A NEW APPROACH TO ACCIDENTAL DAMAGE ON AIRCRAFT METALLIC STRUCTURE

Sébastien Amiable[1], Ben Ogborne[2] and Alain Santgerma[1]

[1] AIRBUS Operations SAS, France
[2] AIRBUS Operations Limited, UK

Abstract: A new approach to define the inspection requirements for Accidental Damage on metallic aircraft structure is described in this paper. Some years ago, based on the tests and service experience accumulated, AIRBUS decided to change from a calculation based approach towards a more realistic and pragmatic approach. The philosophy of the approach was changed from crack detection to accidental damage detection.

An MSG-3 approach is applied to identify the Structural Significant Items susceptible to Accidental Damage and the inspection level. A Stress Sensitivity Rating is combined with an Accidental Damage Rating to determine the inspection frequency. Inspection requirements are consolidated in the Maintenance Review Board Report.

While being less conservative than the previous one, this new approach optimized the overall number of inspections in the scheduled maintenance program.

Keywords: Accidental Damage, crack

INTRODUCTION

Commercial aircraft are exposed to the risk of accidental damages during production, service exploitation, and maintenance. Accidental Damage is characterized by the occurrence of a random discrete event which may reduce, immediately or after a period of time, the inherent level of residual strength of the structure.

Typical examples of accidental damages include ground and cargo handling equipment, the impact by foreign objects such as tools or vehicles, hail, runway debris, human error during manufacturing, operation or maintenance of the aircraft.

Aircraft areas exposed to accidental damage shall be regularly inspected to maintain structural integrity. Visual inspections are applied with the aim to find and repair accidental damages, or any defect resulting from accidental damages such as corrosion, delamination or cracking. The most exposed areas to accidental damage are the aircraft external surfaces of fuselage, wings, empennages, landing gears, control surfaces and any areas with frequent human interaction.

Until recently, AIRBUS defined the inspection requirements for accidental damage on damage tolerant structures using a crack growth calculation approach. This article presents a new, more realistic approach to define these inspection requirements.

APPROACH PREVIOUSLY APPLIED TO DEFINE INSPECTION REQUIREMENTS

The areas susceptible to Accidental Damage are identified using service experience, following an ATA MSG-3 (Air Transport Association Maintenance Steering Group) analysis procedure. MSG-3 is a decision-logic procedure for determining scheduled maintenance requirements in the frame of the MRB (Maintenance Review Board) process. This process is a collaborative process involving operators, airworthiness authorities, and the aircraft manufacturer in maintenance working groups to develop the scheduled maintenance program in the MRBR (Maintenance Review Board Report)

The selected inspection level was primarily General Visual Inspection. Detailed Visual Inspection may have been used in small size areas. An MSG-3 procedure was applied to determine the detectable crack length and the most appropriate inspection technique, accounting for the operator's experience.

The repeat inspection intervals were calculated by the stress specialists and expressed in Flight Cycles and/or Flight Hours. The life for a crack to grow from a detectable to a critical size was calculated at the structural areas prone to this type of damage. This crack growth calculation was done at the highest loaded portion of this structural area. According to the inspection interval obtained, the inspection level was potentially challenged. For instance, selecting a detailed visual inspection instead of general visual inspection was providing a more suitable repeat interval in some occasions.

RATIONALE FOR A NEW APPROACH

From the very first A300, AIRBUS defined and applied a conservative approach to define the inspection requirements for Accidental Damage. The experience accumulated in tests and service usage may now be used to define an approach which is more realistic, in line with the physics.

The previous approach to determine the inspection interval was deemed overly conservative. The accidental damage was assimilated to a fatigue crack of detectable size, e.g. a 70 mm crack when a general visual inspection is applied. Any accidental damage leading instantly to an equivalent level of damage would be of a high energy level and would be readily detectable either immediately or within a few flights of occurrence (Category 3 damage in Figure 1). Also, it is likely that the accidental damages having the potential to interact with fatigue would be detectable by visual means, under scheduled maintenance. Hence, it is more effective to look for accidental damage, instead of hypothetical fatigue cracks that may initiate and grow as a consequence of an accidental damage.

The purpose of the new approach is also to improve the process of determining the suitable inspection level.

NEW ACCIDENTAL DAMAGE APPROACH

Concept idea

The inspection requirements for accidental damage are defined in a more realistic way when the Fatigue and Damage Tolerance analysis results are combined with the Maintenance Engineering data.

The inspections are primarily aimed at finding accidental damages, before any interaction with fatigue could occur. The various damage categories defined in EASA AMC 20-29 (Composite Aircraft Structure) were used in Figure 1 to illustrate the domain of application of the scheduled inspections for accidental damage.

The operator experience is accounted for using MSG-3 analysis procedures. In the areas susceptible to accidental damage, the likely damage source(s) are identified, and their frequency level is rated. The most appropriate inspection level is determined taking service experience in the area into account.

A Stress Sensitivity Rating is introduced. It is intended to rate the likelihood of an accidental damage to reduce the structural strength capability and to interact with fatigue damage.

The repeat inspection interval, expressed in calendar time, is now determined with a double entry table combining the damage frequency rating with the Stress Sensitivity Rating.

The definition of this new approach was supported by a thorough review and analysis of the structural test and in-service experience accumulated by AIRBUS over 50 years, by more than 12,000 aircraft accumulating 450 millions hours in operation.

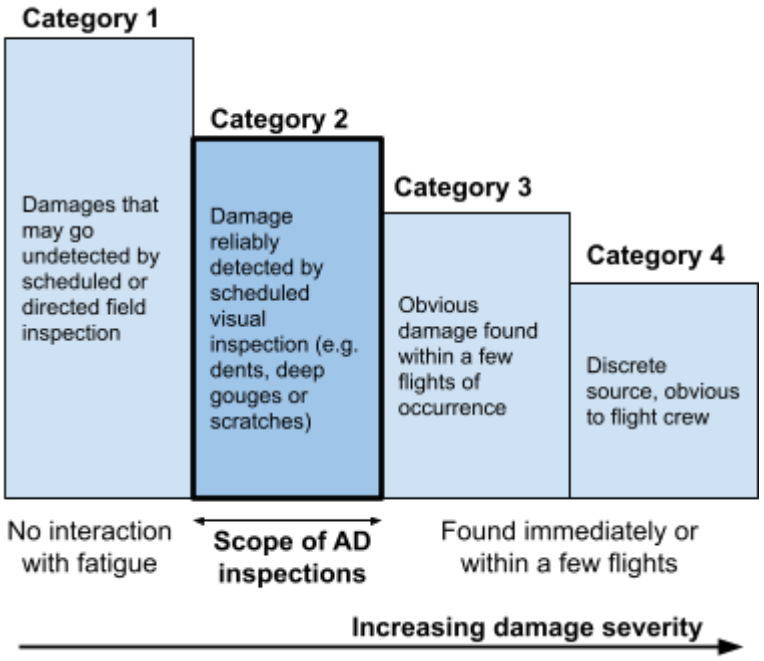

Figure 1: Scope of scheduled inspections for Accidental Damage (AD).

In-service experience

AIRBUS operators and MRO (Maintenance, Repair and Overhaul companies) data are made available to AIRBUS through different sources:

- A database of scheduled maintenance data collected from operators and MROs,
- A communication tool between AIRBUS and all operators or MROs, where damages outside Structure Repair Manual limits are reported.
- Maintenance Working Groups and Conferences with Operators.

These data, collected over many years and recorded in the AIRBUS database, were filtered using keywords. The focus was on cracked or broken parts that may have been caused by a damage of accidental nature.

Several dozens of damage reports of interest were further investigated. The presence of a real fatigue crack was checked, as well as the evidence that accidental damage was the root cause.

Finally, only one of these cases was a true case of fatigue crack caused by accidental damage. This case is presented in Figure 2. A severe impact was applied during cargo loading on the upper plate of the cargo door surround structure of an A320. The back-up structure, a frame foot web, was buckled by the impact. This damage remained undetected at the time of impact and therefore was not repaired. During a scheduled maintenance inspection, cracks were discovered in the frame foot web (see Figure 2). These cracks are a consequence of the impact damage. Safety was not impaired thanks to the structural redundancy. An additional detailed visual inspection of the back-up structure is now systematically required together with the repair instructions when such an impact damage occurs.

This survey demonstrated that accidental damages are found well before significant interaction with fatigue damage occurs.

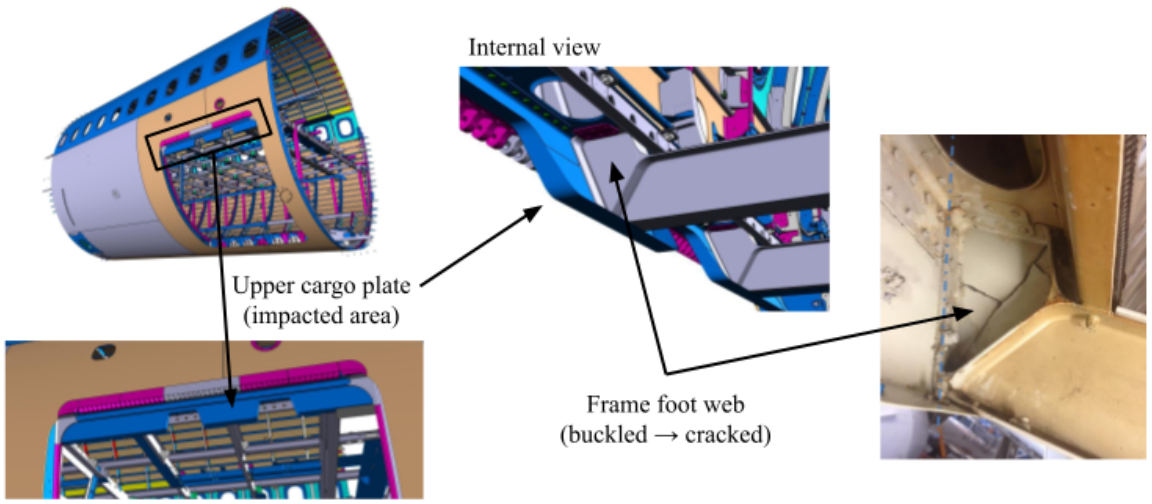

Figure 2: Case of interaction between accidental damage and fatigue.

Test experience

Full-Scale fatigue tests provide an opportunity to assess the structural behavior in the presence of typical repairs, allowable damages, and other defects. As an example, more than 100 dent damages of different severities were intentionally applied on A380 and A320 Full-Scale Fatigue Tests performed in the 2000s. These dents were applied primarily on the most exposed areas of the fuselage structure, at non-riveted and riveted locations: external skins bays, longitudinal and circumferential joints, at stringers and frames attachments to skin.

In the context of this new accidental damage approach, it was interesting to determine the dent depth from which interaction with fatigue may occur, and to compare this with the detectable depth. The graph in Figure 3 shows the number of dents with or without crack initiation and growth, versus the dent depth. No crack initiated on dents with a depth lower than 2.3 mm, after testing for more than three times the Design Service Goal. Dents deeper than 1.3 mm can be detected with a General Visual Inspection.

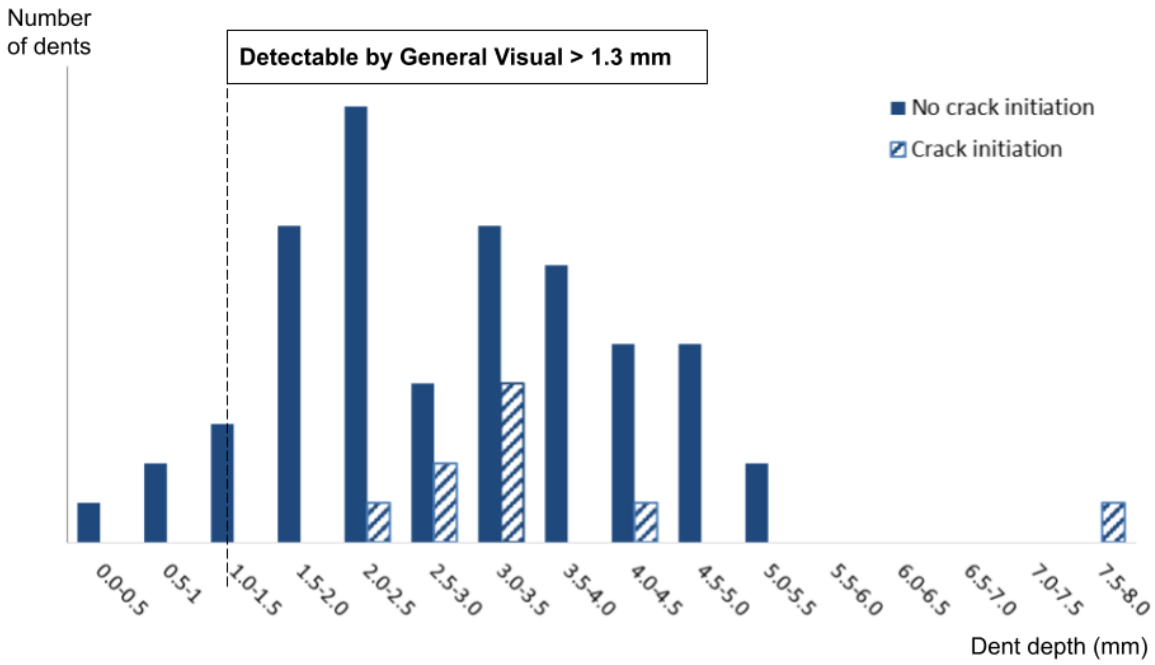

Figure 3: Test results with dents.

Fatigue cracks initiated on some of the deepest dents (see Figure 4). However, it took more than one Design Service Goal before the first cracks were detected during the test.

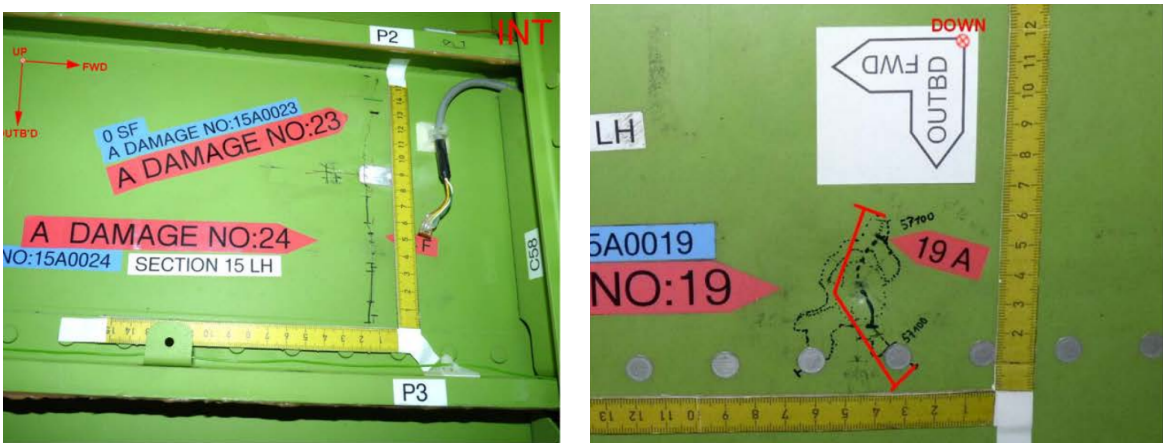

Figure 4: Fatigue cracking from deep fuselage dent.

Based on the results of this service and test experience survey, it is very unlikely that an accidental damage causes the initiation of a fatigue crack or that a fatigue crack initiates from an accidental damage before this accidental damage is found. Accordingly, it confirmed that the initial approach purely based on Damage Tolerance analysis was overly conservative.

The new approach in details

The Accidental Damage analysis is done by means of an assessment based on a rating system, consistent with the ATA MSG-3 philosophy. The following criteria are considered for each Structural Significant Item (see an overview in Figure 5):

- Likelihood of the Accidental Damage sources:

This evaluation aims at defining if the relevant Accidental Damage source (e.g. ground and/or cargo handling equipment, maintenance and/or operations procedure, weather effect, bird strikes, runway debris, …) is “likely” or “unlikely” to be present in the considered area during normal operation of the aircraft. This assessment is based on experience with similar aircraft in similar operations.

- Occurrence frequency of Accidental Damages:

Once an Accidental Damage source is identified as likely for a given area, the probability of occurrence is defined as “occasional” (could occur sometimes in A/C life) or “frequent” (likely to occur several times in A/C life). This evaluation is based on operators and manufacturer experience. It leads to the definition of the Accidental Damage Rating which is 1 for occasional or 2 for frequent.

- Stress Sensitivity Rating (Interaction with fatigue damage):

This evaluation is performed through the determination of a Stress Sensitivity Rating (SSR), which may be “Very low”, “Low”, “Medium” or “High”. The SSR represents the likelihood of the accidental damage to interact with fatigue damage and to reduce the residual strength capabilities of the area.

The Stress Sensitivity Rating assessment combines key Fatigue and Damage Tolerance features.

First, the fatigue and crack growth lives are used to rate the likelihood of the accidental damage to interact with fatigue damage: the larger the resistance of an area to fatigue crack initiation and growth, the smaller the probability of interaction between both phenomena.

Second, the residual strength capability is rated from existing design features such as load path redundancy, and from critical damage size evaluated through Damage Tolerance analysis. This rating is aimed to assess how far the structural strength would be degraded, due to accidental damage.

Finally, both ratings are combined to evaluate the Stress Sensitivity Rating.

- Inspection level determination:

The inspection level has to be defined to ensure the detection of the smallest relevant non obvious accidental damage, which is likely to occur during the A/C operational life. Under good access and inspectability conditions, General Visual Inspection is sufficient to detect signs of all relevant accidental damage that could interact with fatigue. However, under more difficult access and inspectability conditions, Detailed Visual Inspection can be selected to ensure that relevant accidental damage is detected. Specific areas may require a Special Detailed Inspection.

- Repeat Inspection interval:

The Accidental Damage Rating is combined with the Stress Sensitivity Rating in the double entry table shown in Table 1, to determine the repeat inspection interval. The inspection interval is expressed in calendar years.

Table 1: Repeat Inspection interval determination.

		ACCIDENTAL DAMAGE RATING	
		1	2
STRESS SENSITIVITY	0 - Very Low	No task required	12 YE
	1 - Low	12 YE	6 YE
	2 - Medium	6 YE	3 YE
	3 - High	3 YE	Specific justification

- Final inspection requirement:

Once defined, the inspection requirement from the MSG-3 accidental damage analysis is considered together with the inspection requirements from the other MSG-3 damage sources environmental deterioration and fatigue damage. These inspection requirements are accounted for in the MRB (Maintenance Review Board) Report. Inspection requirements with the inspection level General Visual Inspection are compared with the already defined zonal inspection tasks, which may provide an adequate inspection opportunity in terms of inspected area, inspection technique, and repeat interval. If the inspection interval of the existing zonal inspection task is equal or lower, the structure inspection requirements can be “transferred” into the existing zonal inspection task. When no adequate opportunity is provided by the zonal program, a specific inspection task is created in the structure section of the MRB Report.

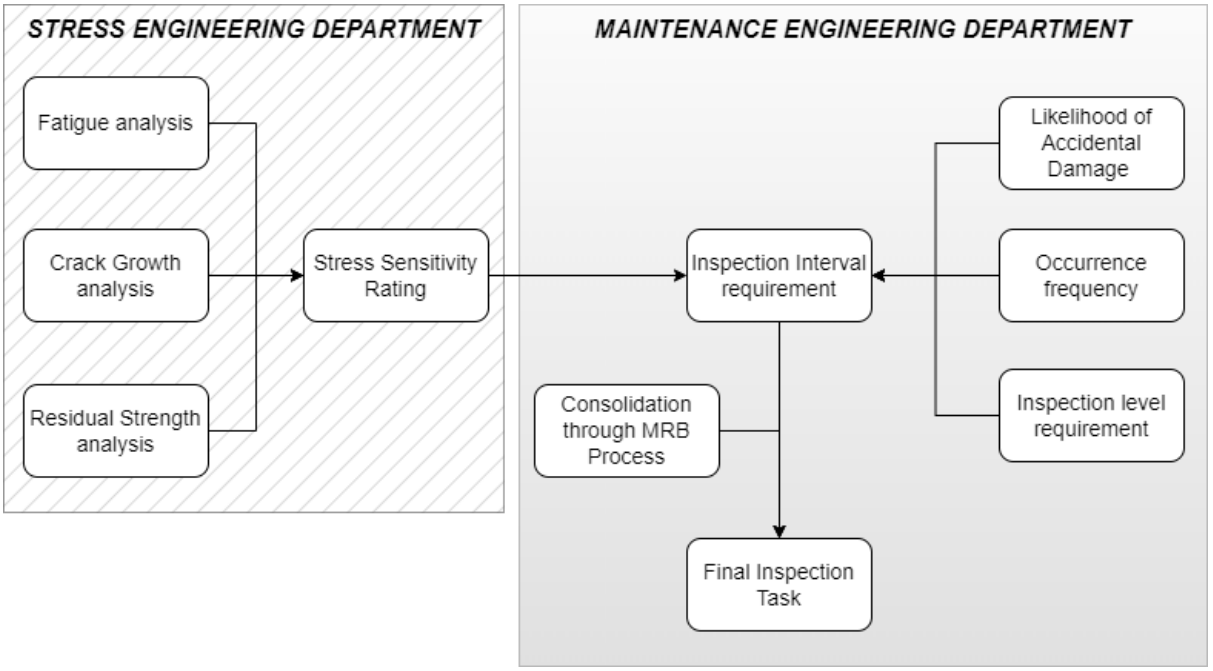

Figure 5: Overview of the new approach.

Application of the new approach

Once defined, the new approach was reviewed and agreed with all stakeholders. The Handbook regulating the policies and procedures applicable to establish the MRB report was updated. Implementation of this new approach on the various AIRBUS products started in 2019, with very good feedback from the operators.

The continuous validity of this new approach will be ensured in accordance with the EASA CS 26.305 (Validity of the continuing structural integrity programme), during the Maintenance Working Groups.

Examples of application

Two examples of application of the new approach are presented hereafter.

The first example is a fuselage side panel of A320 Family, below the cockpit side windows (Figure 6).

- Likelihood of the Accidental Damage sources: Likely (dents, scratches, bird / lightning strikes, surface protection deterioration).
- Occurrence frequency of Accidental Damages: Frequent (may occur several times in A/C life) → Accidental Damage Rating = 2
- Interaction with fatigue damage: Fatigue and crack growth lives are relatively high in this area, with a good level of residual strength → Stress Sensitivity Rating = Very Low.
- Inspection level requirement: General Visual Inspection.
- Repeat Inspection Interval = 12 years (see Table 1).
- Final inspection requirement: existing zonal inspection task adequately covering the area (Interval = 48 months). No new additional task created.

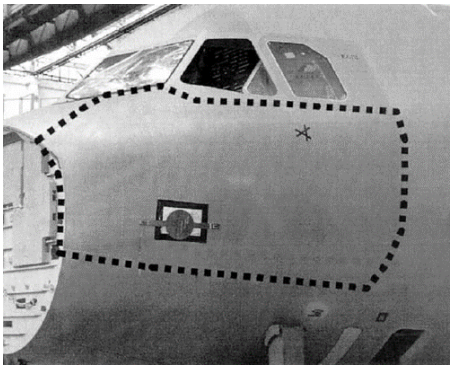

Figure 6: Fuselage side panel below the cockpit side windows (A320 Family).

The second example is a forward cargo door cutout in the fuselage of A320 Family, at the visible part of the surrounding frames (Figure 7).

- Likelihood of the Accidental Damage sources: Likely (scratches, surface protection deterioration).
- Occurrence frequency of Accidental Damages: Frequent (may occur several times in A/C life) → Accidental Damage Rating = 2
- Interaction with fatigue damage: the fatigue life is relatively high in this area. However the damage tolerance properties (crack growth and residual strength) are more critical than in the generic areas → Stress Sensitivity Rating = Medium.
- Inspection level requirement: General Visual Inspection.
- Repeat Inspection Interval = 3 years (see Table 1).
- Final inspection requirement: existing zonal inspection task adequately covering the area (Interval = 12 months). No new additional task created.

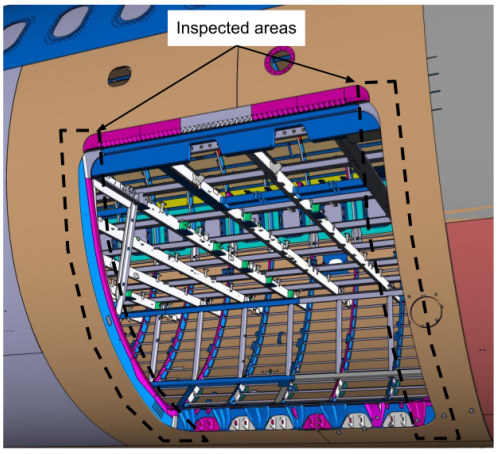

Figure 7: Forward cargo door cutout (surrounding frames).

CONCLUSION

The collective experience from operators, maintenance & repair organizations, AIRBUS maintenance engineering and stress specialists was combined to build a new approach to define the scheduled inspection tasks for accidental damage.

The AIRBUS test and service experience demonstrated that the accidental damages susceptible to interact with fatigue damage are relatively obvious and detected well before any interaction occurs.

The new approach is less conservative, in line with the physics of the phenomenon. It combines an MSG-3 based procedure together with fatigue and damage tolerance analysis results. The consolidation with the environmental and zonal inspection requirements avoids a duplication of inspection tasks. Overall, the effectiveness of the inspection program for accidental damage was improved and the new approach has been recognized as a “huge improvement in scheduled maintenance” by the A350 maintenance working group operators.