extend beyond the aircraft physical asset to include those functions which take place either partially, or fully, off-aircraft. In this way functions related to, for example, remote piloting system that are a part of aircraft type certification must also be included, while functions related to ground-based health monitoring are desirable to be included to support operators as IAHM is described as an end-to-end system.

4.1.1 Alignment of Aircraft Function to Systems and Sub-systems.

Aircraft functions, defined in the Aircraft function and requirement development are aligned to the aircraft system, or systems, where each function is being performed. This step effectively groups the functions and aligns them to the system level. Data such as system description, system requirements, interface description, system schematics and functional block diagrams are additionally used to develop the full list of all aircraft functions. This is treated at the appropriate and detailed level. It is noted that some functions may be at Line Replaceable Unit (LRU) level for integrated systems.

Each function should carry a detailed description to allow allocation to the appropriate MSG-4 Analysis Methodology. It shall not be necessary to list all functional failures, failure effects or failure causes at this point of the analysis.

4.1.2 Physical Breakdown

Following the alignment of functions to systems and sub-systems, the following action partitions the aircraft into major functional areas, ATA or SNS Systems and Subsystems. At this point the functions aligned to systems can also be mapped across, creating a complete understanding of all aircraft functions, the systems to which they align, and the relevant ATA or SNS chapter. At this point all aircraft LRUs are listed regardless of the failure consequence, this includes ATA 6X for turboprop and rotorcraft and 7X for engines.

Each function at aircraft, system and sub-system level should carry a detailed description to allow allocation to the appropriate MSG-4 Analysis Methodology. It shall not be necessary to list all functional failures, failure effects or failure causes at this point of the analysis.

Although this step most closely aligns with that of MSI Candidate Selection in the current MSG-3, it consolidates the starting step for multiple MSG-3 Analysis Procedures. As per the existing MSG-3 Procedure, the analysis, and the physical breakdown are treated at the highest manageable level.

It is noted that when considering off-aircraft functions and systems, there may not be a relevant ATA chapter; Although it is also noted that SNS Chapter 43 includes tactical communications including means of communication from the vehicle to the ground.

4.1.3 Allocation of applicable analysis methodology to each function

From the physical breakdown, classification is carried out to allocate the applicable analysis method for each function. The allocation for applicable analysis can include applying Systems and, or Structural, and or L/HIRF methodology. The intention is that all functions of an aircraft are correctly assessed with the appropriate analysis method.

During discussions within the MSG-4 Working Group, two possible options were discussed. The first option was to carry out a full function, functional failure, failure cause, failure effect analysis for each function within that item of analysis, and from there to classify each functional failure to relevant Analysis Procedure (Systems (L1&L2 analysis), Structural, Zonal, L/HIRF). While incredibly thorough it was felt that this would unnecessarily over burden the analysis. It was also considered that it would be premature to do a full assessment at this early phase of the analysis and that it was very likely that not all details would be available. As a result, a second option of a more streamlined approach has been to classify the functions within the item of analysis and to appropriately align these with the correct Analysis Procedure(s).

An example functional classification assessment is provided in Table 1, below. From the classification table the relevant MSG-4 methodology is followed. These detailed procedures will be subject of further work and detailed in future white papers. Suffice to say, that although an item may be allocated to System, and or Structural analysis (for example), the relevant procedure must still be followed to determine whether an MSI and or SSI will be identified within an analysis candidate list.

a) Func. #	b) Aircraft Function Title	c) Detailed Function Description	d) SNSs (CH-sub CH)	e) LRU/ Structures Item list	f) Analysis methodology allocated	g) Justification for methodology selected	h) Load bearing items for this function, if Structures assessment not selected;
0001	Provide Roll Control Capability	The function uses aircraft hydraulic energy along with control signals to affect the physical roll attitude of the aircraft. The aircraft utilises 4 aileron surfaces (2 per wing named inbd and otbd), each with 2 aileron PCUs that use hydraulic power and control signals to actuate the aileron surface that they are connected to.	27-10	• Aileron surface (as LRU) • Aileron PCU • Wiring (if necessary) • Tubes (if necessary)	Systems: **Yes** Structures: **No** Emer. Equip.: **No** L/HIRF: **No**		• Aileron surface (as LRU)
0002	Provide means for carrying roll aerodynamic loads	The function uses 4 aileron surfaces (2 per wing named inbd and otbd) that are connected to the wing via 3 aileron fittings and 2 PCUs attached to the wing rear spar to transfer aerodynamic loads from the aileron surface to aircraft.	57-60 27-10	• Aileron surface (as LRU) • Aileron rod • Aileron fitting • Items of wing supports roll control loads	Systems: **Yes** Structures: **Yes** Emer. Equip.: **No** L/HIRF: **No**	Systems methodology selected to cover wear concerns for moving parts.	
0003	Provide means to transmit and absorb ground loads during landing and ground maneuvers		32-10 32-10 32-10 32-50	• MLG Shock strut • MLD drag brace • MLG axle • MLG wheels	Systems: **Yes** Structures: **Yes** Emer. Equip.: **No** L/HIRF: **No**	Structures methodology selected to ensure harmonization for corrosion failure modes.	• MLG Shock strut • MLD drag brace • MLG axle
0004	Provide means for carry landing loads		32-10 32-20 32-50	• MLG Shock strut • MLD drag brace • MLG axle	Systems: **Yes** Structures: **Yes** Emer. Equip.: **No** L/HIRF: **No**	Systems methodology selected to cover wear concerns for moving parts.	
0005	Provide means to carrying pitch trim aerodynamic loads		55-10 27-40	• HS surface (as LRU) • HSTA	Systems: **Yes** Structures: **Yes** Emer. Equip.: **No** L/HIRF: **No**	Systems methodology selected to cover wear concerns for moving parts.	• HS surface (as LRU) • HSTA

Table 1: Example of Functional classification assessment.

4.1.4 Aircraft Structural Analysis

As per current process, the mandatory replacement times for structural safe-life parts and mandatory inspection requirements are included in the Airworthiness Limitation Section (ALS), required by the Aviation Authorities as part of the Instructions for Continued Airworthiness (ICA) and are therefore not part of MSG-4 scope. All items considered to be PSE, must be addressed by Structural MSG-4 Analysis.

4.2 Aircraft Zones Flow

In order to ensure that all aircraft zones are accounted for, and that preventative maintenance can be put in place it is necessary to understand the zones and what access is available. A list is created of the aircraft zones and access as well as the high-level aircraft installations. The Zonal items are defined – a zonal item could be a portion of a zone, a whole zone or a combination of zones that have been previously identified.

4.2.1 Accidental and Environmental Damage Assessment

The Accidental Damage (AD), Environmental Damage (ED) sources impacting all zonal items are then considered before AD and ED ratings are assigned to each zonal item. For consistency the AD and ED assessment is performed for all zonal items of the aircraft and disseminated to the Zonal, EWIS, Structural and LHIRF Maintenance Working Groups (MWG).

5.0 Conclusion

Since the introduction of MSG-3 in the 1980s, there have been numerous technological advances within aviation; and MSG methodology has continually evolved over this time. Now though we are facing a step change in emerging technologies, with cutting edge technology including new aircraft designs, unmanned and remotely piloted aircraft innovations, advanced diagnostic and prognostic technologies, novel materials, alternative fuels and electric or hydrogen powered aircraft. The MSG-4 Working Group strongly believes that a new MSG methodology is required to meet these challenges. This paper lays out the top-level structure for MSG-4 analysis and the analysis that has gone into forming this. This is not the complete MSG-4 solution, but represents the first step, which introduces the over-arching structure following the initial recommendation to develop MSG-4 [1].

MSG-3 is the Reliability Centered Maintenance (RCM) process used throughout Civil Aviation since the 1980s. RCM processes are used across all industries to define preventive maintenance for complex assets. The intention is to maintain MSG methodology as an RCM process and to continue to undertake all analyses at the highest manageable level, while also introducing industry's best practices including a move towards Condition Based Monitoring (CBM) and the alleviation of some of the existing challenges with MSG-3.

Modern aircraft consist of a large number of integrated systems, many of which are designed and developed by different OEMs. These have an increasing level of integration and dependencies between them. This also leads to increased integration between the aircraft functions and the systems which implement them. Functions are not limited to what is traditionally seen within MSG-3 as 'systems' analysis. Valid functions can include carrying loads, transmitting loads and provision of Lightning and HIRF protection. The proposal for MSG-4 introduces a fully functional approach to the start of the analysis, starting with the functions of the complete asset, before assigning those functions to the system and sub-system level. Only once this is resolved should the relevant MSG Analysis Procedure be launched. This integrated approach to systems engineering is reflected in SAE ARP4754B [2] which lays out the Guidelines for Development of Civil Aircraft and Systems. Alignment of MSG-4 with ARP4754B would also have the benefit of strengthening of ties with bodies including IATA and SAE by aligning guidance material. Such a change additionally has the additional benefit of encouraging the introduction of MSG concepts earlier in the product design, where it is easier to influence designs in favor of easily maintainable designs, thereby enabling airline operators to maximize aircraft availability while maintaining safety and reliability inherent in the product.

Recommendations for the Development of MSG-4

The Analysis Procedures in MSG-3 initiate independently and concurrently, allowing for potential for analysis items to be overlooked, with some functions missing from the analysis and instances of items of analysis and functions falling between the gaps of the Structural Significant Item (SSI) and Maintenance Significant Item (MSI). Removal of the independent and concurrent starts for the different MSG analysis methods within MSG-4 is intended to correct this, while enabling analysis for future and emerging technologies including hydrogen, all electric and remote piloted aircraft.

In conclusion, this white paper provides a definition of an overarching structure for MSG-4 analysis. The proposal for MSG-4 offers an opportunity to define the future to MSG-4 to meet the anticipated step change in emerging technologies, including new aircraft designs, unmanned aircraft innovations, novel materials, alternative fuels and electric or hydrogen powered aircraft. Building on the foundation of MSG-3, this proposal offers an ability to maintain what works with MSG-3 while aligning with industry standard best practice and positioning Civil Aviation for the future.

Recommendations for the Development of MSG-4

Appendix 1 – Abbreviations

A4A	Airlines for America
AD	Accidental Damage
AMC	Acceptable Means of Compliance
ARP	Aerospace Recommended Practice
ATA	Air Transport Association
CBM	Condition Based Maintenance
CMC	Ceramic Matrix Composites
ED	Environmental Damage
EWIS	Electrical Wiring Interconnection Systems
FEC	Failure Effect Category
IAHM	Integrated Aircraft Health Monitoring
IATA	International Air Transport Association
ICA	Instructions for Continued Airworthiness
IMRBPB	International Maintenance Review Board Policy Board
IMPS	International MRB /MTB Process Standard
IP	Issue Paper
L/HIRF	Lightning / High Intensity Radiated Field
LH_2	Liquid Hydrogen
LRU	Line Replaceable Unit
MPIG	Maintenance Programs Industry Group
MRB	Maintenance Review Board
MSG	Maintenance Steering Group
MSI	Maintenance Significant Item
MWG	Maintenance Working Group
OEM	Original Equipment Manufacturer
PPH	Policy and Procedures Handbook
PSE	Principal Structural Elements
RCM	Reliability Centered Maintenance
RMPIG	Rotor Maintenance Program Industry Group
SAE	Society Automotive Engineers
SAF	Sustainable Aviation Fuel
SNS	Standard Numbering System
SSI	Structural Significant Item
TC	Type Certificate

Appendix 2 - References

[1] ATA Report 2024-01 – Recommendations for the Development of MSG-4

[2] SAE ARP4754B – Guidelines for the Development of Civil Aircraft and Systems.

Appendix 3 – MSG-4 Working Group Members

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Appendix 4 – Case Study

Background:

The purpose of the below case study is to try to demonstrate the feasibility and benefits of the proposed update to the MSG-3 procedures that shall be included in the MSG-4 proposal.

Case Study for MSG-4 Development

1. Aircraft Overview

- Aircraft Type: A single-aisle, twin-engine regional transport (90 passengers), with a Maximum range of 2000 nautical miles and 0.85 Mach at cruise, Altitude ceiling of 41000 feet and An average flight duration of 2 hours. The aircraft life is 80000 flight hours or 40000 flight cycles.

- Development Stage: Early Critical design review (CDR) phase, after the preliminary design review (PDR) completion where all aircraft and system requirements are complete and correct, and that the design approach is consistent with the requirements. Note that design implementation will be confirmed to be consistent with the requirements only at the end of the CDP, i.e. at Critical design review (CDR).

Note: This stage of aircraft development where MSG-4 analysis should start at; since the design implementations is being defined.

2. Gathering Aircraft and System data

2.1. Aircraft Description and Requirements Documents: Typically includes design goals, performance targets, overall operational intent, layout of major components (wing, fuselage, engines, landing gear, etc.);

2.2. System Description and Requirements Documents: Outlines each major system—e.g., Flight Controls, Propulsion, Electrical Power, Hydraulic, Environmental Control, Avionics, etc. Documents include information such as Basic architecture (hardware/software), Interfaces (internal and external) and Operational modes (normal, alternate, emergency).

2.3. Typical required documents usually titled: aircraft description, aircraft requirements, aircraft functional hazard, Engineering drawings and CAD models, systems description, system requirements, system functional hazard, interface description, system schematic, functional block diagrams, etc.

Analysis Example:

The process described by example in steps below is recursive and iterative, i.e. with the development of the aircraft design, if there are changes to function(s), systems, installation or AD/ED sources and ratings; the analysis herein shall be updated and assessed in the same manner. This analysis shall be documented in a structured format.

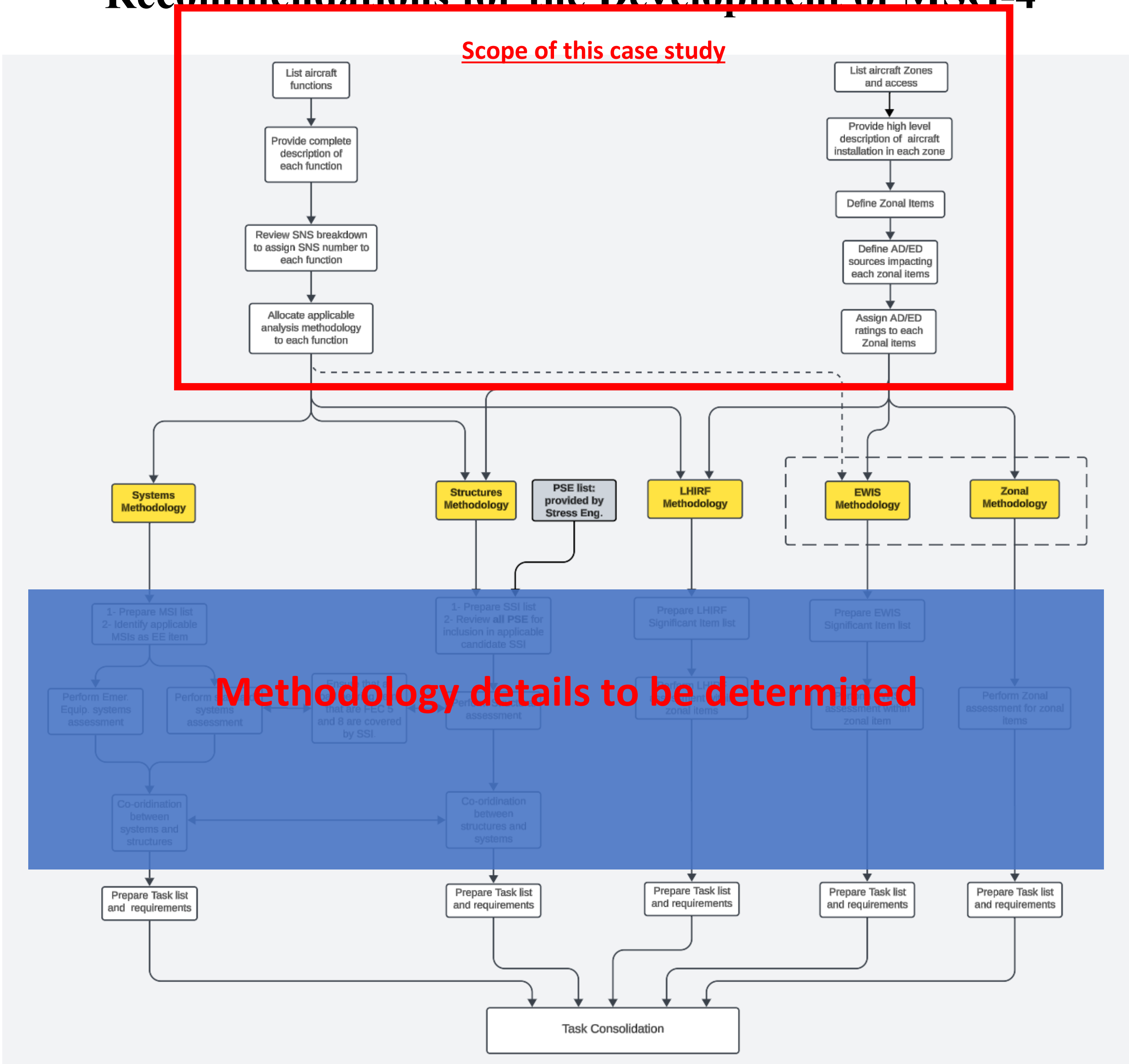

Figure 1

LHS of Flowchart:

3. Identifying and Organizing Aircraft/System Functions

3.1. Extracts All Aircraft Functions from top-level documents.

1. Provide Aerodynamic Performance
2. Provide Controlled Aircraft Trajectory
3. Provide Controlled Aircraft Energy
4. Provide Survivable Environment
5. Provide Crew Situational Awareness
6. Maintain Structural Integrity
7. Provide Emergency Services
8. Provide Passenger/Cargo Services

Those are designated as Level 1 (L1) functions.
[Editor's note: This example provides enough functional definition to support the case study, but is not a complete functional definition for the aircraft.]

3.2. Detail aircraft functions, each high-level function is decomposed into L2 and L3 level functions in a hierarchical manner:

- L1 level function: "Provide Controlled Aircraft Energy"
  - L2 level function: "Maintain or Increase Aircraft Energy"
  - L2 level function: "Reduce Aircraft Energy"
    - L3 level function: "Provide Controlled Aerodynamic Drag"
    - L3 level function: "Decelerate on Ground"
  - L2 level function: "Provide High Lift Capability"

Exercise engineering judgment to decide if the L3 function level is sufficient to assign SNS numbers and allocate analysis methodology (Systems, Structuraland LHIRF); or further detail is required. If further detail is required move to next step 3.3.
Note: the L3 level functions do not imply a specific design/implementation. For example, there are several different design solutions which could be used to decelerate aircraft on the ground.

3.3. Detail System functions; each L3-level function is decomposed into Systems functions in a hierarchical manner:

L3 aircraft level function: "Decelerate on Ground"

1. L4 System function: "Decelerate the wheels on the ground"
2. L4 System function: "Reverse Thrust on ground"
3. L4 System function: "Control Engine thrust on ground"
4. L4 System function: "Provide Aerodynamic braking"
5. L4 System function: "Provide High lift capability"

3.4. Provide detailed description of each function; to be able to allocate appropriate MSG-4 analysis methodology. Note: It should not be necessary to list functional failure/or failure effects as no failure effect categorization will be done at this point.
As a part of this step; significant load bearing items shall be identified, albeit at a high level.

1. L4 System function: "Decelerate the wheels on the ground"

   The aircraft has two main landing gear struts with 2 wheels each for a total of 4 wheels. Each wheel is equipped with a brake. The brake unites are actuated hydraulically by 2 hydraulic system. An electronic brake unit provides brake pedal position inputs to the brake control unit. The brake control unit is electrically controlled and hydraulically actuated to control the hydraulic pressure feeding the 4 brake units.

   - Significant load bearing items: No.

2. L4 System function: "Reverse Thrust on ground"

   The aircraft is equipped with a thrust reverser on each engine. The thrust reversing mechanisms on each engine are hydraulically actuated by 2 hydraulic systems. Each thrust reverser is electrically controlled by an Electronic Engine Control Unit.

- ➢ Significant load bearing items: Yes; TR panels, actuators and fittings.

3. L4 System function: “Control Engine thrust on ground”
   The aircraft has two under-wing mounted turbofan engines in order to produce forward thrust. The engine thrust is reduced during deceleration on ground, to maximize deceleration. The forward thrust on each engine is controlled in response to pilot manual commands via Throttle Quadrant Assembly. There is no automatic propulsion command in this aircraft. Each engine is electrically controlled through an EECU based on the input of the TQAs.

   - ➢ Significant load bearing items: No.

4. L4 System function: “Provide Aerodynamic braking”
   The aircraft’s wings are each equipped with two spoiler panels. The spoilers are intended to be deployed on landing. The spoilers are hydraulically actuated and powered by 2 hydraulic systems in response to input from pilot via spoiler lever. The spoilers are electrically controlled by an Electronic Flight Control Unit (EFCU).

   - ➢ Significant load bearing items: Yes; Spoiler panels, actuators and fittings.

5. L4 System function: “Provide High lift capability”
   The aircraft’s wings are each equipped with two flap panels. The flaps are extended to allow lower takeoff and landing speeds, which facilitates deceleration on ground. The flaps are hydraulically actuated and powered by 2 hydraulic systems in response to input from pilot via flap lever. The flaps are electrically controlled by an Electronic Flight Control Unit (EFCU).

   - ➢ Significant load bearing items: Yes; Flap panels, actuators, fittings and flap tracks.

3.5. Review SNS breakdown to assign SNS numbers to each function;

1. L4 System level function: “Decelerate the wheels on the ground”
   SNS: 32-42 wheel brake system

2. L4 System level function: “Reverse Thrust on ground”
   SNS: 78-30 thrust reverser system

3. L4 System level function: “Control Engine thrust on ground”
   SNS: 73-30 engine control system
   SNS: 76-10 throttle control system

4. L4 System level function: “Provide Aerodynamic braking”

SNS: 27-60 spoiler system
SNS: 57-70 spoilers

5. L4 System level function: “Provide High lift capability”
   SNS: 27-50 spoiler system
   SNS: 57-50 flaps

4. Allocating Functions to Analysis Methodologies
Exercise engineering judgment to allocate applicable analysis methodology to each function (Systems Methodology, Structures Methodology or L/HIRF methodology); based on determination questionnaire (TBD), and if necessary provide comments for methodology not selected.
Note: If load bearing items identified; structural analysis should be required.

[Editor’s Note: Whether an item will qualify as SSI or other structure will be determined in the SSI determination process that will be ratified to ensure that SSI candidates list are not over identified per current experience and understanding.]

[Editor’s Note: Emergency Equipment is structured to be a dedicated assessment within the systems methodology.]

1. L4 System level function: “Decelerate the wheels on the ground”
   - Systems: Yes
   - Structures: No
   - L/HIRF: No

   Comments: Only system methodology selected; No significant load bearing items in this function to justify structures methodology. No especial L/HIRF concerns, hence L/HIRF items will be covered under L/HIRF function.

2. L4 System level function: “Reverse Thrust on ground”
   - Systems: Yes
   - Structures: Yes
   - L/HIRF: No

   Justification: System methodology selected; Structures methodology selected for load bearing items. Wear concerns for structural items shall be addressed in the systems methodology. No especial L/HIRF concerns, hence L/HIRF items will be covered under L/HIRF function.

3. L4 System level function: “Control Engine thrust on ground”
   - Systems: Yes
   - Structures: No
   - L/HIRF: No

   Comments: Only system methodology selected; No significant load bearing items in this function to justify structures methodology. No especial L/HIRF concerns, hence L/HIRF items will be covered under L/HIRF function.

4. L4 System level function: “Provide Aerodynamic braking”
   - Systems: Yes
   - Structures: Yes

- L/HIRF: No

Comments: System methodology selected; Structures methodology selected for load bearing items. Wear concerns for structural items shall be addressed in the systems methodology. No especial L/HIRF concerns, hence L/HIRF items will be covered under L/HIRF function.

5. L4 System level function: "Provide High lift capability"
    - Systems: Yes
    - Structures: Yes
    - L/HIRF: No

Comments: System methodology selected; Structures methodology selected for load bearing items. Wear concerns for structural items shall be addressed in the systems methodology. No especial L/HIRF concerns, hence L/HIRF items will be covered under L/HIRF function.

RHS of Flowchart:

5. List aircraft zones and access; with high level description of aircraft installation within each zone;

Major Zone 100: Lower half of the fuselage, from the nose to the aft pressure bulkhead
Major Sub-Zone 110: Radome and lower nose fuselage, from nose to FS160
Major Sub-Zone 120: Lower Nose Compartment, from FS160 to FS200
Major Sub-Zone 130: Lower Forward Fuselage, from FS200 to FS280

Zone 131: LHS of Forward Equipment compartment, from FS200 to FS280 below floor level, internal and external.
Installations in the zone: ECS LRUs and installations, Avionics LRUs, Flight Control LRUs, Electric LRUs and Power feeders, drain valves, insulation blankets, Hydraulic installation, various electrical harness, various LHIRF components.
Structures in the Zone: Forward Equipment compartment door surround structure, aft face of fwd pressure bulkhead, skin panels, stringers, frames, floor beams.
Access: Forward Equipment compartment door.

Zone 132: RHS of Forward Equipment compartment, from FS200 to FS280 below floor level, internal and external.
Installations in the zone: ECS LRUs and installations, Avionics LRUs, APU LRUs, RAT Power feeders, drain valves, insulation blankets, Hydraulic installation, various electrical harness, various LHIRF components.
Structures in the Zone: Forward Equipment compartment door surround structure, aft face of fwd pressure bulkhead, skin panels, stringers, frames, floor beams, lavatory and galley supports.
Access: Forward Equipment compartment door.

Major Sub-Zone 140: Lower mid fuselage, from FS280 to FS 500
Major Sub-Zone 150: Lower mid fuselage, from FS500 to FS700
Major Sub-Zone 160: Lower aft fuselage, from FS700 to FS800
Major Sub-Zone 170: Lower aft fuselage, from FS800 to FS1000

Major Zone 200: Upper half of the fuselage from the forward pressure bulkhead to the aft pressure bulkhead
Major Zone 300: Empennage, aft fuselage and tailcone
Major Zone 400: Power plants (including nacelle and pylon)
Major Zone 500: Left wing
Major Zone 600: Right wing
Major Zone 700: Landing gear and landing gear doors
Major Zone 800: Doors

6. Define Zonal items; a zonal item (ZI) could be a portion of zone, a whole zone or combinations of zones and portions of zones.

6.1. For Zones 131 and 132;

Zonal item ZI100-05; will be defined for the internal portion of both zones 131 and 132.

Zonal item ZI100-06; will be defined for the external portion of both zones 131 and 132.

7. For each Zonal item (ZI); define AD/ED sources and assign initial AD/ED rating.

For ZI100-05:

Initial AD sources and rating:

- Ground Handling: Low;
- Weather Effects: Low;
- Lightning Strike: Low;
- Runway Debris(FOD): Low;

Initial ED sources and rating:

- Corrosive products: Low;
- Humidity: Moderate;
- Temperature: Moderate;
- Vibration: Low;

For ZI100-06:

Initial AD sources and rating:

- Ground Handling: High;
- Weather effects: Low;
- Lightning Strike: High;
- Runway Debris (FOD): High;

Initial ED sources and rating:

- Corrosive products: Moderate;
- Humidity: Moderate;
- Temperature: Low;
- Vibration: Low;

[Editor's Note: the example above selects zonal items based on internal vs external criterion, other criteria could also be selected and a zonal item could contain internal and external portions of zones if appropriate.]

Conclusion:

This case study shows the following benefits:

- Going through the functional assessments breakdown upfront:
  - Reduces chances of omitting a function or a MSI, especially in a highly integrated system where a LRU may perform multiple functions.
  - Clearly identifies points where co-ordination is needed between systems and structures working group, which help facilitates the merge between volume 1 and volume 2.

- Going through the zonal items and AD/ED ratings upfront:
  - Ensure rating standardization across Structural, Zonal and LHIRF working groups.
  - Save effort and time by eliminating repetition of AD/ED assessment in different working groups.