

# **30 YEARS OF DAMAGE TOLERANCE - HAVE WE GOT IT RIGHT?**

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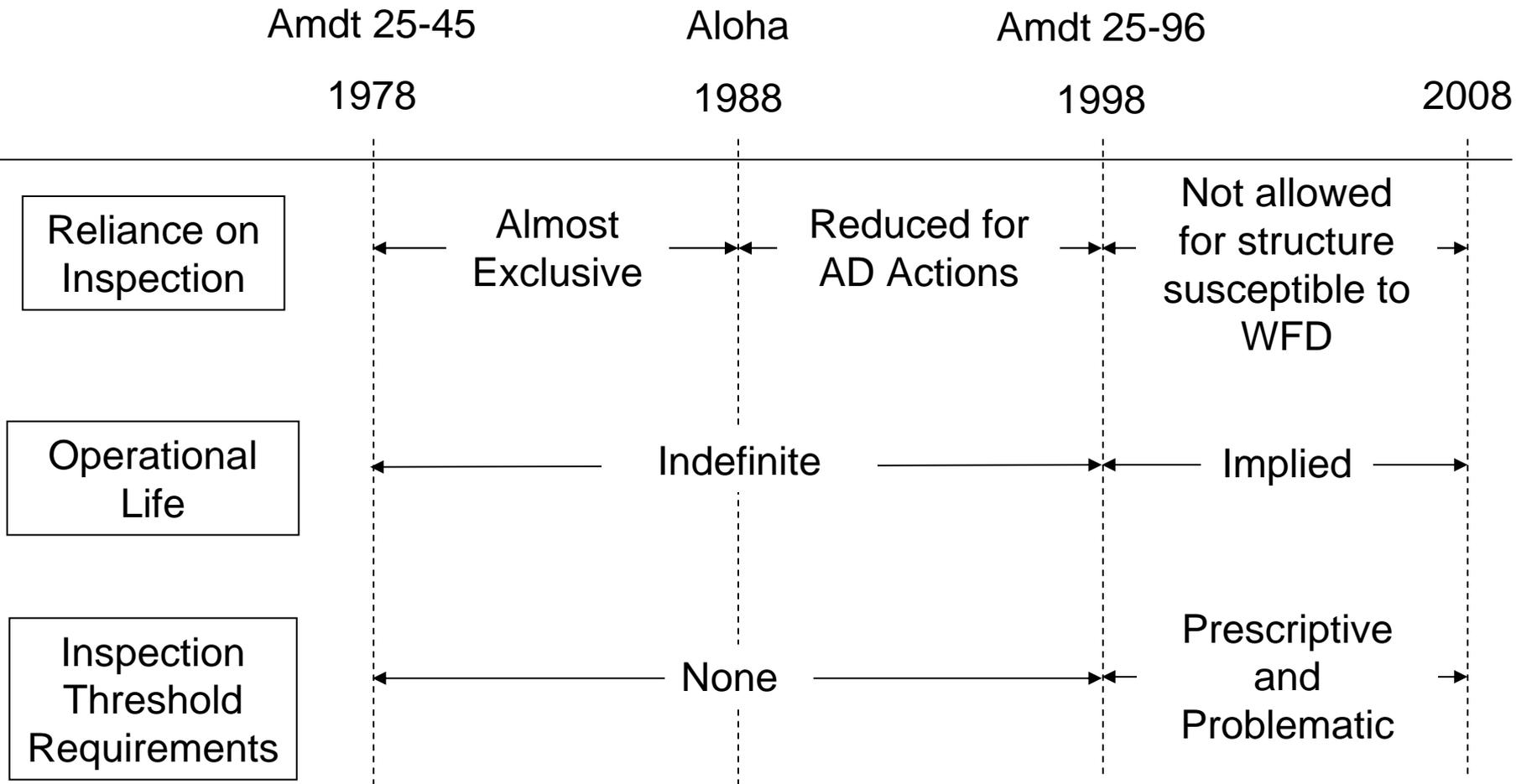
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# 30 Years of Damage Tolerance



# Pre-Aloha Reliance on Inspection

- Safety-by-inspection required unless applicant established that it was impractical
- Advisory material gave limited examples where inspection might be impractical:
  - Landing gear, engine mounts and their attachments
- Safety of existing fleet relied almost exclusively on inspection (e.g. SIDs for “11 aging aircraft”)
- Inspection was the “rule” with replacement (per § 25.571(c)) the exception

# Allowance for Retirement/Replacement

- AC 25.571-1:

*“(4) Assessing the fatigue characteristics of certain structural elements, such as major fittings, joints, typical skin units, and splices, to ensure that the anticipated service life can reasonably be attained, is needed for structure to be evaluated under § 25.571(c).”*

- AC 91-56:

*“5.1 The Supplemental Inspection Document should contain the recommendations for the inspection procedures and replacement or modification of parts or components necessary for continued safe operation of the airplane.”*

# Post Aloha Reliance on Inspection

- Major change in FAA policy for airworthiness directive actions:

*“.....repetitive long term inspections or special procedures may not be providing the degree of safety assurance necessary for the aging transport airplane fleet.”*

*“This, ....., has led us to consider placing less emphasis on repetitive inspections and special procedures, and more emphasis on design improvements.”*

*“In lieu of our previous position, we now acknowledge that long term continued operational safety will be better assured by design changes to remove the source of the problem, rather than by repetitive inspections or special operating procedures.”*

**1989 Internal FAA Memorandum**

# Amdt 25-96 Reliance on Inspection

- Precludes reliance on inspection for structure determined to be susceptible to MSD/MED
  - WFD must be shown to be unlikely up to DSG based on full-scale fatigue test data
- Safety-by-inspection required for structure not susceptible to MSD/MED unless shown to be impractical

# Reliance on Inspection – Have we got it right?

- Close....but some revisions needed,
  - Remove presumptions that inspection will always be:
    - impractical for MSD/MED susceptible structure
    - practical for all other structure
  - Inspection viability to be based on results of damage tolerance evaluations
  - Full-scale fatigue testing required to address structure where inspections not viable
- No revisions pending

# Operational Life

*“An evaluation of the strength, detail design and fabrication must show that catastrophic failure due to fatigue, corrosion, or accidental damage, will be avoided throughout the operational life of the airplane.”*

*“Based on the evaluations required by this section, inspections or other procedures must be established as necessary to prevent catastrophic failure....”*

**14 CFR § 25.571(a)**

# Compliance Options?

1. Leave the operational life indefinite and establish all the “inspections or other procedures” needed to insure safety for an indefinite period of time.
2. Establish a finite operational life and establish the “inspections or other procedures” needed to insure safety to that point but not necessarily beyond.

# Past Standard Practice

- Establish a design service goal (DSG) for marketing, fatigue analysis/test and establish “inspections or other procedures” based on damage tolerance with DSG in mind
- No operational limit established (no explicit requirement for one)
- Post certification analysis/testing performed voluntarily on a case-by-case basis to support operation beyond the original DSG

# Amdt 25-96

- Reliance on inspection to manage WFD not allowed
- WFD must be shown unlikely prior to DSG based on full-scale fatigue test data
- Implies,

Operational Limit = DSG

if compliance is to minimum requirements (i.e. likelihood of WFD beyond DSG not justified)

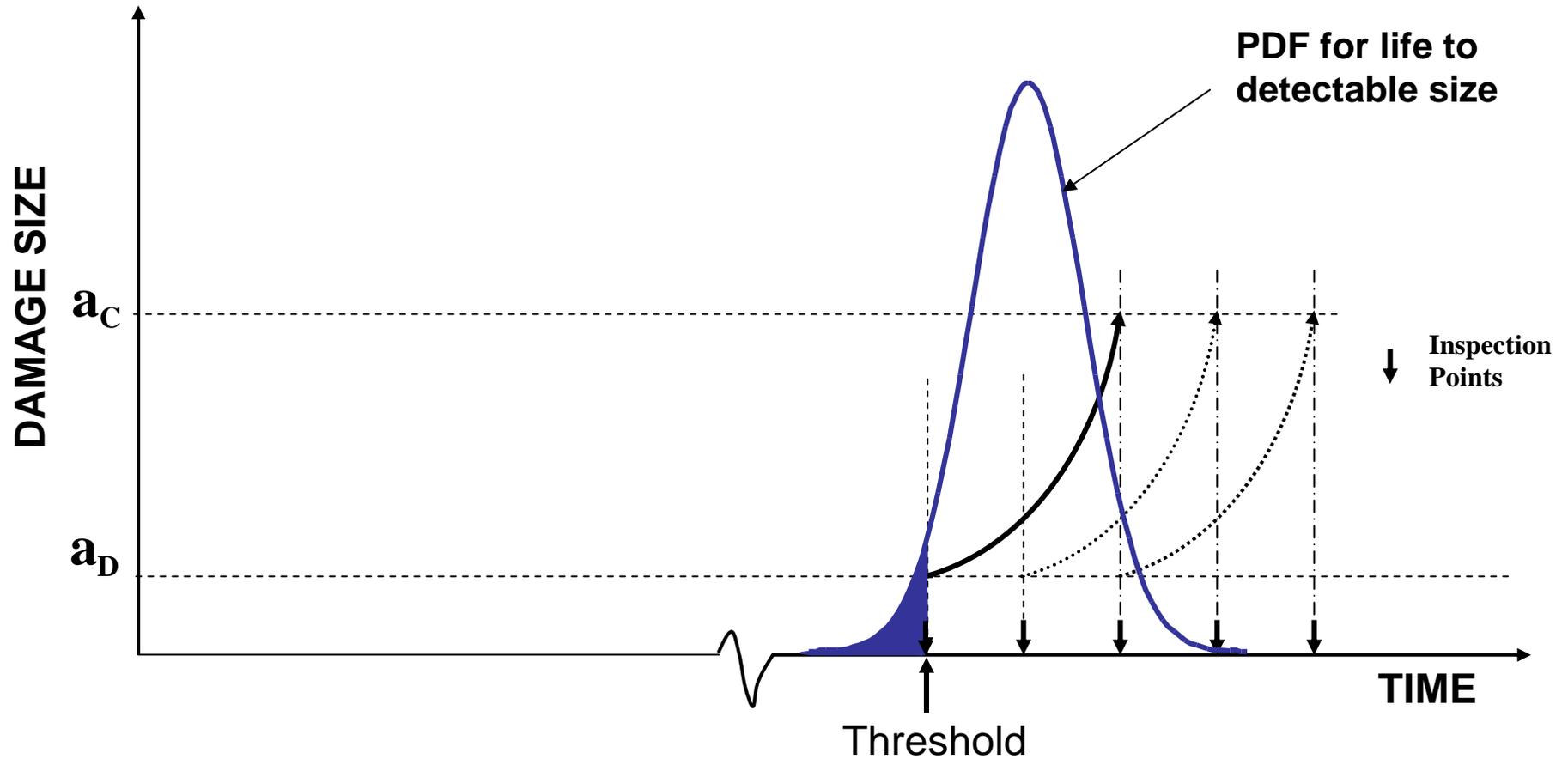
# Operational Life – Have we got it right?

- Not yet ...but industry is leading the way with voluntary establishment of a “limit of validity” (LOV) of the fatigue management program (FMP) established for type certification
- Revisions needed,
  - Require establishment of an LOV
  - Allow for extensions based on post certification analyses/test and supplements to the FMP
- Revisions part of pending “WFD Rule”

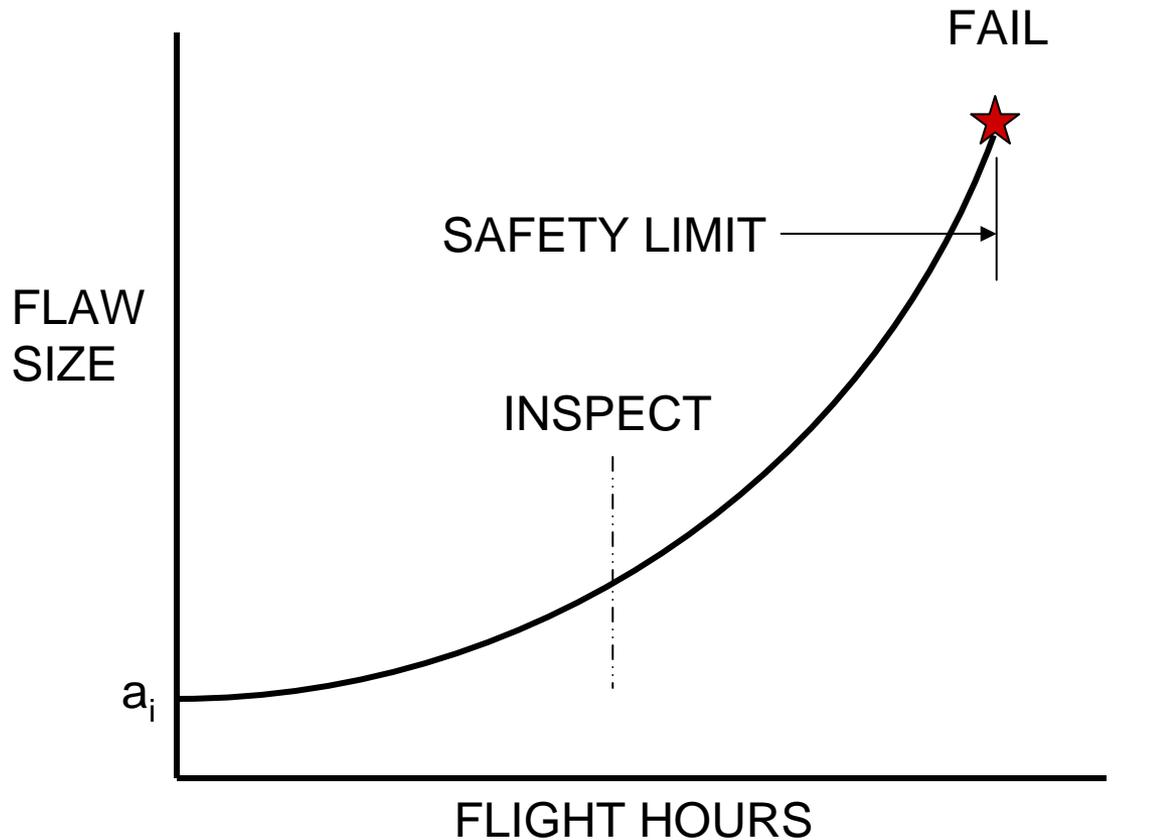
# Pre-Amdt 25-96 Inspection Threshold

- No requirements or guidance
- Two commonly accepted approaches
  - Fatigue
  - USAF “Rogue Flaw” Crack Growth

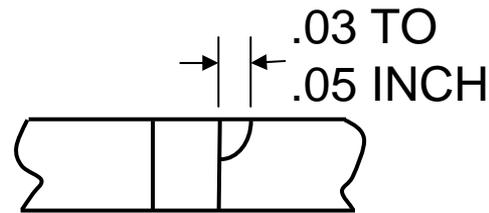
# Fatigue Based Threshold



# USAF "Rogue Flaw" Crack Growth



FLAW SIZES  
AND SHAPES:

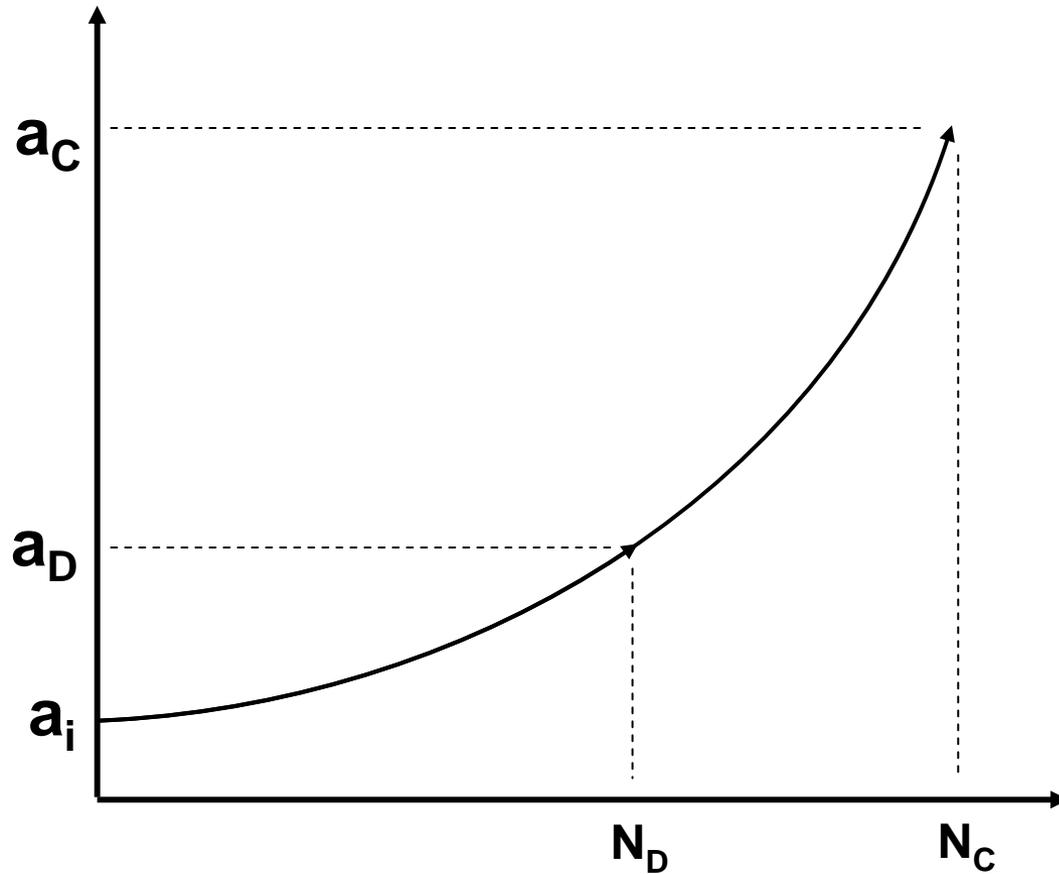


# Amdt 25-96 Inspection Threshold Requirement

*“Inspection thresholds for the following types of structure **must be established based on crack growth analyses and/or tests**, assuming the structure contains an **initial flaw of the maximum probable size** that could exist as a result of **manufacturing or service induced damage**:*

- (i) Single load path structure, and*
- (ii) Multiple load path “fail-safe” structure and crack arrest “fail-safe” structure, where it cannot be demonstrated that load path failure, partial failure, or crack arrest will be detected and repaired during normal maintenance, inspection, or operation of an airplane prior to failure of the remaining structure.”*

# Crack Growth Analysis Details?



- Cracking scenario?
- $a_i = ?$
- $N_{\text{thres}} = N_D/f$   
or  
 $N_c/f$
- $f = ?$

# Paradoxical Guidance

*“Where it can be shown by observation, analysis, and/or test that a load path failure in multiple load path “fail-safe” structure, or partial failure in crack arrest “fail-safe” structure, will be detected and repaired during normal maintenance, inspection, or operation on an airplane prior to failure of the remaining structure, the thresholds can be established using either:*

- (i) Fatigue analysis and tests with appropriate scatter factor; or*
- (ii) Slow crack growth analyses and tests, based on appropriate initial manufacturing damage.”*

# Inspection Threshold – Have we got it right?

- No – Major revisions needed
  - Remove specification of methodology
  - Remove “maximum probable....service induced damage”
  - Require consideration of probable variations in manufacturing quality
  - Provide useful guidance on acceptable methods, methods validation, etc.
- Acceptable recommendations submitted to FAA by ARAC-GSHWG in 2003 report

# Summary

- Significant changes have occurred over the last 30 years:
  - Less reliance on inspection
  - Implied operational limit
  - Prescriptive inspection threshold requirements
- Additional revisions needed especially with respect to threshold determination
- We haven't got it right yet! But, we are getting closer.

# Questions?

