STC Structural Substantiation Workshop - Antenna Installation Damage Tolerance & Cabin Interior Issues

Structural substantiation analyses by Airbus DS

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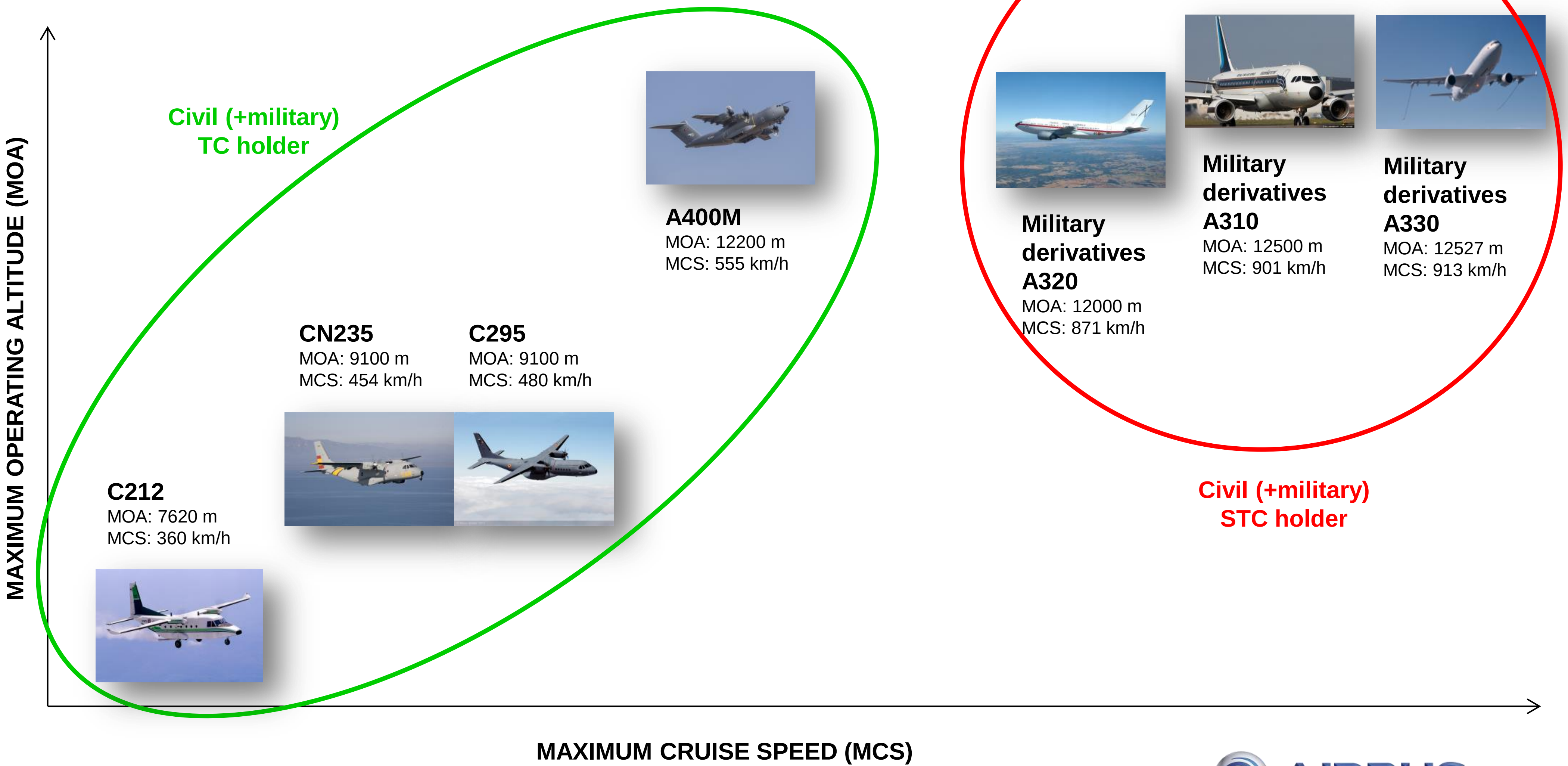
Structural modifications in Airbus DS

Structural modifications in Airbus DS

Structural modifications performed in a wide range of platforms, from pure civil to pure military models, with intermediate scenarios (mission aircraft, military derivatives):



Structural modifications in Airbus DS

Scope of structural modification is different, but usually a combination of several of the following alterations:

ALTERATION	ASSOCIATED EFFORT
Installation of new antennae	Low
Relocation of already existing civil antennae	Low
Installation of military sensors and/or lights	Medium
Installation of countermeasures	High
Installation of mission equipment (e.g., tanker kit)	High

Structural modifications in Airbus DS

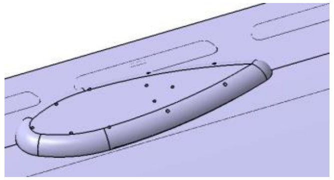
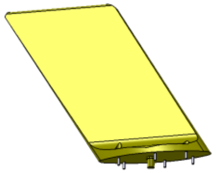
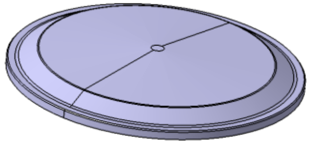
Most complex case under STC is the conversion of civil aircraft into military tanker (e.g., A330 Multi Role Transport Tanker). A standard process involves 20-30 actuations in antennae.

The scope of the civil STC includes the structural provisions for the installation and, eventually, a change of usage in the aircraft. Military STC includes the operation of the antennae (not structural) and a change of usage in the aircraft.

Antennae installation

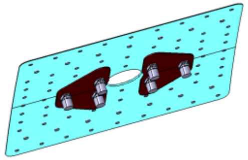
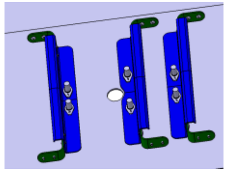
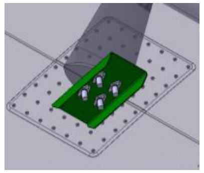
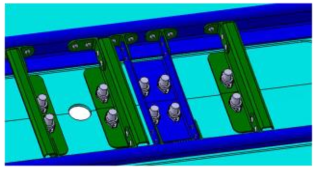
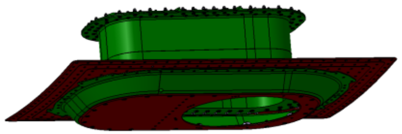
Antennae installation

The most common antennae installed can be grouped into four categories:

TYPE	DESCRIPTION	FEATURES
A	Protruding 	Standard installation
B	Blade-like 	Standard installation + backup structure
C	Towel bar 	Standard installation + backup structure (several attachment points)
D	Flushed 	Requires a fairing and a dedicated pressure box

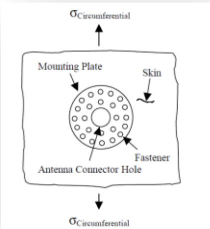
Antennae installation

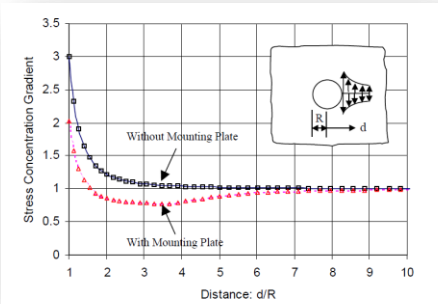
Similarly, up to five different structural installation designs are commonly used:

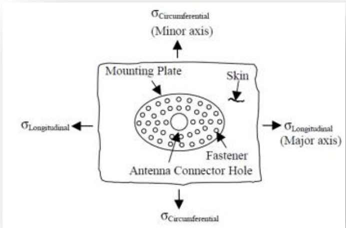
DESIGN TYPE	APPLICATION			
	A	B	C	D
Doubler + nut strap/s 				
Doubler + z-profiles (+ nut straps) 				
Doubler + channel reinforcement 				
Doubler + z-profiles + channel reinforcement 				
Doubler + fairing + pressure box 				

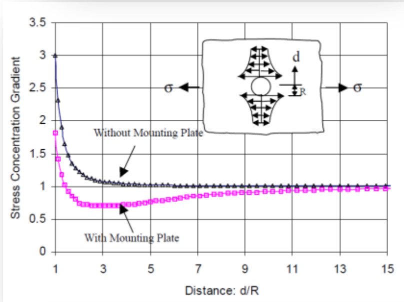
Antennae installation

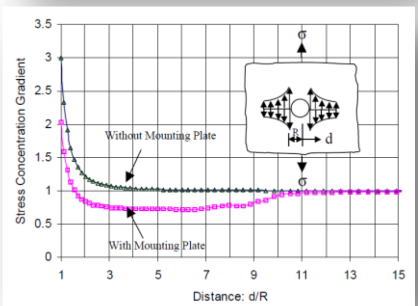
Square/rectangular doublers preferred for types A, B and C, following Structural Repair Manual (SRM) guidelines. This pattern is the most efficient in order to reduce the stress concentration at the connector hole, but requires the installation of a larger number of fasteners:

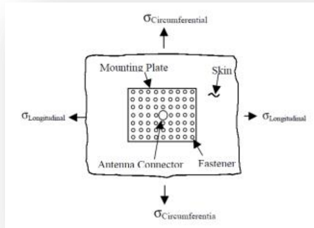


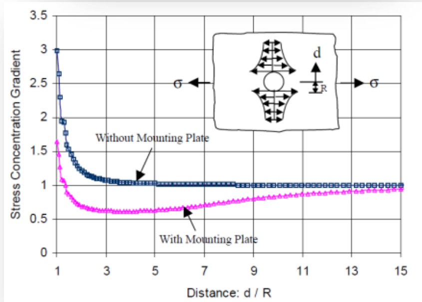


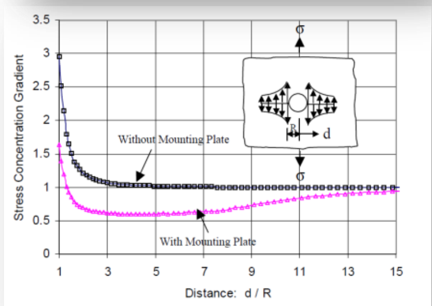








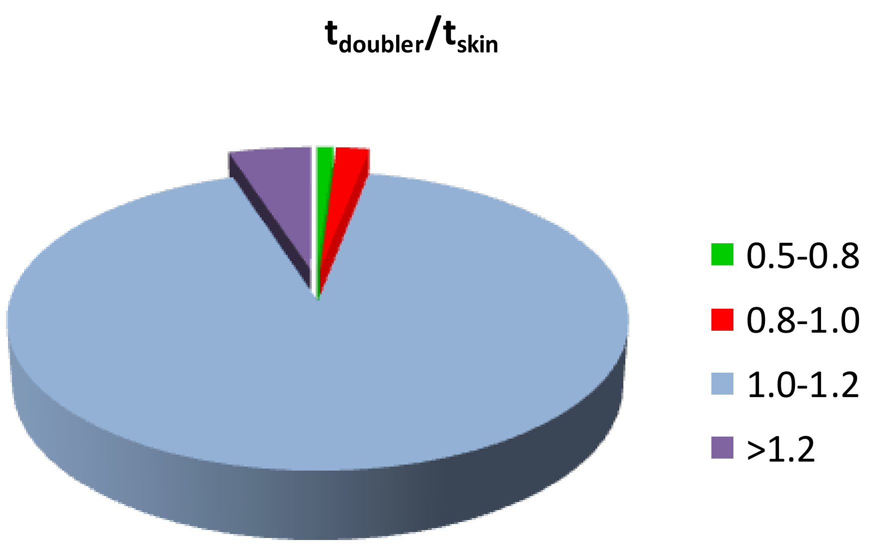




Source: Chen C., Nomura M., Yu J., *Enhancements to Repair Assessment Procedure and Integrated Design (RAPID). Analysis methods enhancements,* Wright-Patterson Air Force Base, 2000

Antennae installation

- For installations type A, B and C, sheet formed doublers (mainly Clad 2024) are used with $t_{doubler}/t_{skin}$ ranging from 0.5 to 1.2 (in most of the cases in the range 1.0 to 1.2)



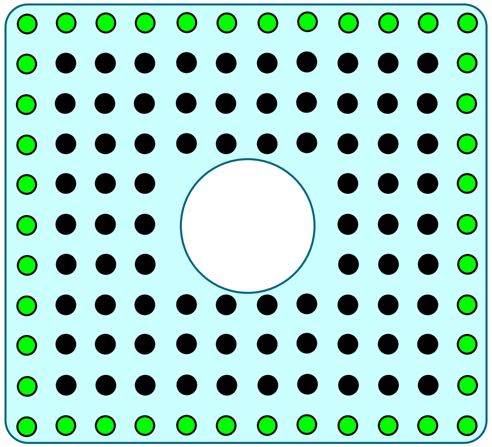
- Doublers are extended beyond the adjacent stringers
  - <u>Advantanges</u>: better load reaction, avoidance/minimization of secondary bending moments
  - <u>Disadvantanges</u>: larger doublers, removal of fasteners in stringers

Antennae installation

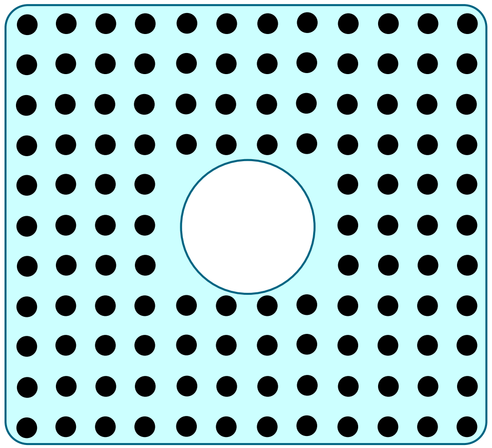
- External doublers are used for this purpose
  - Advantages: minimize the impact on the stringers (lower installation costs)
  - Disadvantages: inspectionability impacted (inspections from outside no longer possible, skin sandwiched between doubler and stringer, nut straps are a concern)

- Internal backup structure (either Z-profiles or channel fittings) added depending on the loads transferred by the antenna. No predefined threshold, case-by-case analysis

- Solid/hi-lok fasteners following SRM guidelines, uniform diameter (∅4.0mm or ∅4.8mm). No attempt to control the load in the first row by combining different diameters in the same doubler



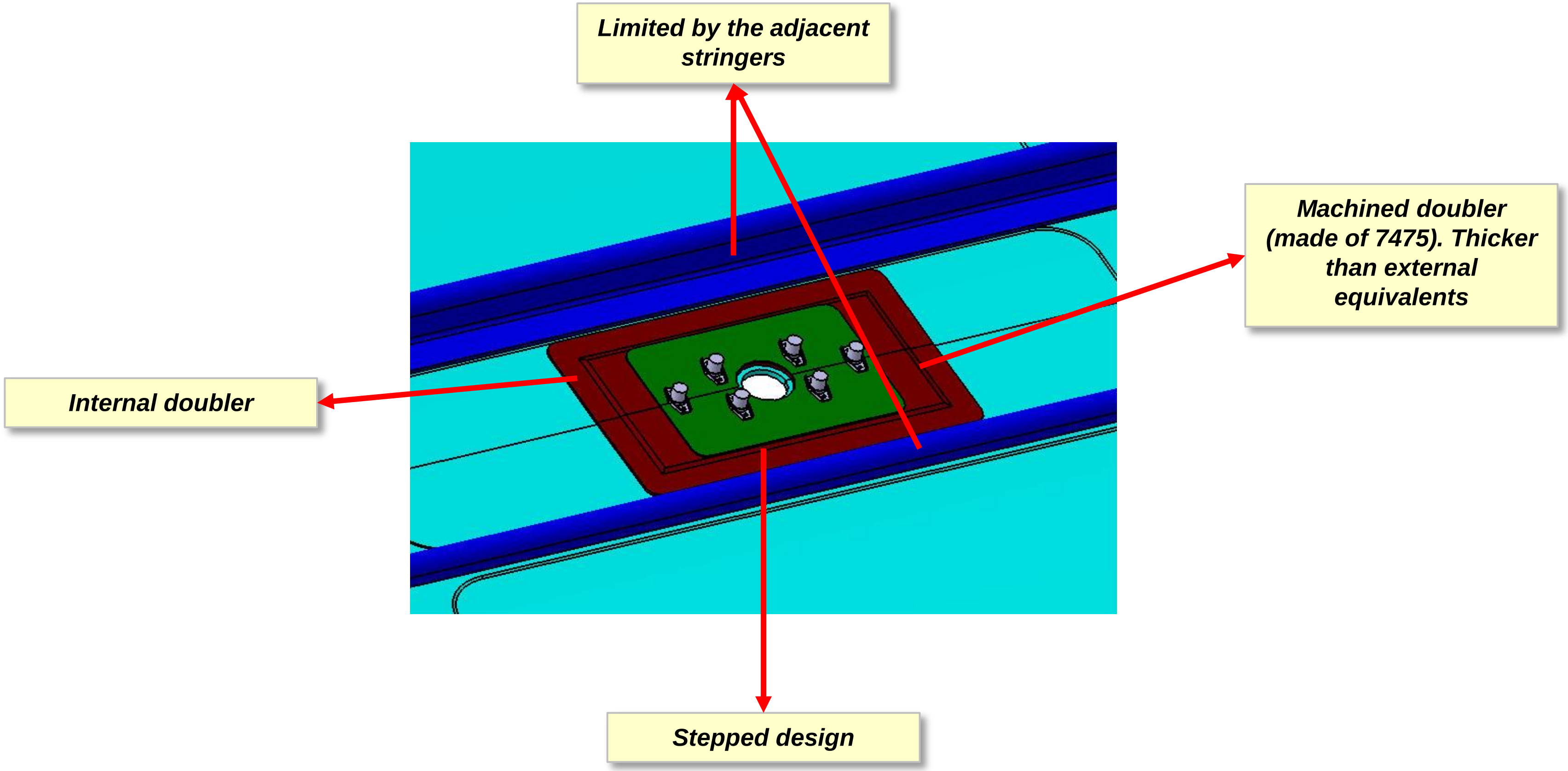
Unused fastener pattern



Standard fastener pattern

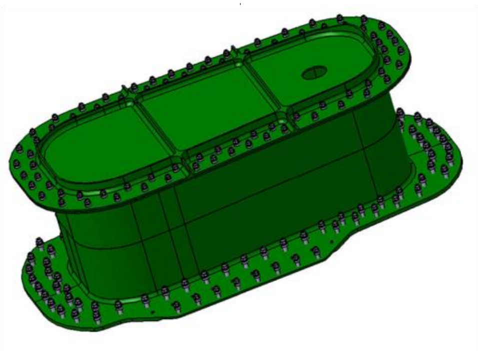
Antennae installation

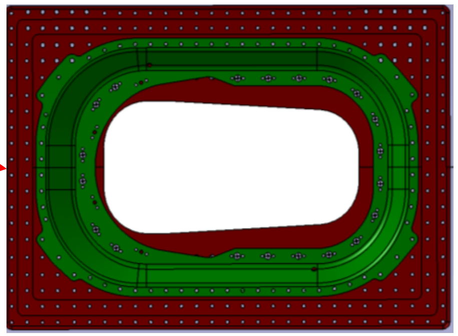
In some cases, initial SRM-like doublers have been evolved in order to optimize weight and simplify the assembly process:



Antennae installation

- Type D installations (flushed) are different in nature:
  - No SRM guidelines to be followed, although parts of the philosophy reused (for example, extension beyond frames and stringers)
  - Doublers are usually machined elements (7075, 7475, etc), in order to restore the stiffness and load path
  - Higher $t_{doubler}/t_{skin}$ than in A, B and C installations (stepped thickness used)
  - Extensive impact on adjacent stringers and frames
  - No backup structure
  - Careful design of pressure box in order to avoid abrupt changes in the loads (secondary bending moments)





Loading

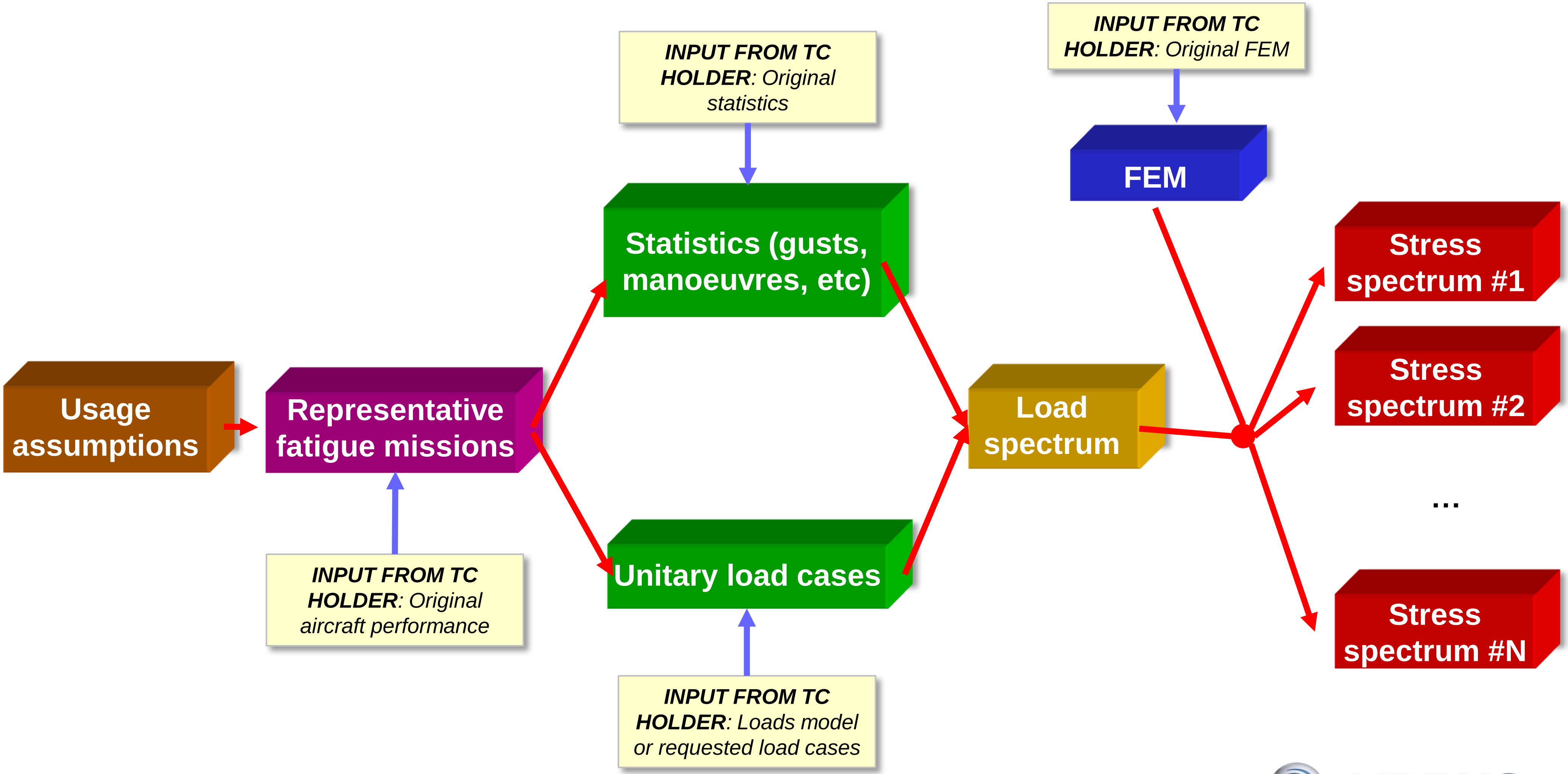
Loading

Local stress sequences are generated from a load spectrum that is representative of the expected usage of the aircraft. The steps taken to generate these stress sequences are:

•Analysis of the requirements from the customer
•Analysis of the airplane performances and build of typical flight profiles
•Generation of statistical data of the aircraft load distribution at the center of gravity for ground operations, flight maneuvers, airplane gust responses, etc
•Creation of load cases (1g, incremental) for the appropriate load environments for each operating segment of the typical flight profiles
•Assembly of the load case from each segment to form a complete flight load sequence
•Conversion of the load sequence into a stress sequence representative of the location of the antenna installation using a full-scale/component finite element model. The stress sequences for the analysis location are counted using the rainflow counting method

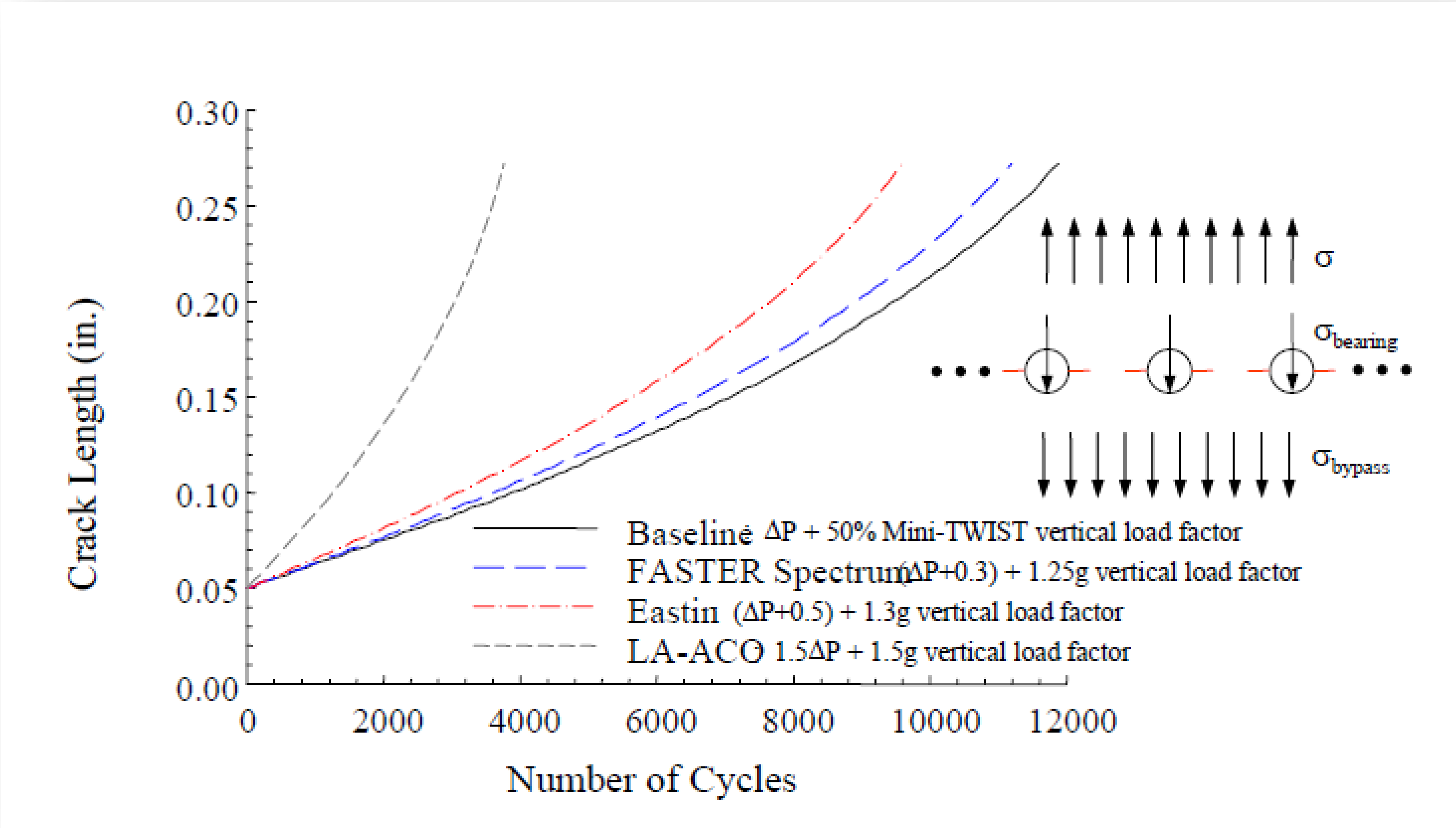
Loading

This approach implies a close cooperation with the TC holder in order to receive the appropriate input data.



Loading

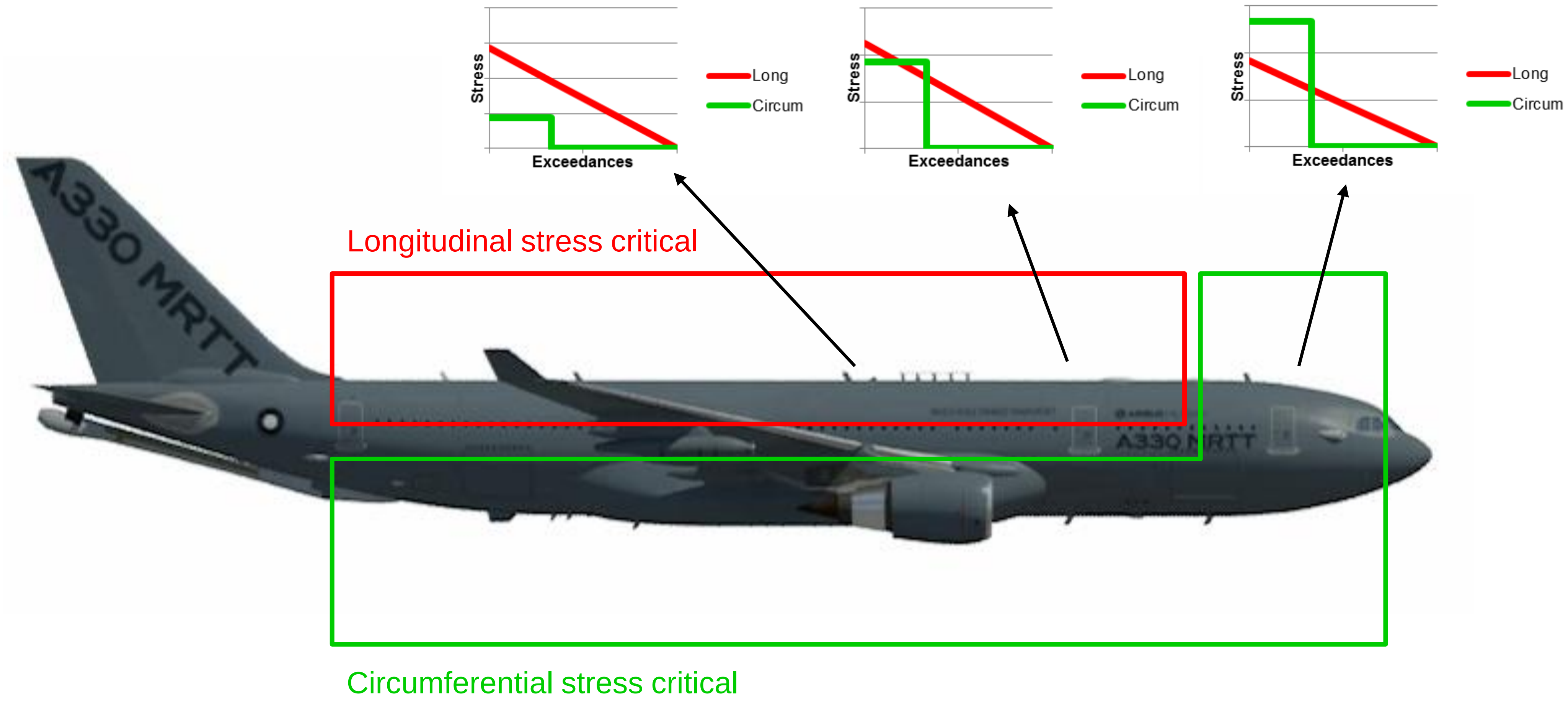
A detailed stress spectrum avoids the conservatism associated to the different simplified approaches (of the form A(ΔP+B)+Cg) that have to be used in absence of this information:



Source: Mosinyi, B., ; Bakuckas, J.; Steadman, D.: *Destructive evaluation and extended fatigue testing of retired transport aircraft, Volume 4: extended fatigue testing,* Federal Aviation Administration, 2007

Loading

As could be expected, longitudinal stress spectra are critical in the upper fuselage installations, except close to the nose fuselage:



The location of the transition between circumferential and longitudinal is not inherent to the geometry, but changes with the usage of the aircraft

Analysis

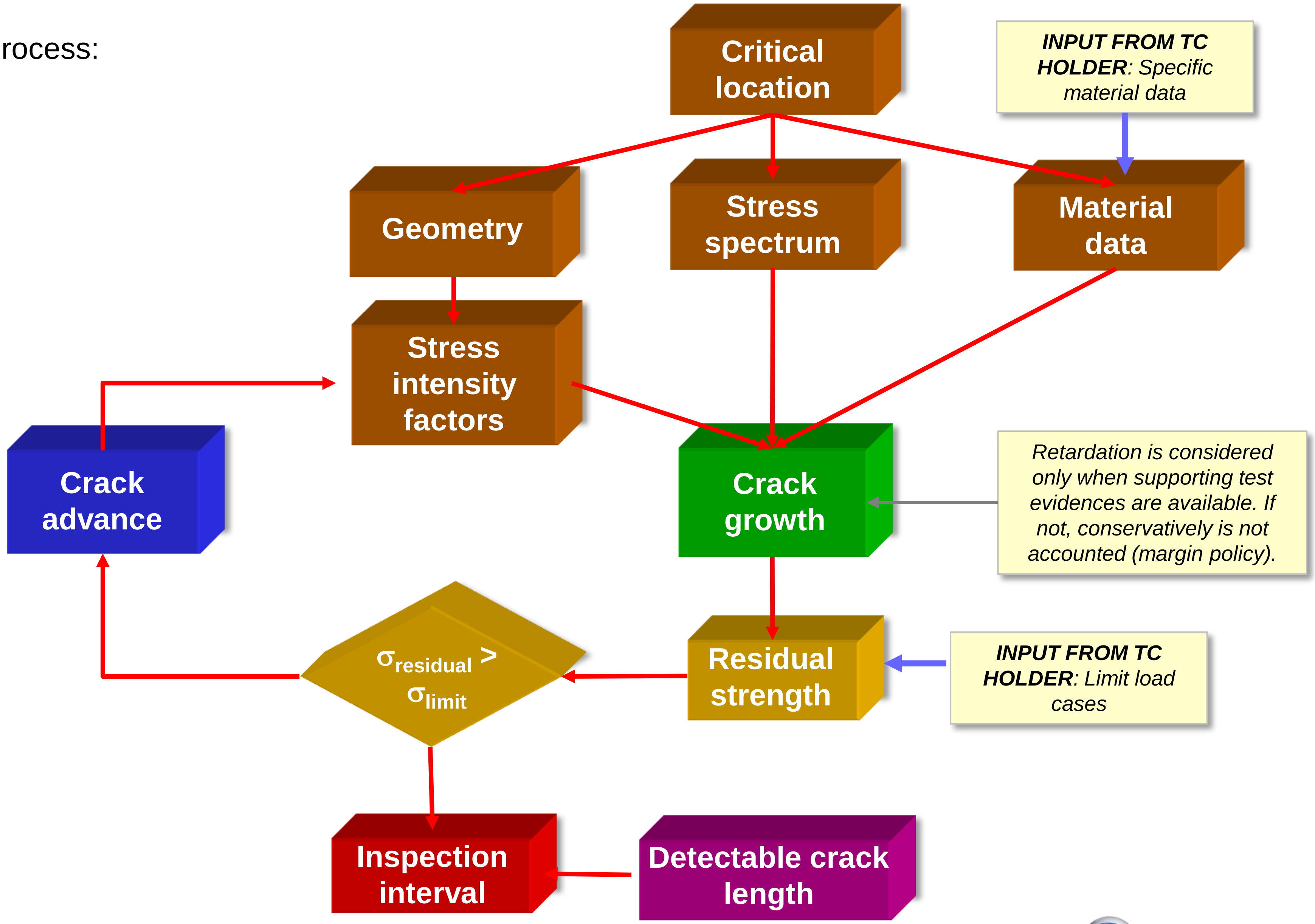
Analysis

No specific methods applied for antennae installations. This scenario is a particular case of the general methodology based on an in-house implementation of the Linear Elastic Fracture Mechanics (LEFM). Steps:

- Selection of critical locations
- Assumptions of initial flaws at the critical locations, and of the scenarios for the subsequent continuing damage
- Calculation of the appropriate stress spectra
- Compilation material data:
    - Crack growth rate data of the skin material (da/dN curves)
    - Fracture toughness of the skin material
- Compilation geometrical data:
    - Stress intensity factors of relevant crack configurations

Analysis

Calculation process:



Analysis

Conventional designs

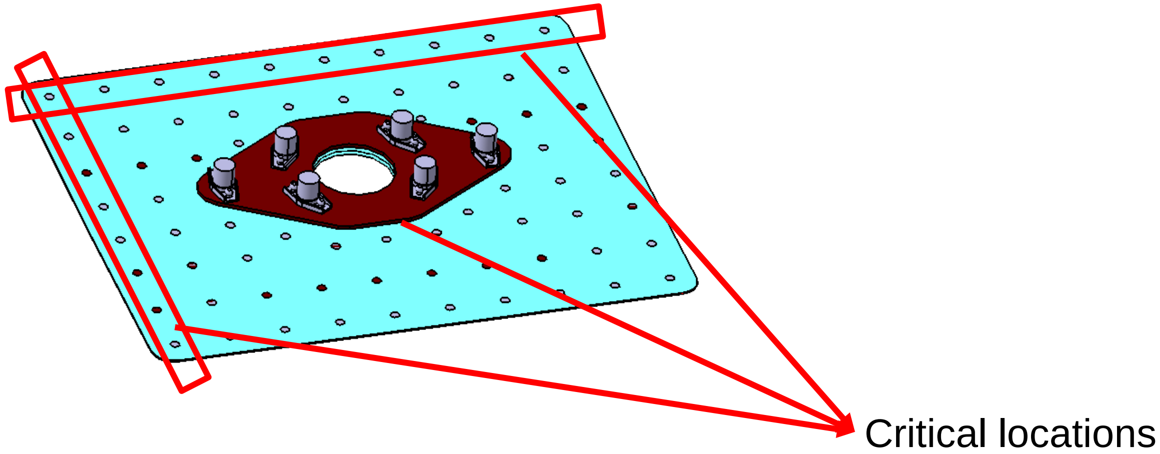
Analysis (conventional designs)

Three critical locations are considered for rectangular installations:

- Longitudinal cracking at the outer row of fastener holes
- Circumferential cracking at the outer row of fastener holes

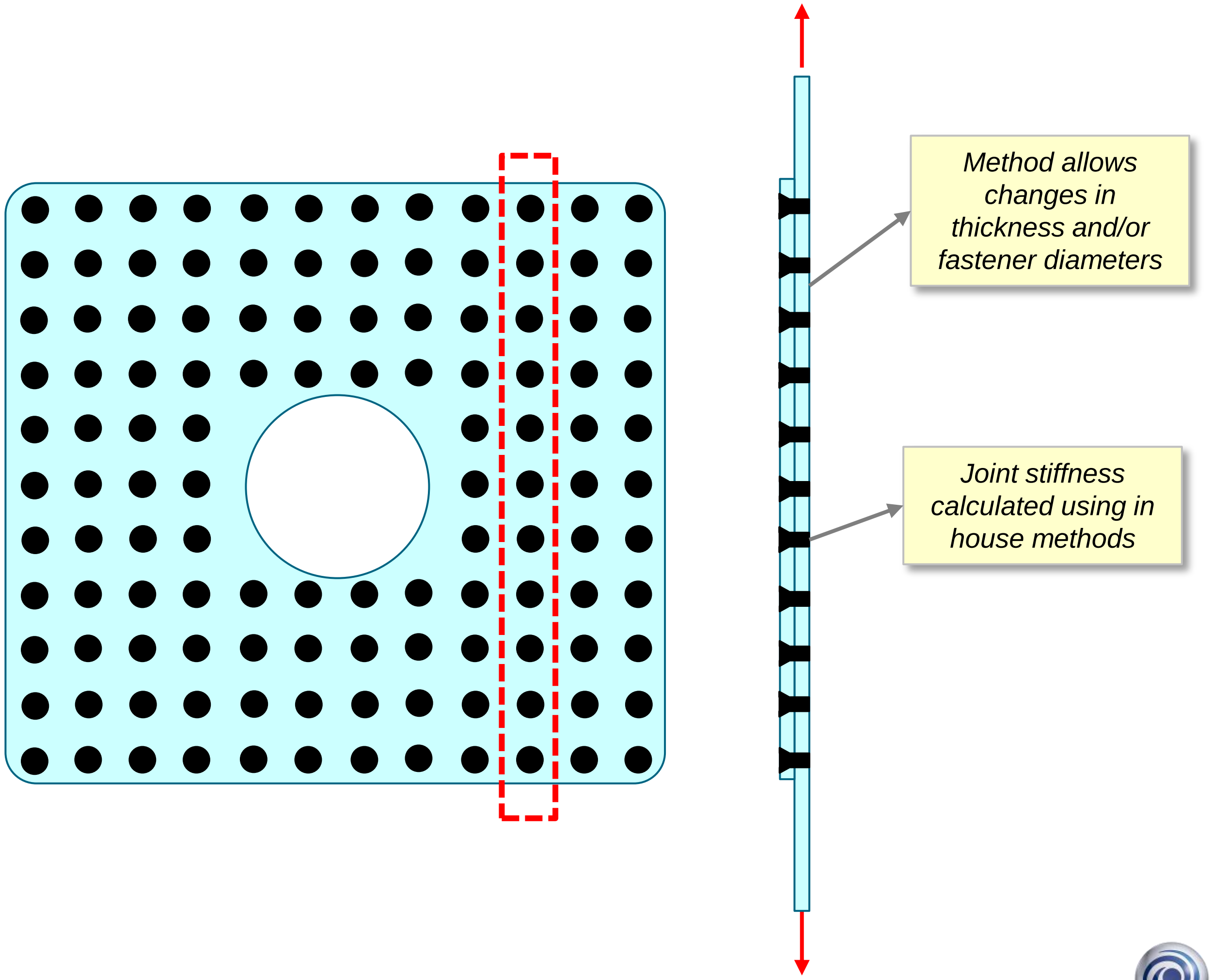
Particularly central and corner fasteners (maximum load transfer)

- Edge of antenna connector hole in the skin (maximum geometrical stress concentration)



Analysis (conventional designs)

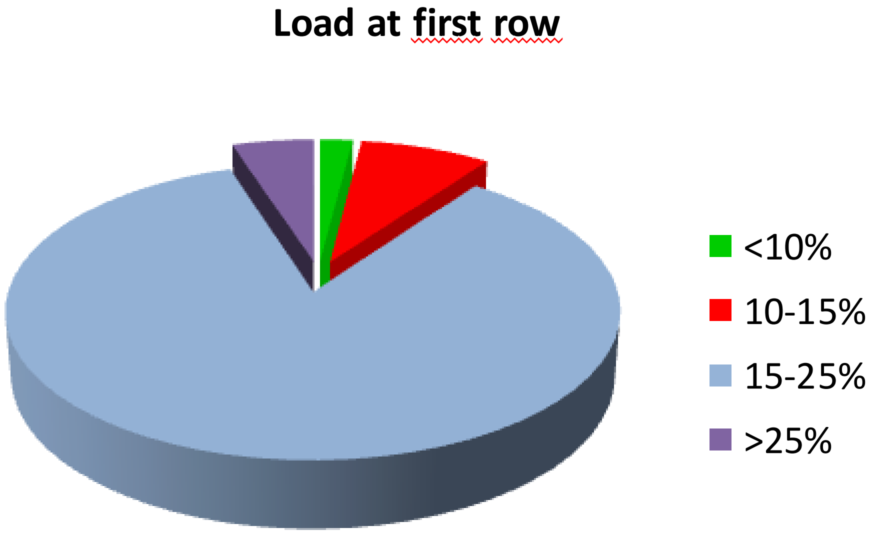
Fastener loads are calculated using an idealized strip of 1 rivet spacing in width, and performing a displacement compatibility analysis.

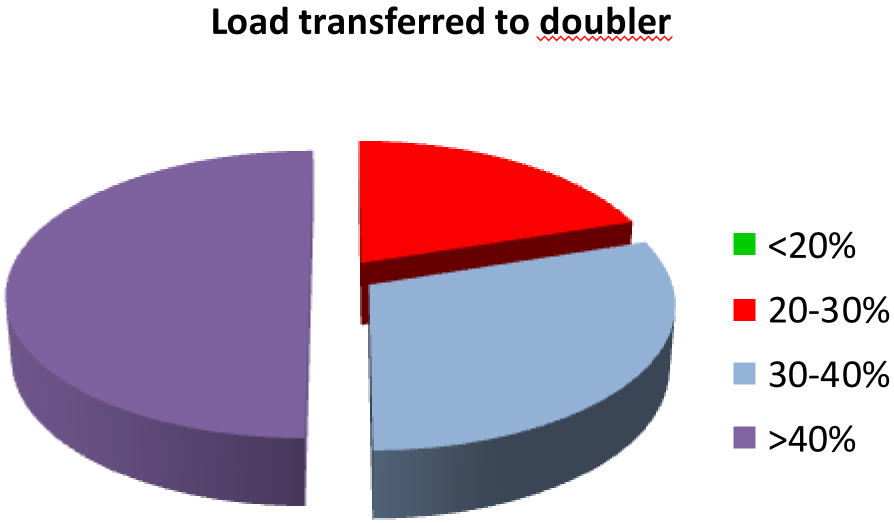


Analysis (conventional designs)

Typical loads at first row and typical total load transferred at doubler are a combination of several factors, including:

- Skin/doubler thickness
- Number and diameter of fasteners



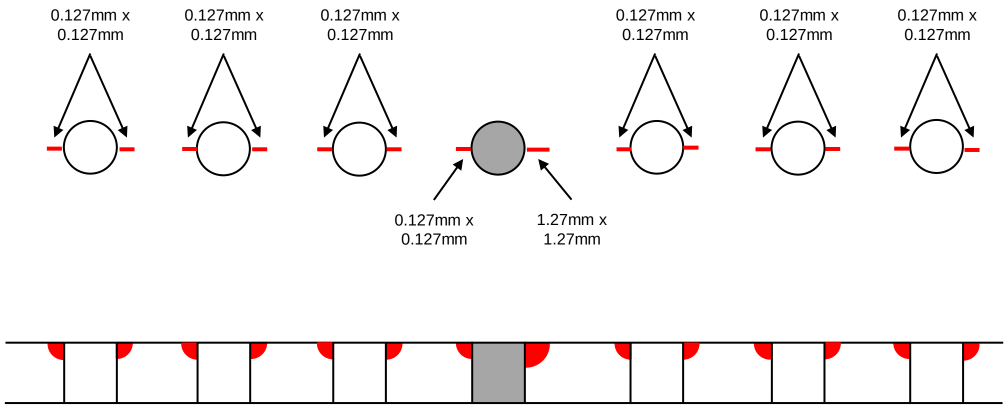


Analysis (conventional designs)

Three scenarios are considered for rectangular antenna installations:

<u>Scenario 1a: Center fastener hole in the outermost fastener row</u>

<u>Initial Crack</u>: Two diametric corner cracks of lengths 1.27 mm x 1.27 mm (rogue) and 0.127 mm x 0.127 mm (quality), respectively, emanating from the center fastener hole together with two 0.127 mm x 0.127 mm corner cracks at both sides of every other hole:



Analysis (conventional designs)

Three scenarios are considered for rectangular antenna installations:

Scenario 1a: Center fastener hole in the outermost fastener row (cont'd)

Subsequent Damage: All cracks grow concurrently and interaction between cracks is considered. The amount of growth of all cracks is updated in every step of the calculation. The same process continues in successive growth.

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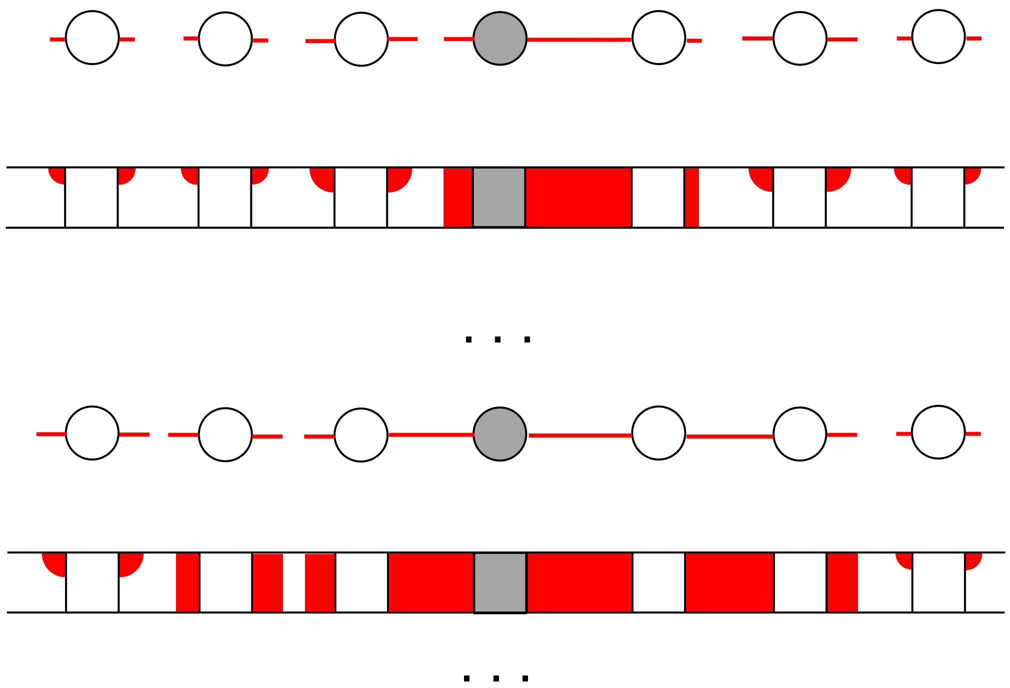
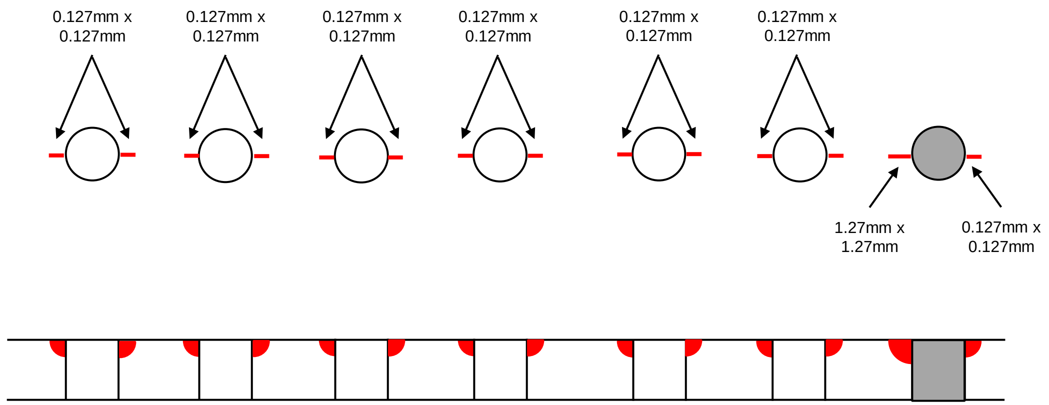


Analysis (conventional designs)

Scenario 1b: Corner fastener hole in the outermost fastener row

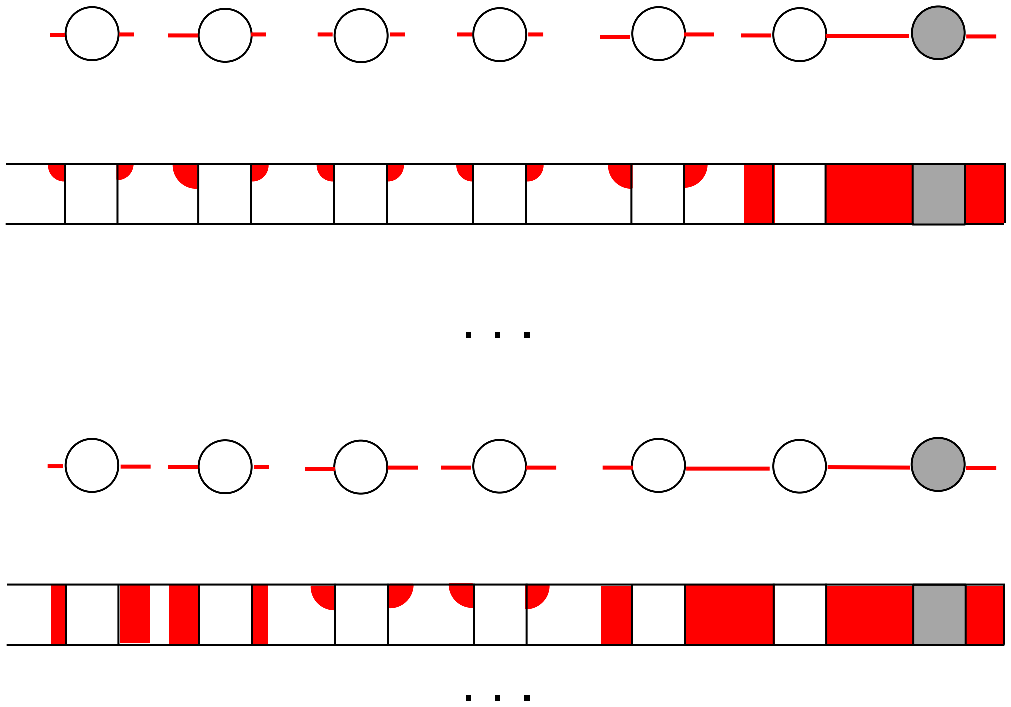
Initial Crack: Two diametric corner cracks of lengths 1.27 mm x 1.27 mm (rogue) and 0.127 mm x 0.127 mm (quality), respectively, emanating from the corner fastener hole together with two 0.127 mm x 0.127 mm corner cracks at both sides of every other hole:



Analysis (conventional designs)

<u>Scenario 1b: Corner fastener hole in the outermost fastener row (cont'd)</u>

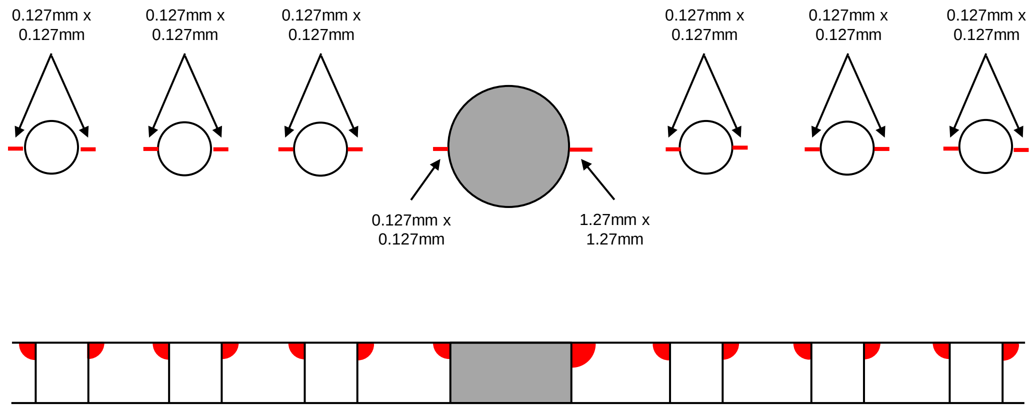
<u>Subsequent Damage</u>: All cracks grow concurrently and interaction between cracks is considered. The amount of growth of all cracks is updated in every step of the calculation. The same process continues in successive growth.



Analysis (conventional designs)

Scenario 2: Antenna connector hole

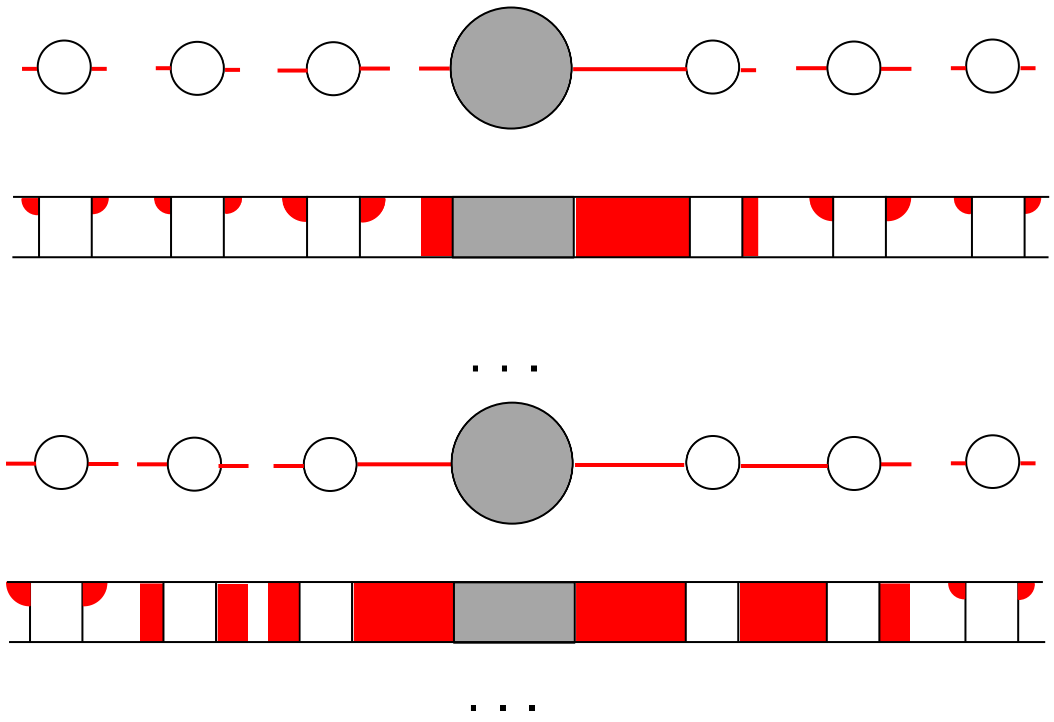
Initial Crack: Two diametric corner cracks of lengths 1.27 mm x 1.27 mm (rogue) and 0.127 mm x 0.127 mm (quality), respectively, emanating from the antenna connector hole hole together with two 0.127 mm x 0.127 mm corner cracks at both sides of every other hole:



Analysis (conventional designs)

Scenario 2: Antenna connector hole (cont'd)

Subsequent Damage: All cracks grow concurrently and interaction between cracks is considered. The amount of growth of all cracks is updated in every step of the calculation. The same process continues in successive growth.



Analysis

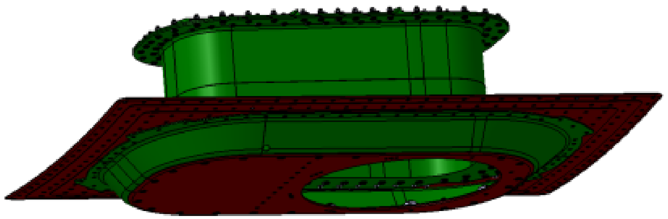
Non-conventional designs

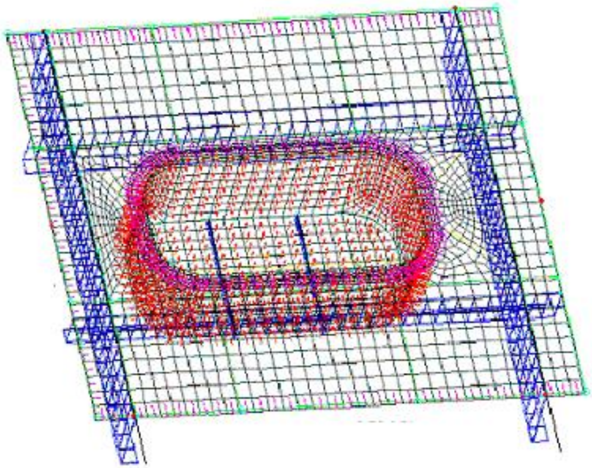
Analysis (non-conventional designs)

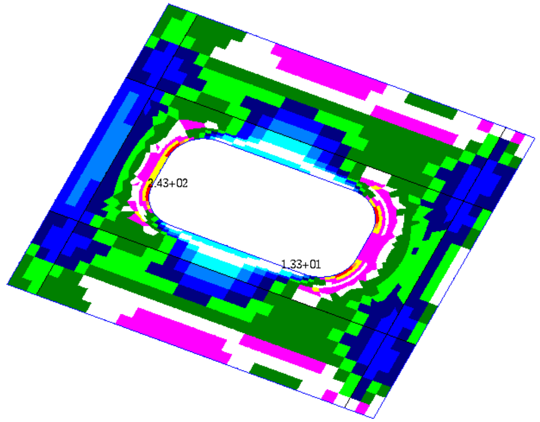
Analysis of type D installations (flushed antennae) follows a case-by-case procedure.

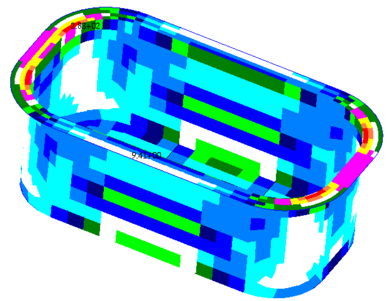
Main differences with respect to conventional designs:

- Stress distributions based usually on detailed ad hoc FE models
- Basic crack growth scenarios qualitatively apply, but additional ones may appear
- Far more complex calculation of stress intensity factors and crack interaction









Retardation is considered only when supporting test evidences are available. If not, conservatively is not accounted (margin policy).

AIRBUS DEFENCE & SPACE

Associated maintenance program

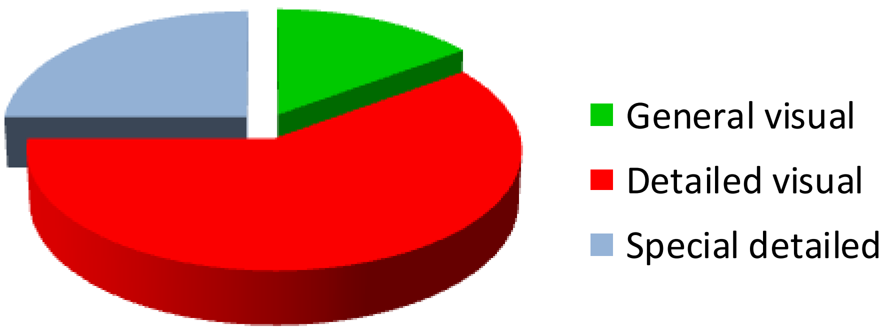
Associated maintenance program

For internal doublers in installations of types A, B or C, general/detailed visual inspections will be usually enough to meet the maintenance requirements, depending on the size of the reinforcements.

For external doublers, two alternatives are available:

- Visual detailed inspections from inside
- Special detailed inspection from outside

Distribution of inspections:

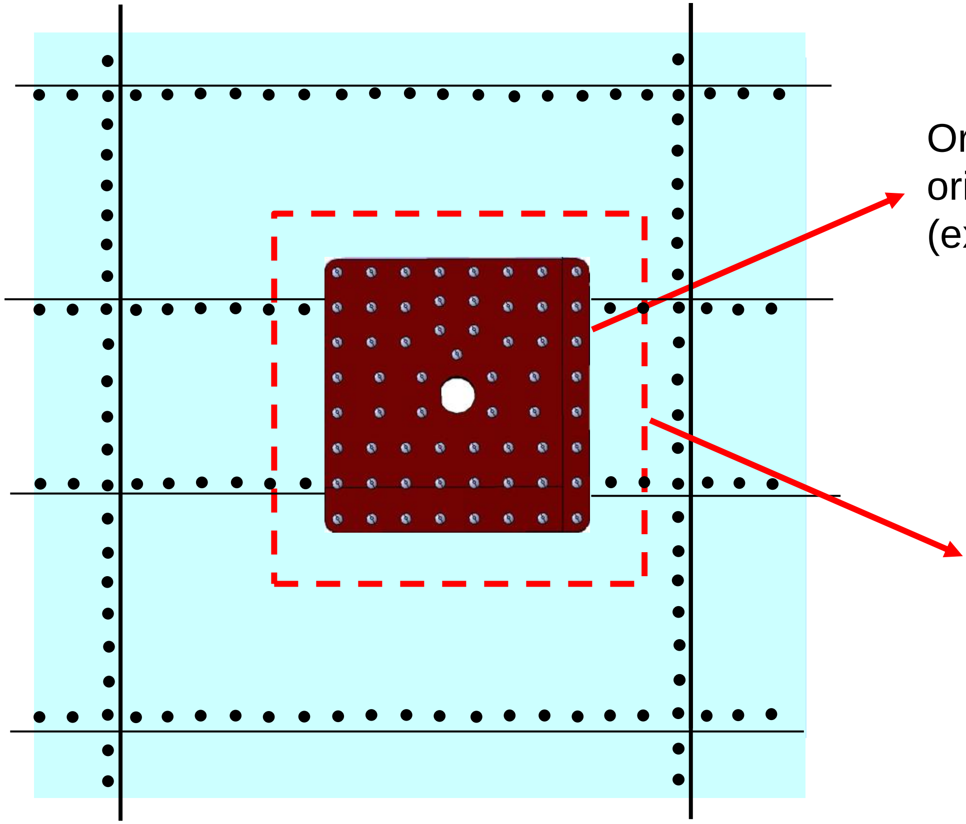


Procedure for special detailed inspections can be obtained from aircraft NTM. However, installations of type D usually require the development of ad hoc procedures (→ specific detectable crack length to be considered in the analysis).

Associated maintenance program

Usual safety factors for the determination of the inspection periodicity, although they can be increased in several cases (e.g., quick growth of quality cracks in large doublers).

The periodicity of the associated local inspection should be harmonized with that of the surrounding structure before the installation.



Original crack growth patterns + original inspectionability impacted (external doublers)

Original crack growth patterns impacted (external + internal doublers)