INTRODUCTION TO AIRCRAFT STRUCTURES

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INTRODUCTION TO AIRCRAFT STRUCTURES : AIRCRAFT STRUCTURAL REQUIREMENTS

Or ‘the “basic ‘rules” for making an airframe safe’

Aircraft Structural Requirements

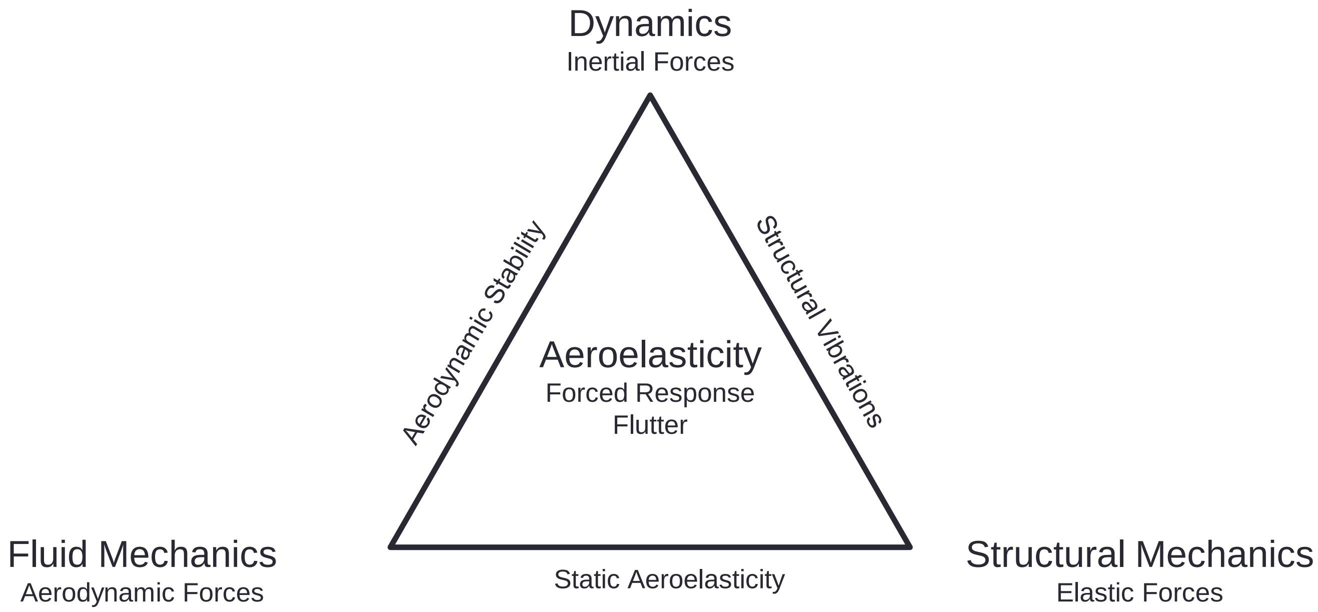
- **Strength**
- The structure must carry limit loads (maximum loads anticipated during service) without damage.
- Ultimate loads (normally 1.5 x limit loads) must be carried without failure.
- No detrimental permanent deformation is permitted under Limit load.

Aircraft Structural Requirements

- **Stiffness**
- Deflections must not be excessive (e.g. wing must retain its cross-section)
- Buckling is also controlled by stiffness
- Flight controls must physically function at a typical factor of 1.15 times Limit Load

Aircraft Structural Requirements

- **Stiffness**
- Aeroelasticity



- Aerodynamic loading produces a twisting moment in the wing due to the offset of the centre of lift relative to the torsional centre. Increased torsion leads to increased loading, and this can be unstable if the wing has inadequate torsional stiffness (static divergence). Aileron control reversal can also occur due to insufficient stiffness.

Aircraft Structural Requirements

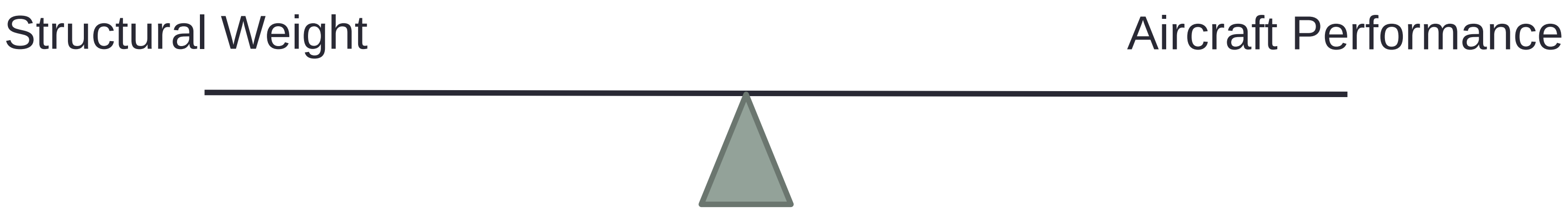
- **Stiffness**

- Flutter is caused by interaction between the structural dynamics and aerodynamics, and can be precipitated by inadequate stiffness. The classical case is when a wing bending and torsional mode of vibration occur at the same frequency. The modes become coupled, and can extract energy from the airflow, leading to increasing oscillations.

- And now ……… the videos ☺

Aircraft Structural Requirements

- **Low Weight**
- The structure of a passenger aircraft is typically around 30% of all-up weight, whereas the payload may be only 15%, so small increases in weight can significantly affect performance.



Aircraft Structural Requirements

- **Resistance to Fatigue**

- Fatigue is failure due to repeated application of a load which is not large enough to cause failure when applied statically.

- Fatigue damage initiates at stress concentrations, and can be reduced by good detail design (e.g. using fillet radii and avoiding sudden changes of geometry).

Aircraft Structural Requirements

- **Resistance to Corrosion**

- Aircraft structures are normally painted to provide protection.

- Surface treatments such as anodising aluminium are also important.

- Galvanic protection is required on carbon to aluminium interfaces (i.e. glass fibre isolation plies between the mating surfaces)

- Environmental concerns are a priority when selecting a protective treatment

Aircraft Structural Requirements

- **Damage Tolerance**

- Must be able to operate safely in the presence of manufacturing defects or damage arising during service (fatigue, corrosion, impact).

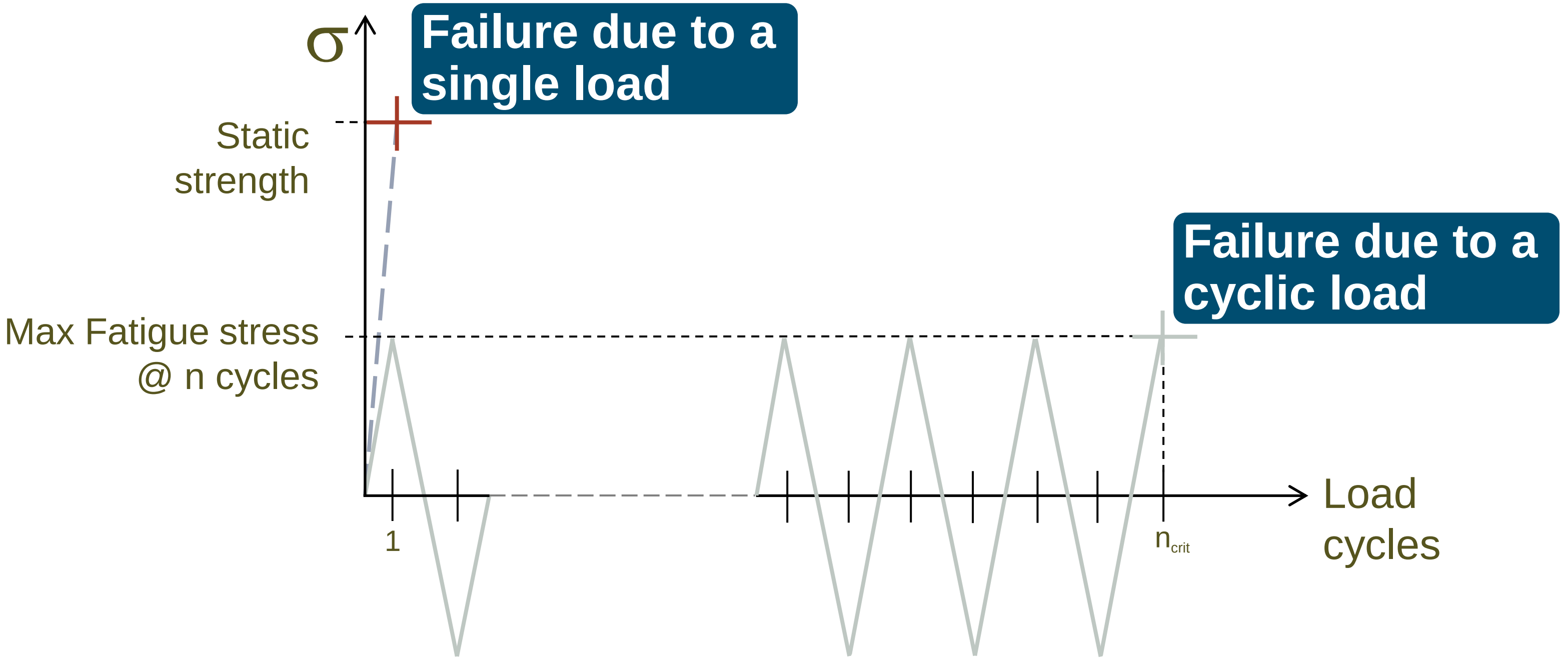
- Structure must be able to withstand large damage for economic repair. This is not an Airworthiness requirement but is a pragmatic commercial requirement.

INTRODUCTION TO AIRCRAFT STRUCTURES : FATIGUE AND DAMAGE TOLERANCE

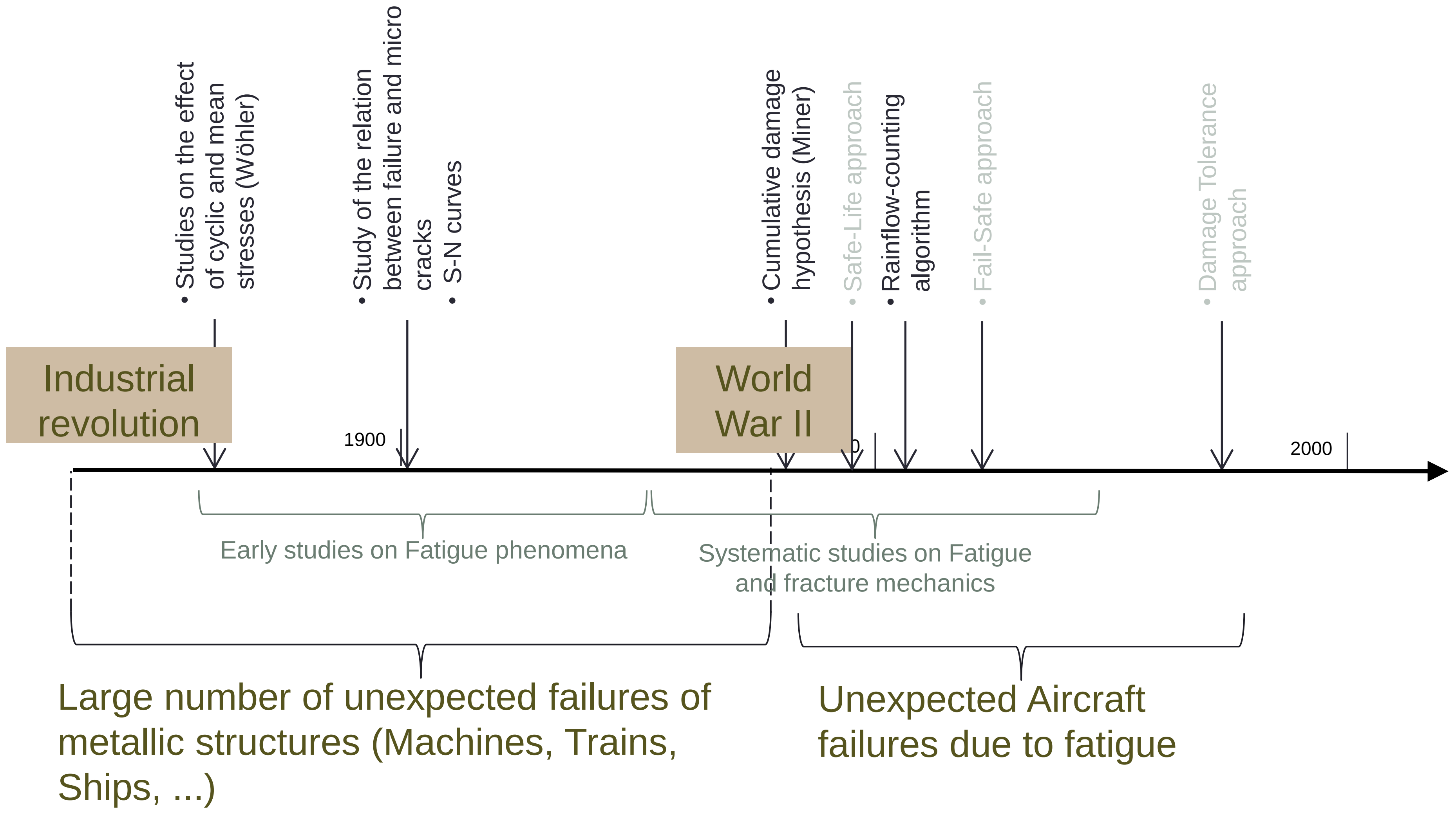
Or ‘How to give an airframe a safe and economic life’

Introduction to Fatigue & Damage Tolerance

- Fatigue: Progressive weakening of a material caused by repeated and fluctuating loads which never reach a level sufficient to cause failure in a single application



Introduction to Fatigue & Damage Tolerance



Introduction to Fatigue & Damage Tolerance

- **Safe-life design** – structure will not fail by fatigue over its lifetime.

- Generally now only used where:

- Impractical to provide necessary redundancy – single load path
- e.g. undercarriage leg

- damage would propagate too quickly
- e.g. some helicopter rotor and dynamic drive components

Introduction to Fatigue & Damage Tolerance

- **Fail-safe design** – structure has adequate strength and stiffness in the presence of fatigue or other types of damage
- Requires:
  - Redundant structure with multiple load paths
  - Crack propagation resistance
  - Inspection to detect damage
- Need to demonstrate safe operation with:
  - Any single member ineffective
  - Continuous structure severed between effective crack barriers
  - No unstable propagation of damage before inspection

Introduction to Fatigue & Damage Tolerance

- **Damage tolerant design**

- Capable of withstanding service loads with failed element and cracks in adjacent structure, i.e. multi-site damage.

- This is the predominant design philosophy for metallic and composite airframe structures

Introduction to Fatigue & Damage Tolerance

- **DE HAVILLAND COMET**

Introduction to Fatigue & Damage Tolerance

- **DE HAVILLAND COMET**
- The need for damage tolerance is illustrated by the fate of the first jet airliner, the Comet, which failed by catastrophic decompression of the fuselage.
- This was a fatigue failure due to repeated pressurisation cycles.
- The square shape of the windows increased the stress concentrations.

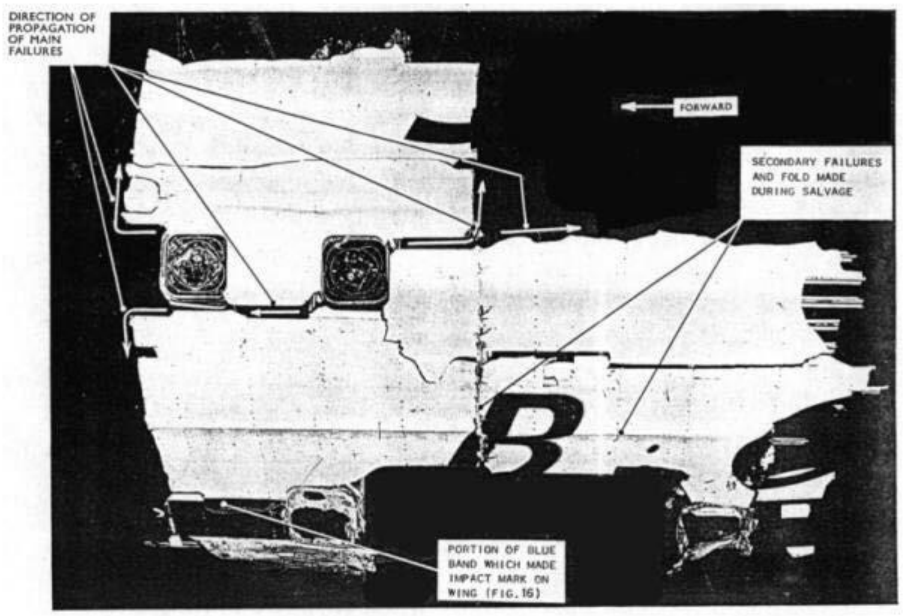
Introduction to Fatigue & Damage Tolerance

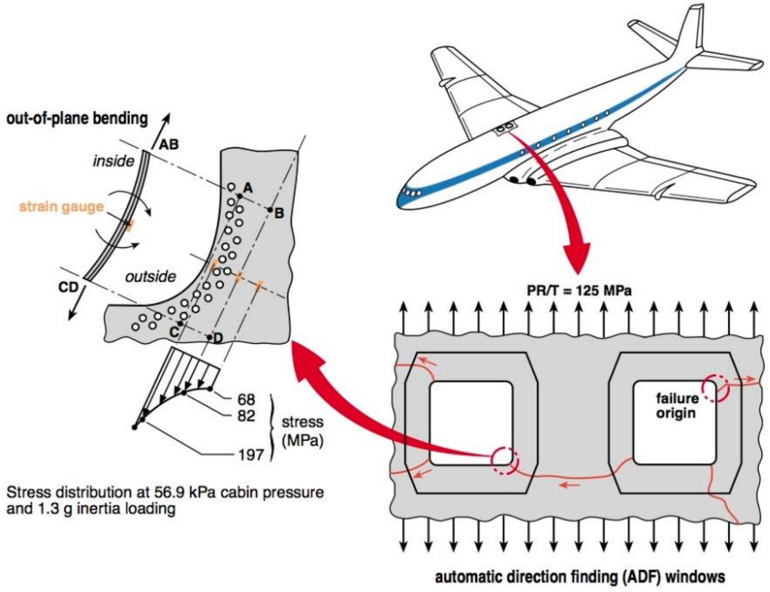
- **DE HAVILLAND COMET**
- A fatigue test was carried out as part of the development programme, but an overpressure proof test was performed first, causing plastic deformation which increased the subsequent fatigue life.
- The design was not damage tolerant, and the fatigue crack was able to propagate catastrophically before it could be detected

Introduction to Fatigue & Damage Tolerance

- **DE HAVILLAND COMET**

- Wreckage of Comet showing crack initiation at corner of window





Introduction to Fatigue & Damage Tolerance

- **DAN AIR BOEING 707-300**
- Crash during approach to Lusaka Airport
- Aircraft had around 47,000 flight hours
- On -300 the horizontal tailplane had been increased in size

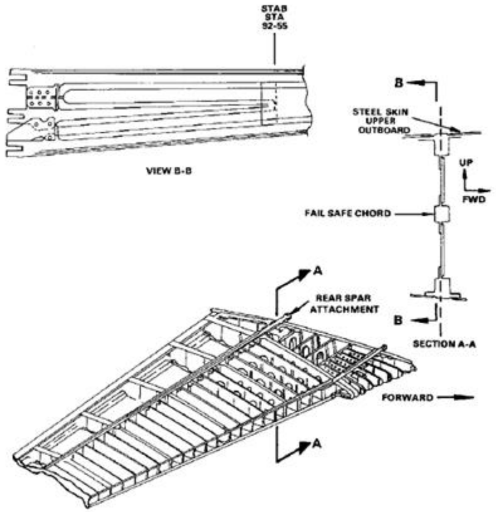
Introduction to Fatigue & Damage Tolerance

- **DAN AIR BOEING 707-300**

- Rear spar failed prior to the accident due to a fatigue crack that was not detected

- Remaining structure was not able to sustain flight loads for long enough for the failure to be detected

- Combination of fatigue and poor fail-safe design



Introduction to Fatigue & Damage Tolerance

- **ALOHA BOEING 737**
- The whole top of the forward fuselage failed in flight at 24,000 ft

Introduction to Fatigue & Damage Tolerance

- **ALOHA BOEING 737**

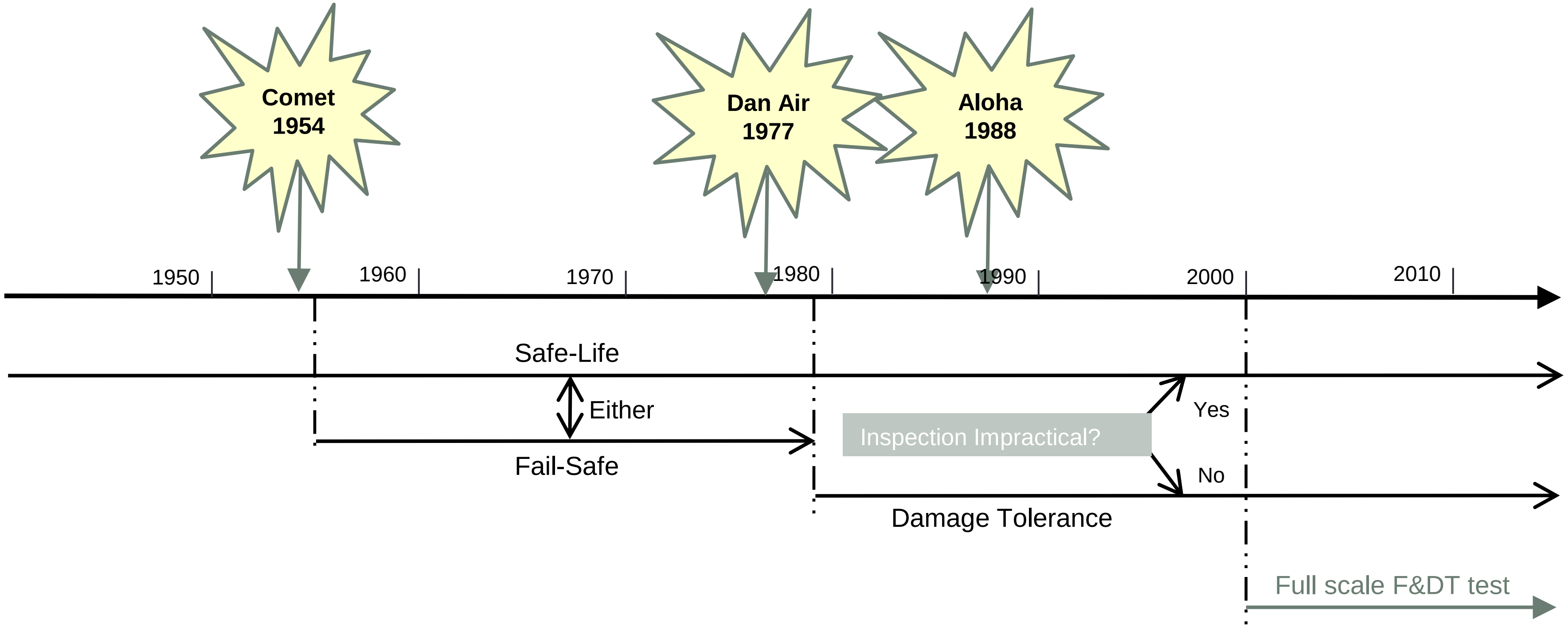
- This was caused by a combination of multi-site corrosion and fatigue.

- It led to new rules on damage tolerant design to prevent such catastrophic failure. This rule set covers what is called ‘Widespread Fatigue Damage’.

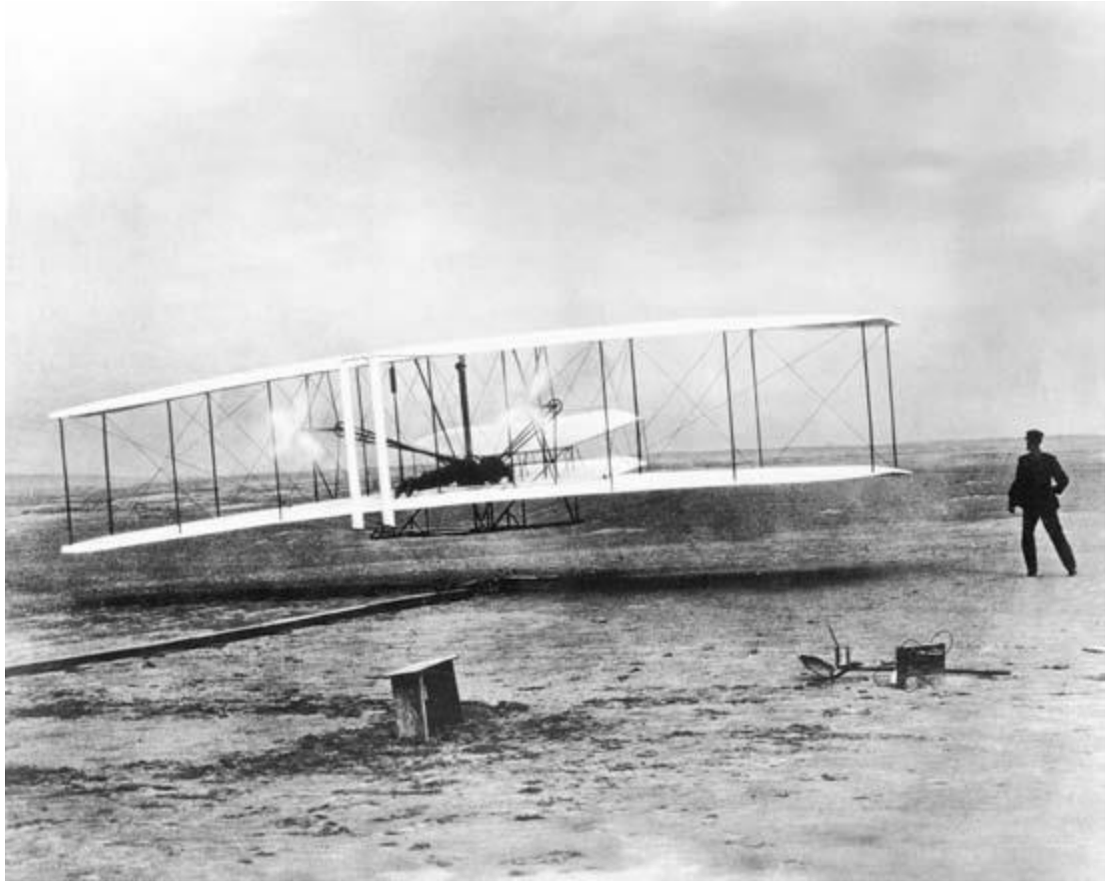
- The survival of the aircraft was largely due to the strong underfloor structure required to withstand loads during crash loadings.

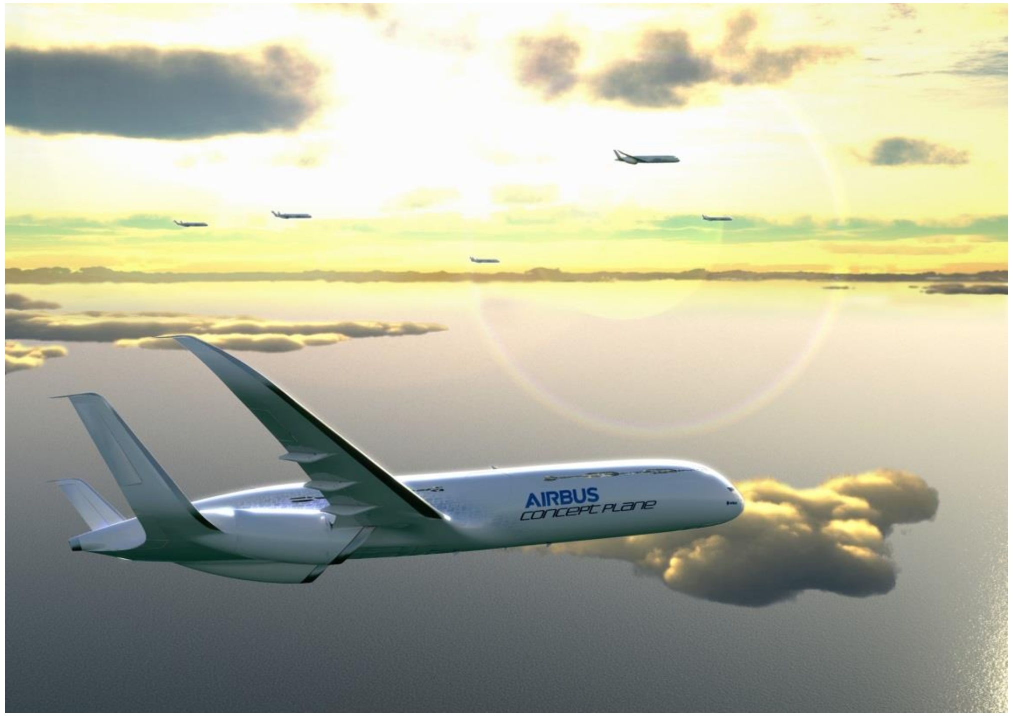
Introduction to Fatigue & Damage Tolerance

- **Airworthiness requirements have changed based on in-service incidents**



Thank You ☺





A Challenge for you all !