# LOAD ENHANCEMENT FACTOR

**Damage Tolerance Workshop**

**for Composite Test Spectra**

**(Raytheon Method)**

**Ric Abbott**

**July 2006**

**Method First Published in 1987**
**Certification of the Beech Starship**

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# Summary



- In order to represent scatter in composite flaw growth rates compared to that in metallic materials, a Load Enhancement Factor (LEF) may be applied to a test load spectrum
- More economical than testing an increased number of lifetimes
- Similar to method used for metallic propeller fatigue

# Test Loading



- **Testing is based on flaw growth life from initial damage rather than fatigue testing with virgin specimens**
- **The initial damage may be BVID or detectable damage that would be of interest to in-service inspections**
- **Critical loading modes are compression and shear**

# Test Matrix



- **Method can be applied to generic laminates or design specific laminates (or sandwich panels) and critical joints**
- **Static strength of the specimens with initial damage represents the strength at one cycle**
- **At least six specimens at each of at least two cyclic loading levels establish the (log) mean life**

# Test Results

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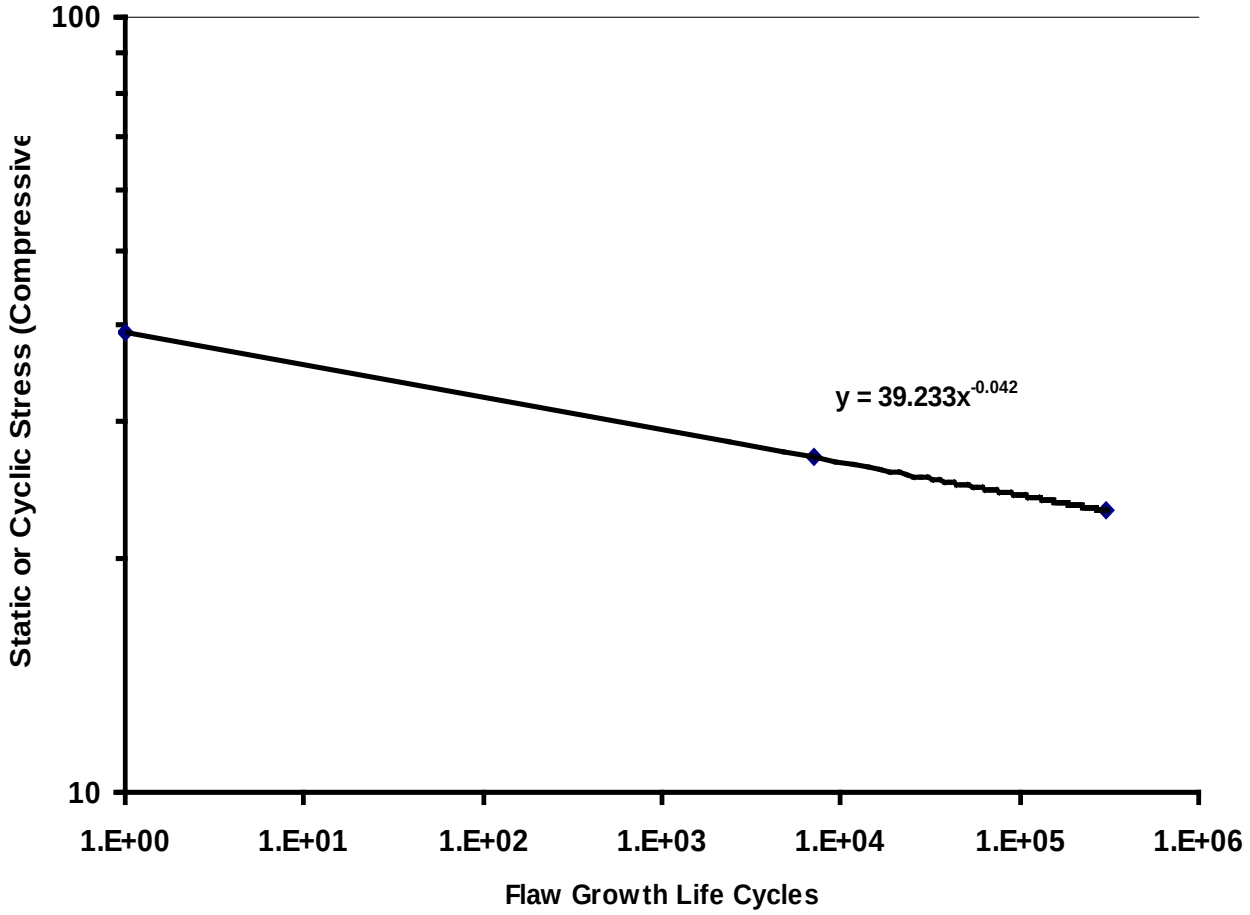
**Figure 1**

**Static Strength and Mean flaw Growth Life**



# Test Issues



- **Because the critical loading modes are compression and shear, the specimens should be resistant to buckling or be supported to avoid unrepresentative failures**

- **Cyclic loading should be deflection or strain controlled**

  **In a large component such as a fuselage or wing the local *strain* will not change unless the flaw is a large proportion of the total load path.**

# Test Issues



- **More than one criterion should be considered to define failure under flaw growth cycling.**

  **Total specimen collapse under cyclic loading**

  **Loss of specimen stiffness (say 10 %)**

  **Delamination over a large percentage of the specimen surface**

# Development of LEF



- **B-Basis flaw growth life line is established by calculating the B-Basis life of the cyclic test results**

- **This line is forced to be parallel to the mean life line**
  - **Keeps the relationship between the two lines the same along the x axis**

# Development of LEF

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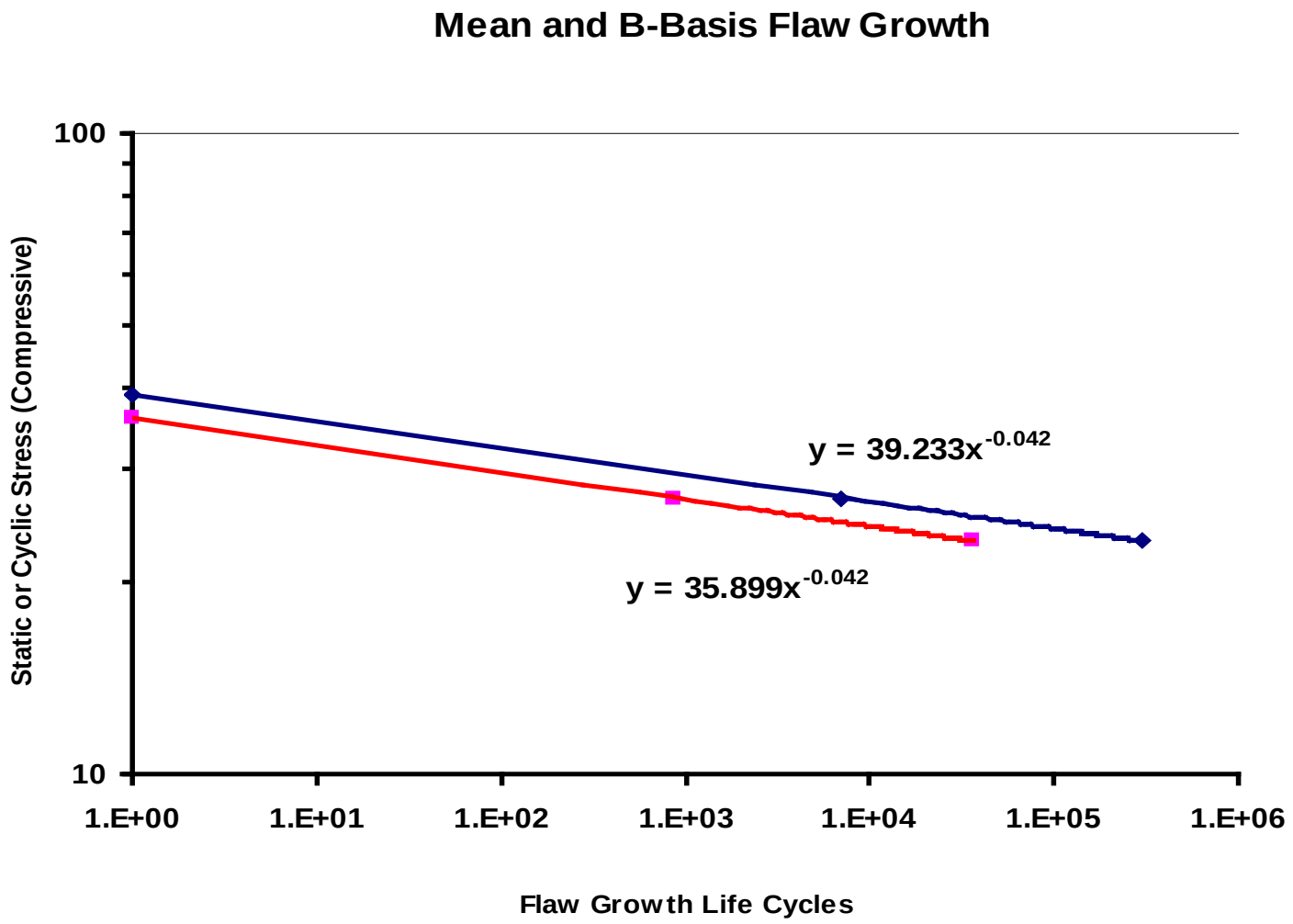


# Application of LEF



- **The relationship between the mean and B-Basis flaw growth lines can be determined on the life axis**
  - **scatter factor traditionally used to establish the number of test lifetimes**
- **The relationship can also be determined on the load axis.**
  - **The nominal spectrum loads will be increased by the ratio of mean strength to B-Basis strength**
- **Test lifetimes can be traded for LEF**
  - **A minimum of two test lifetimes are required per 25.571 (b)**

# Example Scatter Factor and LEF



## SCATTER FACTOR AND LEF

| TEST DATA | SCATTER FACTOR WITHOUT LEF Test Lifetimes | LEF for ONE LIFETIME TEST Spectrum loads Factors | LEF for TWO LIFETIME TEST Spectrum loads Factor |
|---|---|---|---|
| Compression flaw growth | 8.0 | 1.09 | 1.06 |

# Test Spectra Load Levels



- **Delete** lower load levels from the full scale test spectrum based on Flaw growth threshold

  The stress or strain level below which significant flaw growth will not occur

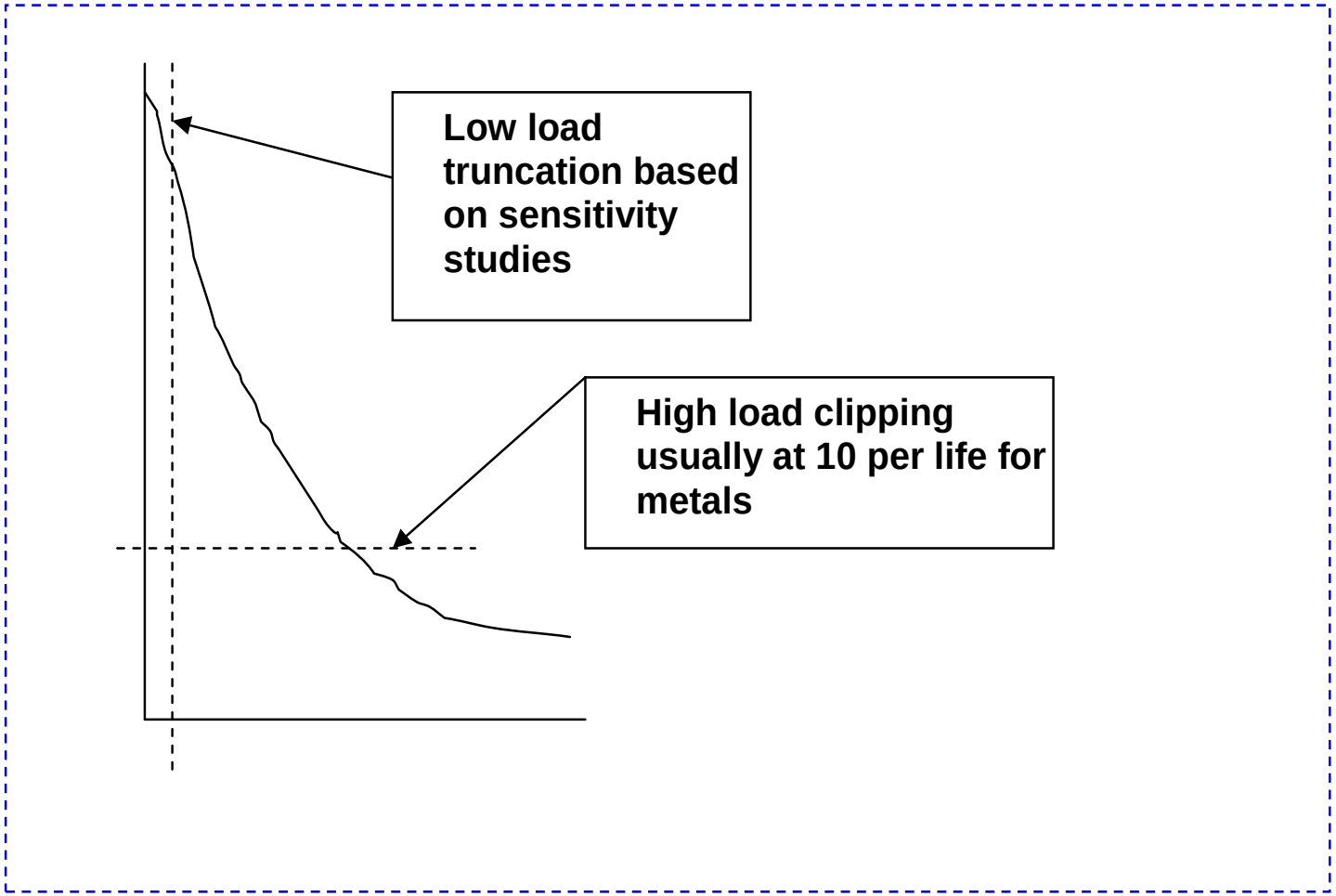
  Defined by extrapolation of the B-Basis flaw growth line out to E 07 cycles (or greater for rotating components)

- **Include** load levels up to per lifetime occurrence
  (Mission configuration; not limit load)

- Fracture mechanics crack growth analysis may be applied to account for excess loading on metal parts

# Spectrum Treatment--Metals





# Treatment of Spectrum--Composites

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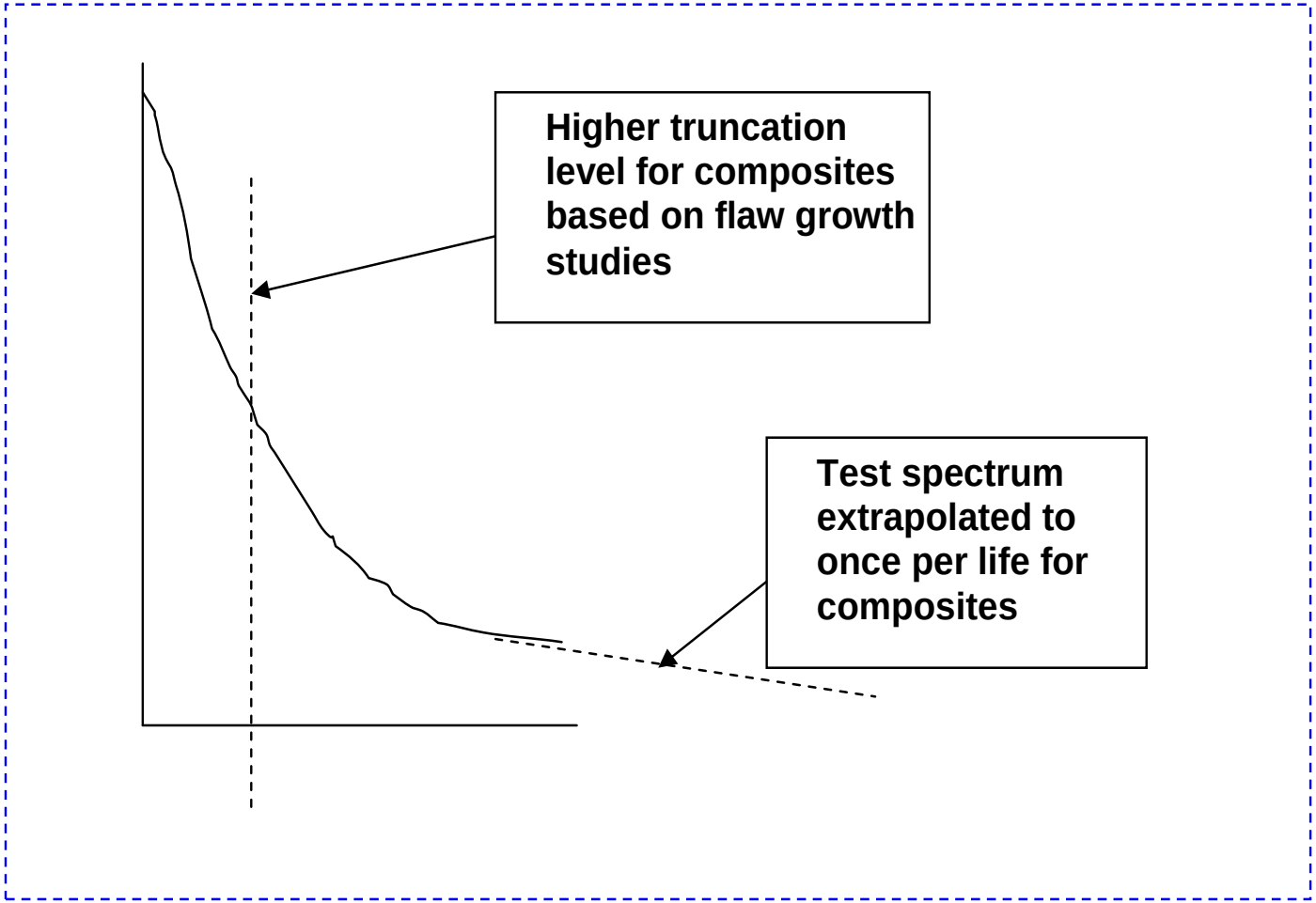

## FAA / NIAR Investigation

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- **FAA has funded an investigation of Damage Tolerance Certification methods**
- **Development and application of LEF's is included**
- **So far testing has started on notched and un-notched fatigue (Airbus) method**

Possible Test Matrix for

FAA / NIAR Investigation of Raytheon Method

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| Loading | Laminate | BVID | Visible Damage | Open Hole |
|---|---|---|---|---|
| Compression RTD | Soft | | 18 | |
| | Quasi | 18 | 18 | 18 |
| | Hard | | 18 | |
| Compression RTW | Quasi | 6 | 18 | 6 |
| Shear RTD | All 45's | 18 | 18 | 18 |
| Shear RTW | All 45's | 6 | 18 | 6 |

# Conclusions



- Load enhancement factors for test spectra should be developed based on flaw growth testing
- Factors and thresholds can be applied to reduce time and cost in large scale testing
- Larger loads than usual for metals should be included
- FAA investigation should include multiple LEF methods