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**Title:** Interaction of Systems and Structure

**Submitter:** EASA, MRB Section

**Issue:** MSG-3 addresses systems and structures in separate chapters, during the MRB process systems and structures are assessed by different working groups.
Nevertheless, systems and structure are not independent in real life. Therefore EASA introduced a new paragraph with Ammendment 1 to CS-25 (12.12.2005):

***CS 25.302 Interaction of systems and structures***
*For aeroplanes equipped with systems that affect structural performance, either directly or as a result of a failure or malfunction, the influence of these systems and their failure conditions must be taken into account when showing compliance with the requirements of Subparts C and D.*

Exactly the same interaction exists with respect to continued airworthiness and maintenance, but is not fully addressed in MSG-3

**Problem:** For many items of an aircraft, it is not easy to designate them to be pure system or pure structure (or in terms of MSG-3, to be pure MSI or pure SSI). There are many items that are a combination of both, or that are influenced by each other and should not be analysed independently.

The following cases are obviously existing :

**Systems which contribute significantly to carrying flight, ground or control loads**
**(Systems that meet SSI definition and need Systems and Structure analysis)**

- **Actuators that act as primary load path**

  Typical examples are flap drive system parts, that transfer a significant portion of the flap loads into the wing structure.

- **Actuators that act as single load path**

  Even more important are actuators, that are the only single path for significant loads, where the functional failure of the system may lead to a loss of certain parts of the aircraft structure. (single failure which may result in loss of the structural integrity of the aircraft)

  Typical examples are landing gear retraction actuators that also act as sidestray (typically found on smaller business jets), or the THS trim actuator which is the only load path for the significant pitching moment of the horizontal stabilizer.

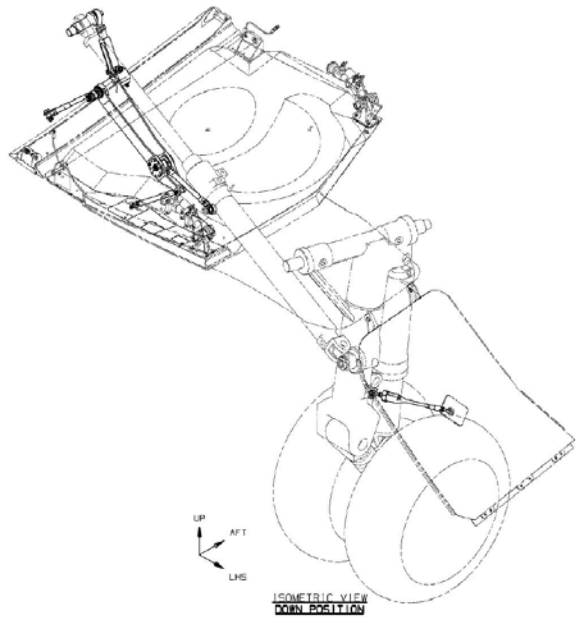


Figure 1: Retraction actuator acting as side stray

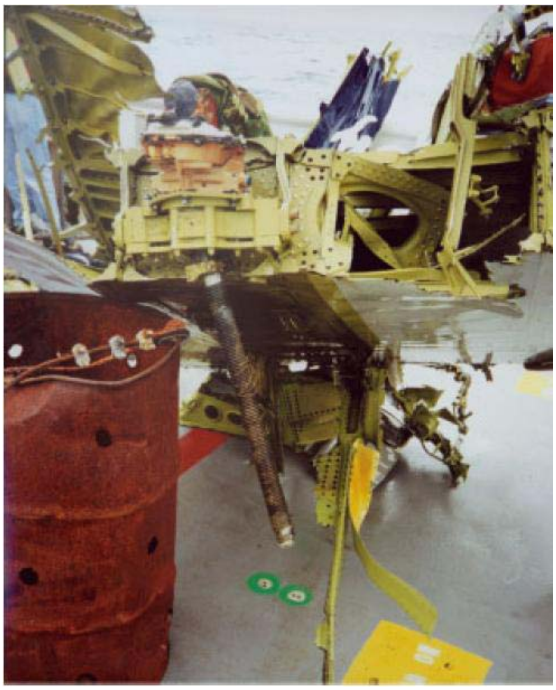

Figure 2: Trim spindle acting as single load path
for the THS pitching moment (Alaska Air)

It is not logical to analyse the attachment brackets of an actuator in much greater detail than the actuator itself, if both together create a significant load path. There are several cases of actuator failure due to corrosion, that would have been easily predictable, if the structures analysis logic and the structures rating system would have been applied.
The same applies to actuators failing due to fatigue cracking.

**Systems which could affect Significant Structure**
**(Systems with damage to SSI as a possible failure effect)**

- **Systems which can cause immediate failure of Significant Structure**

  Question 2 of the Level 1 analysis contains already "SECONDARY DAMAGE RESULTING FROM THE FUNCTIONAL FAILURE", but this does only cover such cases, in which the function of the system and the secondary damage do occur at the same time.

  Typical examples are load limiters in the high lift device drives, whose failure could result in overload of significant structure, which may have a lower reserve factor than the actuators and therefore fails first in case of the load limiter failure.
  An other Example are landing gear retraction actuators, in case of total failure during extension, the landing gear performs an undamped freefall extension, which may create extreme loads exceeding the strength of the landing gear when reaching the downstop, as recently seen on two SAS Canadair Dash8 Q400.

  This issue is mostly covered during certification, but it is assumed that such systems are maintained to a condition minimizing the probability of failure. Therefore certification relies partly on ICA and maintenance program development to meet the requirements.
  MSG-3 should reflect this relation.

- **Systems which can cause Accidental Damage (AD) to Significant Structure**

  One example may be bleed air systems, which in case of a leak can overheat significant structure, causing either immediate reduction of static strength (mainly for non-metallic structure), or degradation of the protection system (paint, sealant etc.).
  Another example might be a flap drive system which due to wear causes an incorrect positioning of the flap, resulting in the flap coming in contact with the wing structure, scratching the flap and the wing.

- **Systems with long term effects on SSI as result of undetected failure (Systems that affect environmental conditions for SSI structure)**

  System failures are not listed as typical ED/AD source in MSG-3 so far, corrosive fluids used is systems are only mentioned as "spillage" not as leaks, so they are taken into account as result of a mishandling, and not as a result of system failure.
  Systems known from in-service experience to cause permanent exposure to deteriorating environment are not systematically taken into account when rating their failure effects and ED for the affected structure.

  Due to the top-down approach used for MSG-3 system analysis, failures that are not related to the function of the system, will not be taken into account. Therefore small leaks which do not affect the function of the system may remain unanalysed.

Typical examples for such systems are and all lines and tanks for corrosive fluids (hydraulics, toilets).

All drainage systems (valves, tubes, fittings) also have long term effects (deterioration of structure) as functional failure.

The combination of two hidden failures (leaking system and blocked drainange system) are typically not taken into account.

- **Systems with long term effects on SSI as result of undetected failure (Systems that affect loads)**

  This issue is covered during certification.

**Structure which has an important function**
**(Structure that meets MSI definition and need Systems and Structure analysis)**

- **Firewalls / Structure around fire zones**

  A good example is the Inner Fixed Structure (IFS) of thrust reversers, which are part of the fire zone boundaries for the engine. A failure of the IFS, which happened several times on various models of different manufacturers, causes the air from the fan to blow into the fire zone, which means loss of the fire extinguishing system, as the concentration of halon within the fire zone can no longer extinguish a potential fire, additionally the debris of the IFS can damage wires or lines and cause a fire.

  Such structure "*could affect safety (on ground or in flight), and/or is undetectable during operations, and/or could have significant operational impact, and/or could have significant economic impact*", but does not "*contribute significantly to carrying flight, ground or pressure loads*", hence does meet the MSI, but not the SSI criteria and is not analysed in detail.

- **Fuel tank boundaries**

  Although not carrying loads, some parts of the structure build the boundaries of fuel tanks, hence their structural integrity is essential for preventing fuel leaks, which meet the safety definition of MSG-3.
  The Slat Track Cans are one good example for such structural items, which recently caused a hull loss, narrowly avoiding multiple fatalities.
  *Note: This specific accident was caused by AD to the slat track can caused by a system failure, but the same result could have happened due to undetected corrosion within the can.*

Figure 3: Structural failure of a slat track can resulting in a fuel leak

- **Shields and Fairings**

  Many systems are not designed for exposure to airflow or rain/hail etc. Therefore they are installed in zones that are closed by secondary structural items.
  Typical examples are the systems installed outside the pressure hull, like A/C packs and  high lift system hydraulic motors, protected by the belly fairing.
  Degradation or loss of those structure may cause systems to fail or deteriorate as consequence

  The same applies to heat shields that protect systems or SSI structure from heat radiation or from hot air.

On MSG-3 analysis level, another important interaction exists:

**Systems for which structural degradation (corrosion, cracking) is a typical failure cause.**

For many systems this type of degradation is taken into account during system analysis, but not to the same extent as it would be done for structures.

Some parts listed under the systems ATA chapters and therefore not analysed as structures, are in fact purely structural like control rods, flap links etc.

It would be much more appropriate to analyse such items by applying the structures logic for this failure cause.

**Recommendation (including Implementation):**

1. **Clarify status of system parts that meet SSI definition**
(Systems *which contributes significantly to carrying flight, ground, pressure or control loads, and whose failure could affect the structural integrity necessary for the safety of the aircraft*).

2. **Clarify status of structure that meet MSI definition**
(Structure which *could affect safety (on ground or in flight), and/or is undetectable during operations, and/or could have significant operational impact, and/or could have significant economic impact*).

## 2-3-1. MSI Selection

Before the actual MSG-3 logic can be applied to an item, the aircraft's significant systems and components must be identified.

Maintenance Significant Items (MSIs) are items fulfilling defined selection criteria (see Step 3., below) for which MSI analyses are established at the highest manageable level.

This process of identifying Maintenance Significant Items is a conservative process (using engineering judgment) based on the anticipated consequences of failure. The top-down approach is a process of identifying the significant items on the aircraft at the highest manageable level.

The MSI selection process is outlined below:

### 1. Step 1.

The manufacturer partitions the aircraft into major functional areas; ATA Systems and Subsystems. This process continues until all on-aircraft replaceable components have been identified.

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|---|---|
| ~~NOTE:~~ | ~~Items within the Structural ATA Chapters (51-57) that lend themselves to System analysis (e.g., flight control hinge bearings, fuselage drains, door hinge and mechanisms, etc.) should be included in this step and coordinated with the Structures Working Group in accordance with established transfer policy and procedures. In addition, all safety/emergency systems or equipment should also be included.~~ |

- Structual items not designed to carry significant loads but having important functions (i.e. firewalls, shields, integral fuel tank boundaries) need to be included in the MSI selection process.

- Items within the Structural ATA Chapters (51-57) that lend themselves to System analysis (e.g., flight control hinge bearings, fuselage drains, door hinge and mechanisms, etc.) should be included in this step and coordinated with the structures analysis.

- Items within the Systems ATA Chapters that carry significant loads and whose failure could affect the structural integrity necessary for the safety of the aircraft (System parts that would meet SSI definition, i.e. THS spindle actuators or landing gear retraction actuators that also act as sidestray) need to be analyzed as MSI and coordinated with the structures analysis

- All safety/emergency systems or equipment should also be included

**3. Clarify analysis of structural degradation of MSI**
Development of applicable and effective tasks to detect and limit degradation of function due to structural degradation (corrosion, cracking).

**Chapter 2-3-7-3.1**
Add one note

## 3. Inspection/Functional Check (All Categories)

| QUESTION 5B, 6B, 7B, 8C & 9C. | IS AN INSPECTION OR FUNCTIONAL CHECK TO DETECT DEGRADATION OF FUNCTION APPLICABLE AND EFFECTIVE? |
|---|---|

**An inspection is:**

A. GENERAL VISUAL INSPECTION (GVI)

A visual examination of an interior or exterior area, installation or assembly to detect obvious damage, failure or irregularity. This level of inspection is made from within touching distance, unless otherwise specified. A mirror may be necessary to enhance visual access to all exposed surfaces in the inspection area. This level of inspection is made under normally available lighting conditions such as daylight, hangar lighting, flashlight or drop-light and may require removal or opening of access panels or doors. Stands, ladders or platforms may be required to gain proximity to the area being checked.

OR

B. DETAILED INSPECTION (DET)

An intensive examination of a specific item, installation or assembly to detect damage, failure or irregularity. Available lighting is normally supplemented with a direct source of good lighting at an intensity deemed appropriate. Inspection aids such as mirrors, magnifying lenses, etc. may be necessary. Surface cleaning and elaborate access procedures may be required.

OR

C. SPECIAL DETAILED INSPECTION (SDI)

An intensive examination of a specific item, installation, or assembly to detect damage, failure or irregularity. The examination is likely to make extensive use of specialized Inspection Techniques and/or equipment. Intricate cleaning and substantial access or disassembly procedure may be required.

A functional check is a quantitative check to determine if one or more functions of an item performs within specified limits.

### *3.1. Applicability Criteria*

Reduced resistance to failure must be detectable, and there exists a reasonably consistent interval between a deterioration condition and functional failure.

> Note: If the deterioration identified is mainly structural (e.g. corrosion), an applicable inspection task to detect deterioration (inspection level and interval) could be developed by using the structures analysis procedure described in chapter 2-4.
> The other steps of the MSI analysis and development of the final task is done by use of the Systems logic.

### 3.2. Effectiveness Criteria - Safety

The task must reduce the risk of failure to assure safe operation.

### 3.3. Effectiveness Criteria - Operational

The task must reduce the risk of failure to an acceptable level.

### 3.4. Effectiveness Criteria - Economic

The task must be cost-effective; i.e., the cost of the task must be less than the cost of the failure prevented.

4. **Clarify analysis of ED/AD due to system failure effects**
   Add system failure to the ED/AD analysis and establish guidelines for workshare and transfer between Systems- and Structures Working Group.

**Chapter 2-3-2**
Add one paragraph

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## 2-3-2. Analysis Procedure

After the MSI's have been selected, the following must be identified for each MSI:

a) Function(s) - the normal characteristic actions of an item

b) Functional Failure(s) - Failure of an item to perform its intended function within specified limits

c) Failure Effect(s) - what is the result of a functional failure

d) Failure Cause(s) - why the functional failure occurs

Defining some functional failures may require a detailed understanding of the system and its design principles. For example, for system components having single element dual load path features, such as concentric tubes or back-to-back plates, the function of both paths should be analyzed individually. The degradation and/or failure of one path may not be evident.

When listing functions, functional failures, failure effects, and failure causes, care should be taken to identify the functions of all protective devices. These include devices with the following functions:

a) to draw the attention of the operating crew to abnormal conditions

b) to shut down equipment in the event of a failure

c) to eliminate or relieve abnormal conditions which follow a failure

d) to take over from a function that has failed

Protective function statements should describe the protective function itself, and should also include the words "if" or "in the event of" followed by a brief description of the events or circumstances that would activate or require activation of the protection. For example, "To open the relief valve to atmosphere in the event of system X pressure exceeding 300 psi."

Tasks and intervals required in the scheduled maintenance are identified using the procedures set forth herein. Both the economic and safety related tasks are included so as to produce initial scheduled maintenance tasks/intervals.

All available Vendor Recommendations (VR) should be fully considered, discussed in the MWG meetings, and accepted only if they are applicable and effective according to MSG-3 criteria.

Prior to applying the MSG-3 logic diagram to an item, a preliminary work sheet will be completed that clearly defines the MSI, its function(s), functional failure(s), failure effect(s), failure cause(s) and any additional data pertinent to the item; e.g., ATA chapter reference, fleet applicability, manufacturer's part number, a brief description of the item, expected failure rate, hidden functions, need to be on M.E.L., redundancy (may be unit, system or system management), etc. This work sheet is to be designed to meet the user's requirements and will be included as part of the total MSG-3 documentation for the item.

When defining failure effect(s), secondary failure to structure, either long term (i.e. degradation of surface protection due to hydraulic leaks, fluid accumulation due to drainage system failure) or immediate (i.e. overload due to failure of a load limiting device or heat damage due to leaking bleed air) needs to be identified and taken into account for the structures analysis.

The approach taken in the following procedure is to provide a logic path for each functional failure. Each functional failure and failure cause must be processed through the logic so that a judgment will be made as to the necessity of a task. The resultant tasks and intervals will form the initial scheduled maintenance.

**Chapter 2-4-5**
Add bullet 8 and note
(see IP TBD for the change to bullet 7)

## 1. Rating Accidental Damage

Accidental damage rating systems should include evaluations of the following

a. Susceptibility to minor (not obvious) accidental damage based on frequency of exposure to and the location of damage from one or more sources, including:

   1. Ground handling equipment
   2. Cargo handling equipment
   3. Those resulting from human error during manufacture, maintenance, and/or operation of the aircraft, that are not included in other damage sources.
   4. Rain, hail, etc.
   5. Runway debris
   6. Lightning strike
   ~~7. Water entrapment~~ Fluid spillage
   8. System failure

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**Chapter 2-4-5**
Add note

## 2. Rating Environmental Deterioration (metals)

Environmental deterioration rating systems should allow for evaluations of susceptibility to and timely detection of corrosion and stress corrosion.

Susceptibility to corrosion is assessed on the basis of probable exposure to an adverse environment and adequacy of the protective system. For example:

a. Exposure to a deteriorating environment such as cabin condensation, galley spillage, toilet spillage, cleaning fluids, etc.

b. Contact between dissimilar materials (potential for galvanic activity).

c. Breakdown of surface protection systems; for example, deterioration of paint, primer, bonding, sealant, corrosion inhibiting compounds and cladding systems with the resulting corrosion of metallic materials or fluid incursion into permeable non-metallic materials, etc.

Note: When rating exposure to a deteriorating environment and breakdown of surface protection systems, leaks from systems (i.e. hydraulic lines, toilets) or failure of drainage systems have to be taken into account.
Functional Failure(s) and Failure Effect(s) and frequency of occurrence identified during MSI analysis could be used as input to rate the environmental conditions caused by system failure.
If such leaks or fluid accumulation are accepted during system analysis (i.e. no task was found to be economic), this information needs to be taken into account for ED assessment.

Material characteristics, coupled with the likelihood of sustained tensile stress, are used to assess susceptibility to stress corrosion.

Timely detection is determined by sensitivity to relative size of damage and visibility of the SSI for inspection.

NOTE: Rating system evaluations should be made taking into account the requirement for each operator to control the aircraft structure at corrosion Level 1 or better.

**Chapter 1-3-2**
Add note

## 1-3-2. Working Groups

One or more Working Groups, consisting of specialist representatives from the participating operators, the prime manufacturer, and the Regulatory Authority, may be constituted. The Industry Steering Committee, alternatively, may arrange some other means for obtaining the detailed technical information necessary to develop recommendations for scheduled maintenance in each area. Irrespective of the organization of the working activity, written technical data must be provided that supports its recommendations to the Industry Steering Committee. After approval by the Industry Steering Committee, these analyses and recommendations shall be consolidated into a final report for presentation to the Regulatory Authority.

NOTE: If separate Working Groups are constituted, means of cooperation need to be established to assess items that do not clearly fall into one category. (i.e. landing gear)

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| **IMRBPB Position:** |
|---|
| **Date:**<br>**Position:** |

**Status of Issue Paper (when closed state the closure date):**

**Recommendation for implementation:**

**Important Note:** The IMRBPB positions are not policy. Positions become policy only when the policy is issued formally by the appropriate National Aviation Authority.