Compilation of Damage Findings from Multiple Recent Teardown Analysis Programs

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Gregory A. Shoales, Scott A. Fawaz and Molly R. Walters,
USAF Academy/CAStLE, Colorado, USA

Overview

- Purpose
- Aircraft Structural Teardown Programs
  - Common goals
  - Primary tasks
- Subject Aircraft
- Findings
- Future Work

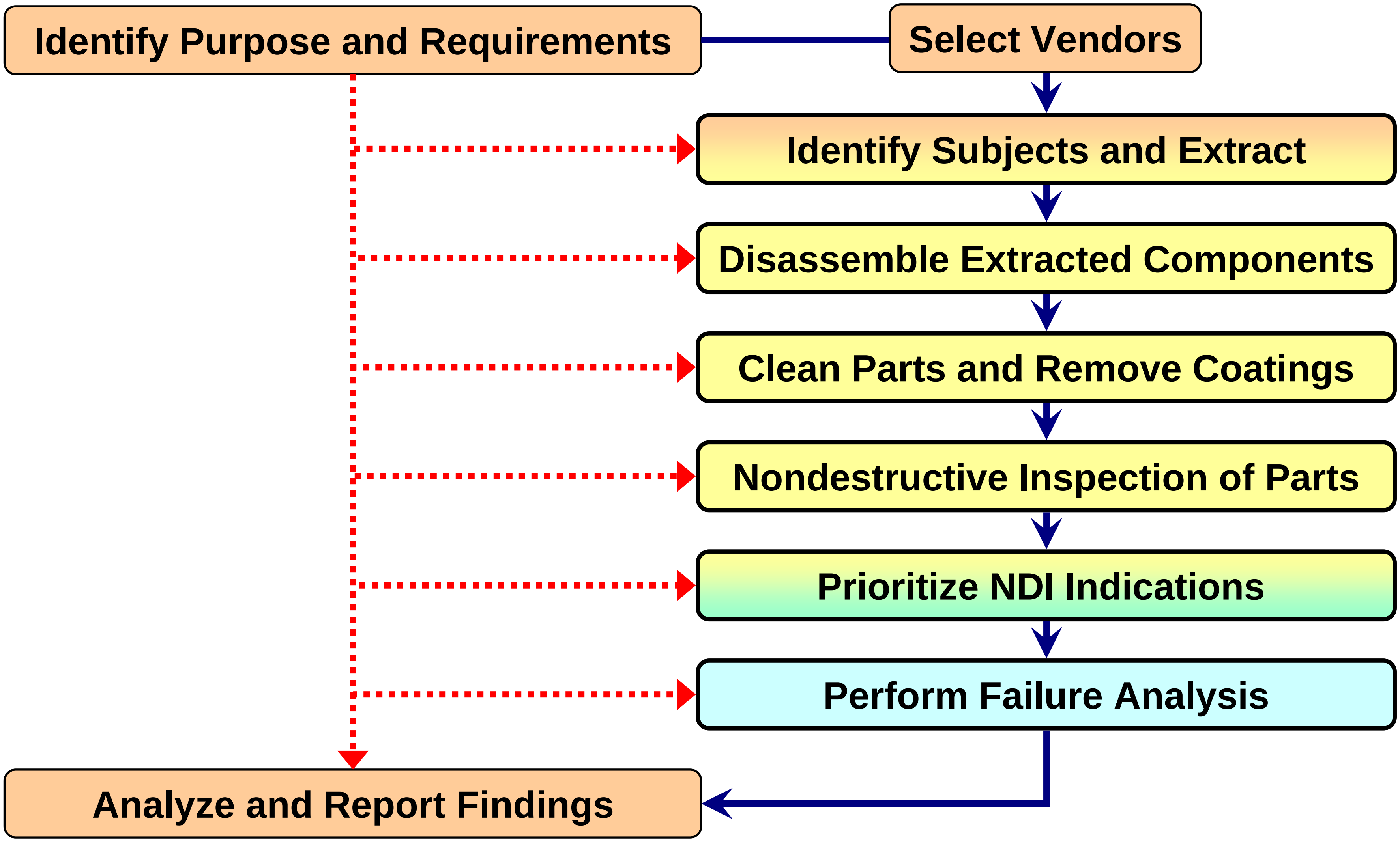
Purpose

- To present an overview of failure analysis (FA) findings from a variety of teardown analysis programs
  - Conducted 2005-2007
  - Three aircraft categories
  - Eight total aircraft
  - Aircraft production years between 1957 and 1968
- All findings presented are from CAStLE analysis
  - 711 total failure analysis
    - 395 from light trainer/attack aircraft (1957-1968)
    - 282 from medium transport aircraft (1968)
    - 34 from heavy transport aircraft (1963)

Teardown Program Goals

- Assess damage state after a period of known usage
- Evaluate and/or revise damage prediction models
- Assist in the validation of inspection methods
- Other
  - Input to help determine inspection intervals (an output of damage prediction models)
  - Prepare for future repair action or redesign

Teardown Program Tasks



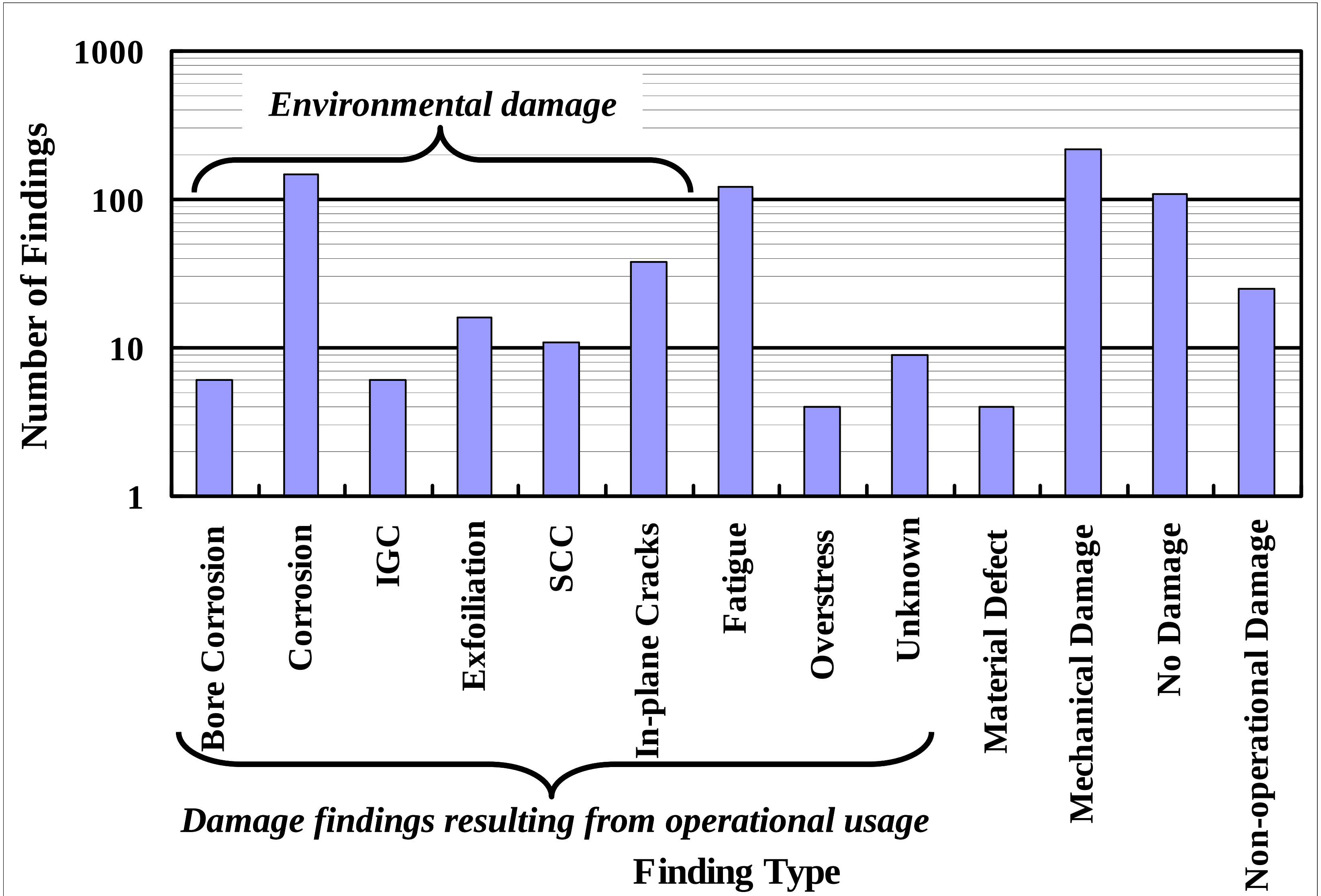
Subject Aircraft

- Light trainer/attack class aircraft
  - All wing structure in four aircraft
  - Wing to fuselage attach structure in four aircraft
  - All fatigue critical structure throughout two aircraft
  - Flight hours (FH) ranging between 16K and 23K
- Medium transport aircraft
  - Center wing from a single aircraft
  - 22K FH, 46K equivalent hours
- Heavy transport aircraft
  - Fatigue critical structure throughout a single aircraft
  - 18K FH, 12K landings, 3.5K pressure cycles

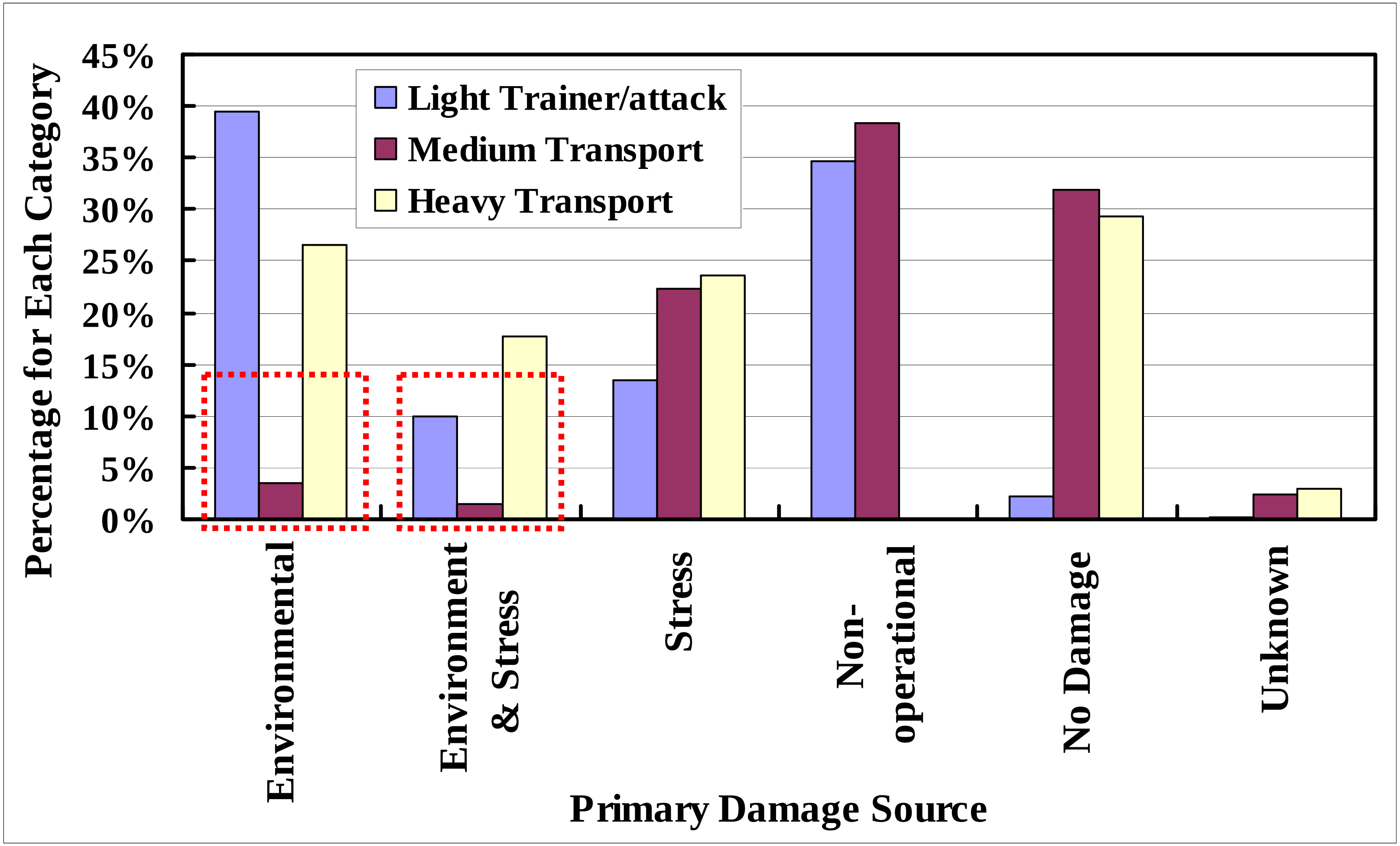
Findings

- Finding type
- NDI implications
- Operational usage damage scale
- Corrosion damage
- Damage location
- Initiation site size distribution

Finding Type

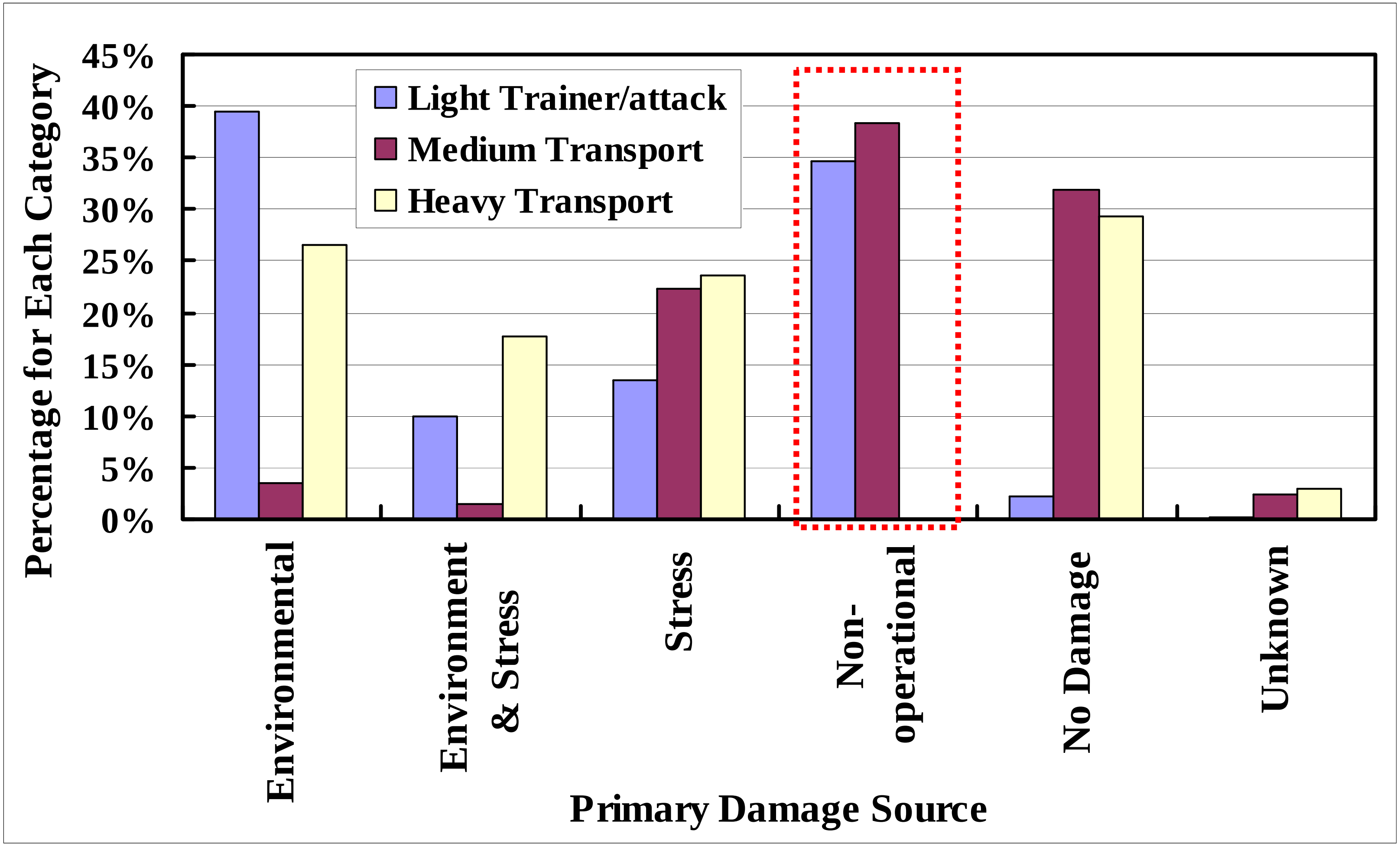


Finding Type by Aircraft Category



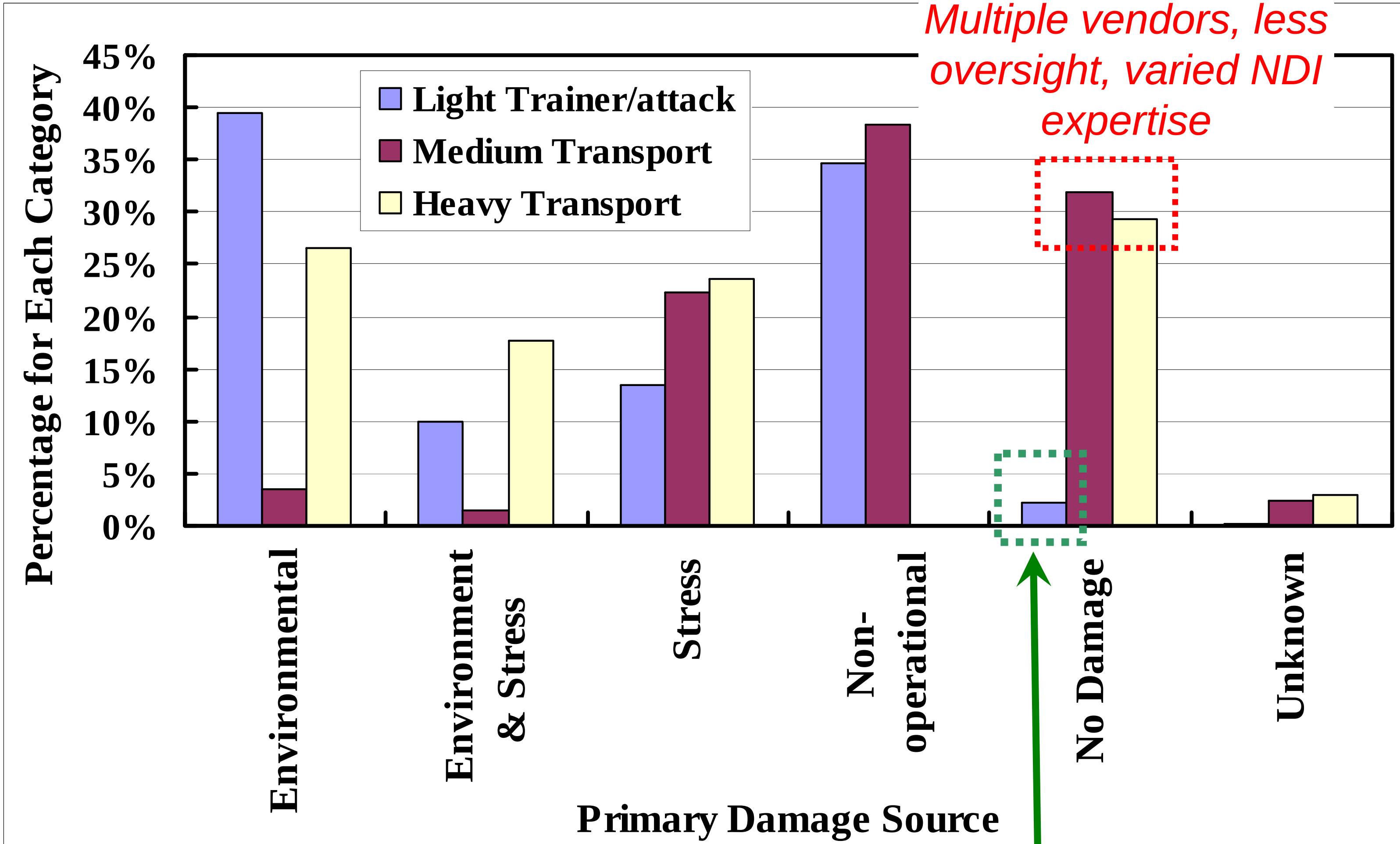
Newest aircraft, least corrosion

Finding Type by Aircraft Category



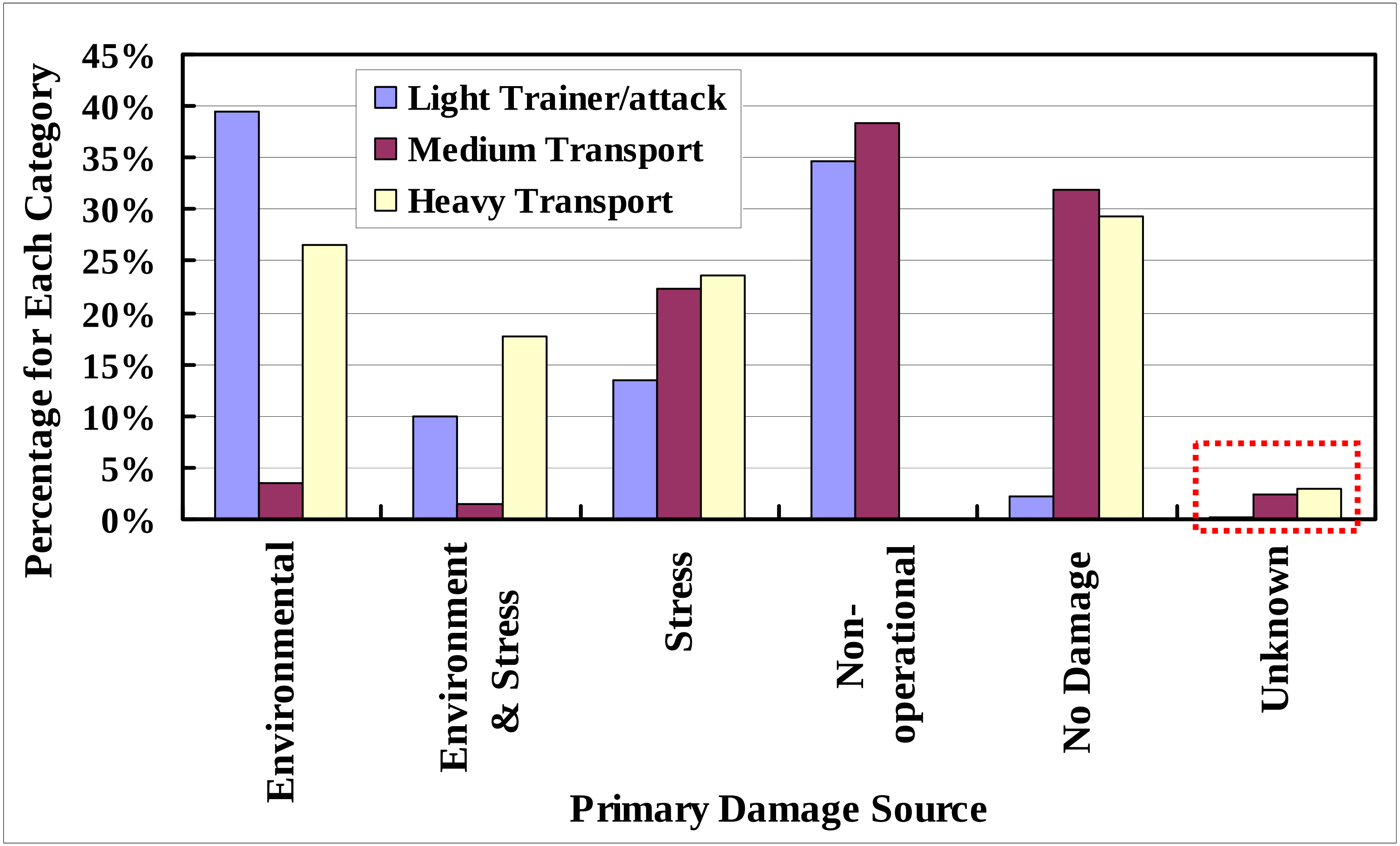
Production and maintenance quality indicator and programmatic decisions

Finding Type by Aircraft Category



One highly skilled/experienced inspector, high degree of oversight

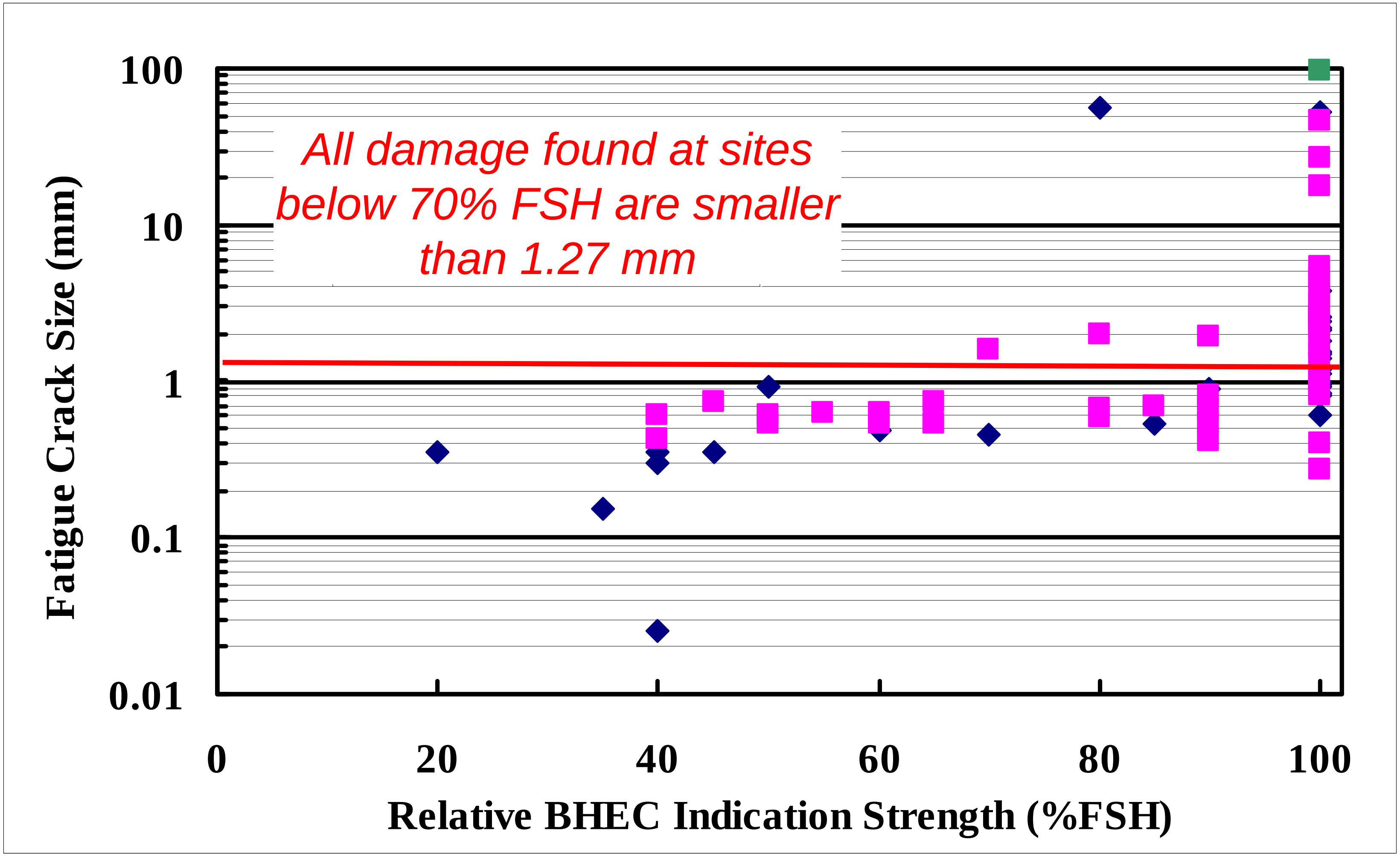
Finding Type by Aircraft Category



We usually find the root cause

NDI Implications

fatigue crack size vs. indication strength



NDI implications

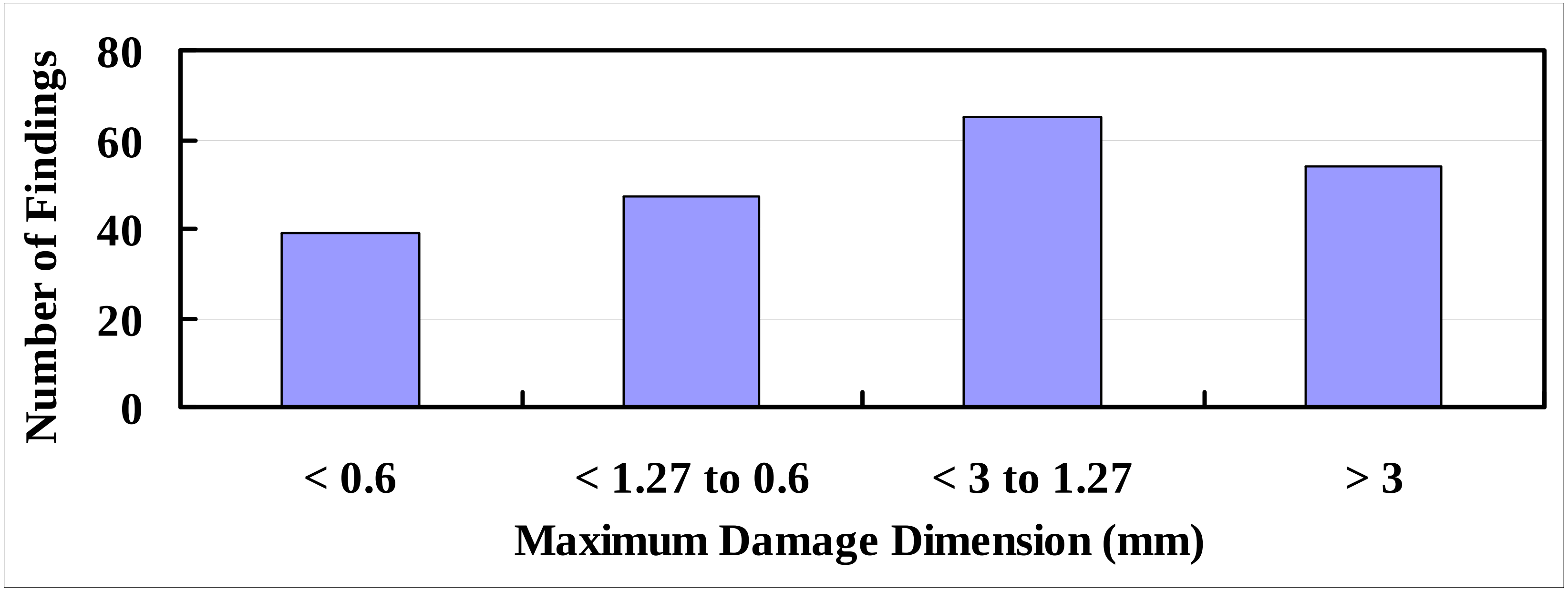
damaged component type

Component Type	Corrosion	SCC	In-Plane Cracks	Fatigue	Overstress	Unknown
Skin	20	8	0	50	0	4
Skin Stiffenner	0	0	0	16	0	3
Rib Cap	11	0	0	14	1	0
Spar Cap	140	1	36	27	2	1
Fitting	4	2	2	13	1	1

- **357 total findings**
- **Most corrosion and most fatigue cracks are in hidden, 2nd layer, unreliable operational NDI available, if any**
- **SCC cracks in skin; 4 in each of the transport aircraft**
- **In-plane cracks; no available inspection**

Operational Usage Damage Scale

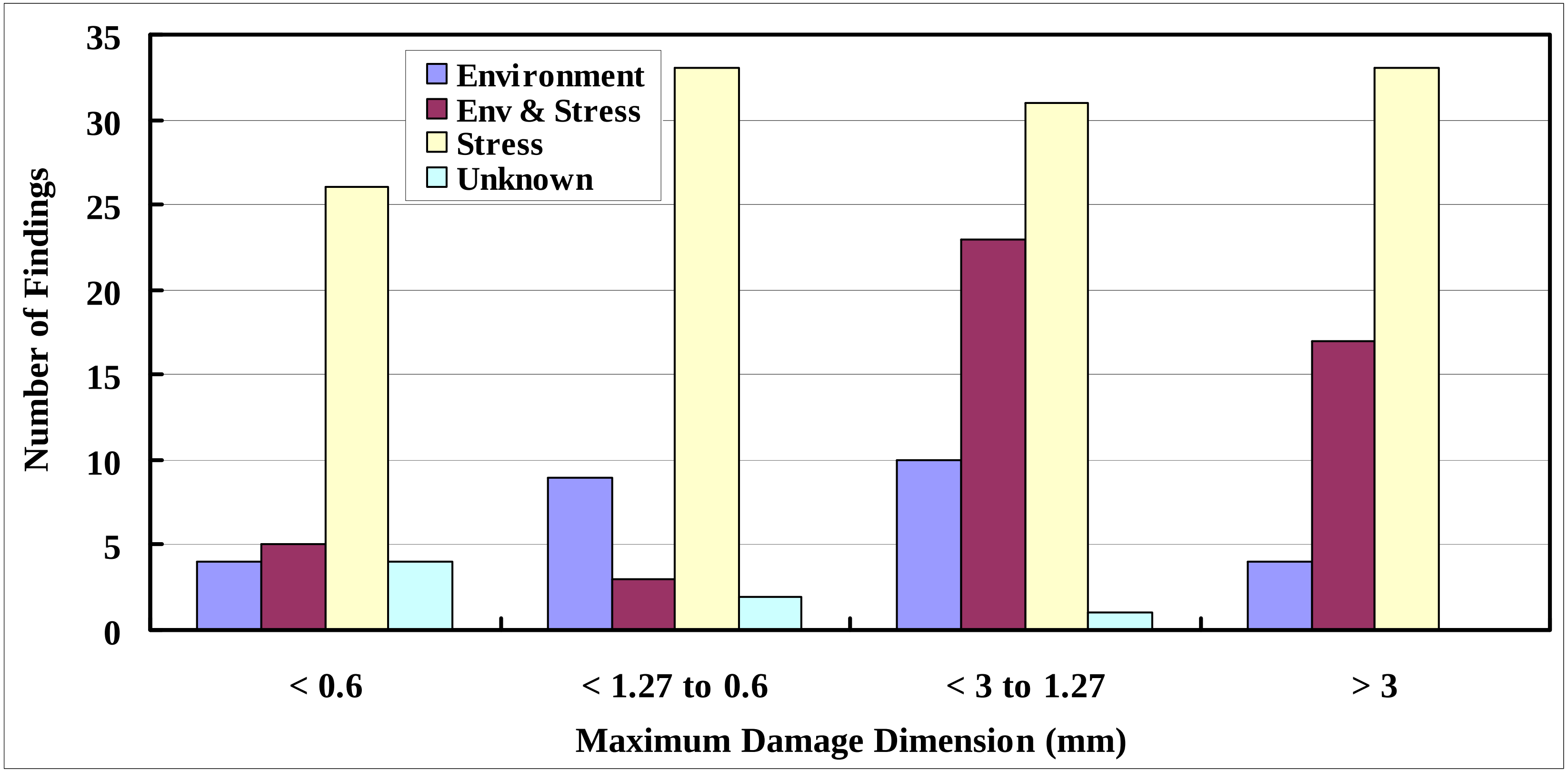
crack damage only



- **205 crack findings attributed to operational usage**
- **42% are smaller than 1.27 mm**
- **4 findings are smaller than 0.127 mm**

Operational Usage Damage Scale

crack damage by source

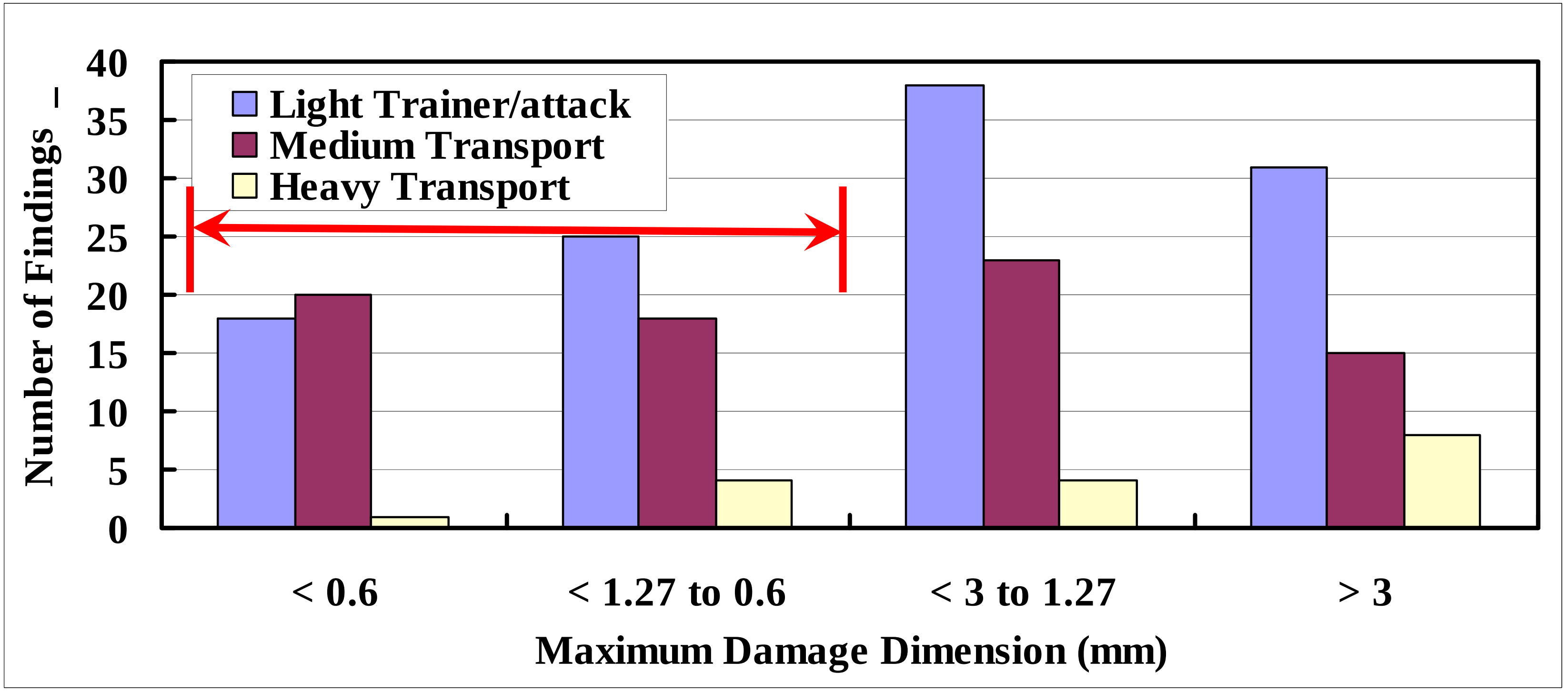


- **Majority of damage is due to stress**
- **"Unknown" only exists in the very small scale damage**

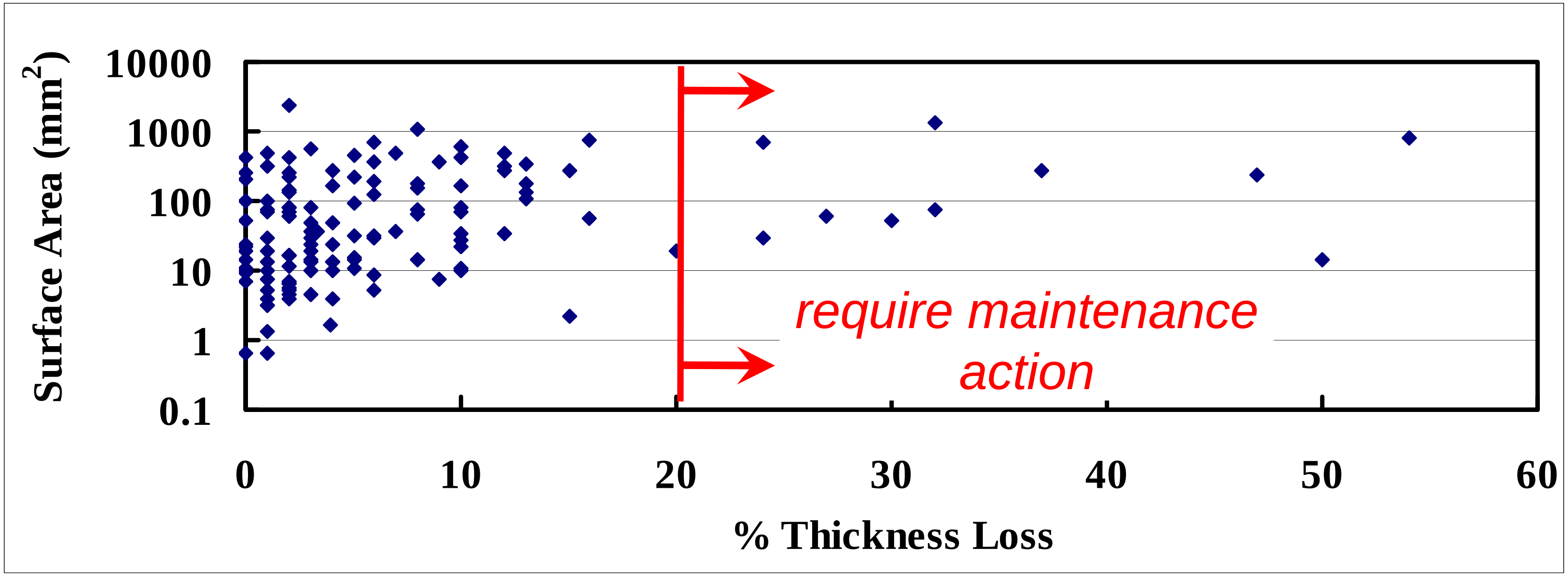
Operational Usage Damage Scale

by aircraft category

- **Lower two bins represent part through cracks for all three aircraft categories**
- **Lower three bins are part through cracks for medium transport**

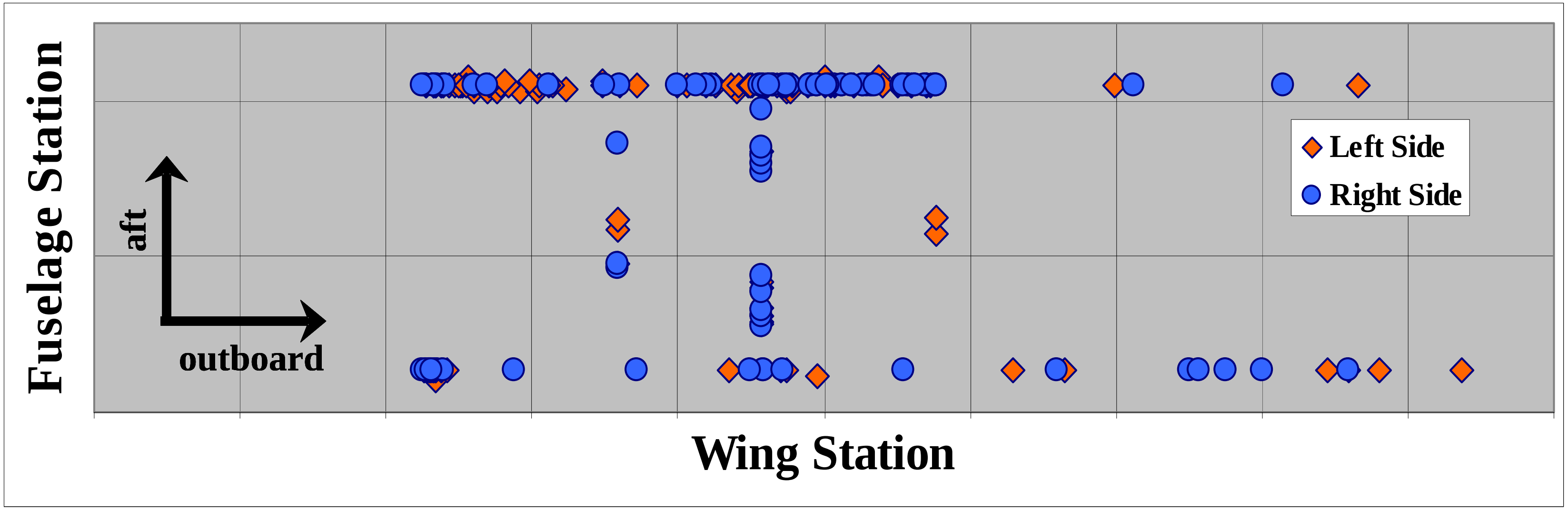


Corrosion Damage



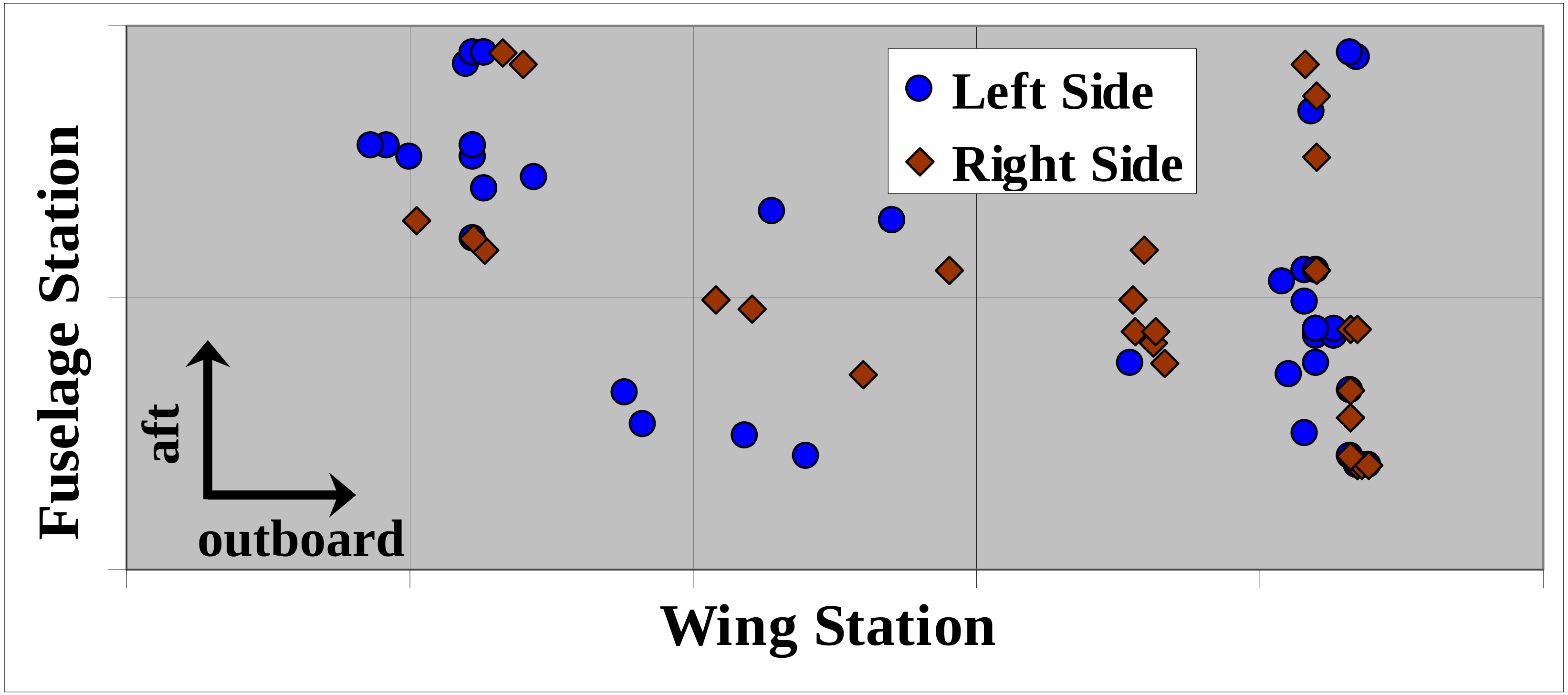
- Light Trainer/attack category only
  - No corrosion damage evaluated in medium transport
    - Severe corrosion in one region attributed to retirement decision
    - No additional corrosion found during teardown program
  - Corrosion damage ignored in heavy transport
- Most damage broad but not deep
- Only 10 of 138 require maintenance action

Damage Location
light trainer/attack aircraft wing



- Damage is concentrated on front and aft spar and along two ribs near main gear attachment fitting
- No significant difference right to left
- Data permits analysis for MSD, MED, WFD

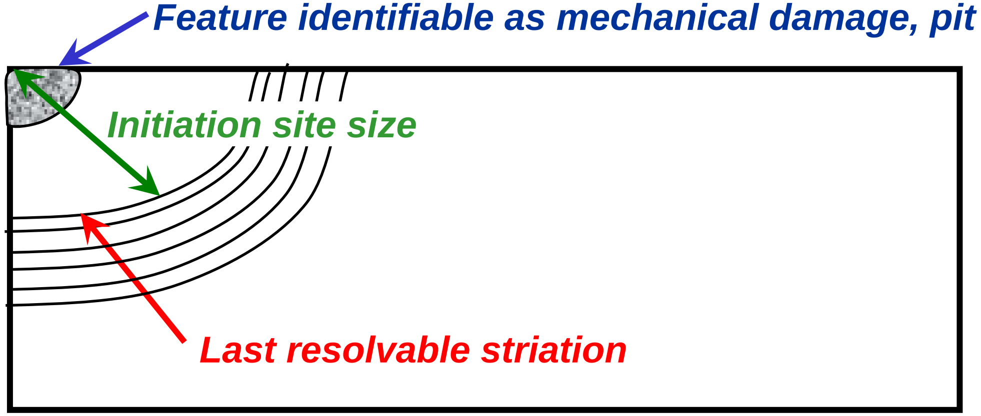
Damage Location
medium transport aircraft wing



- Damage concentrated near two critical wing details; aft wing to body attach point and outboard wing fitting
- No significant difference left to right
- Data permits analysis for MSD, MED, WFD

Fatigue, SCC & Corrosion-Fatigue Initiating Site Size Distribution

- What is "initiation feature size"?

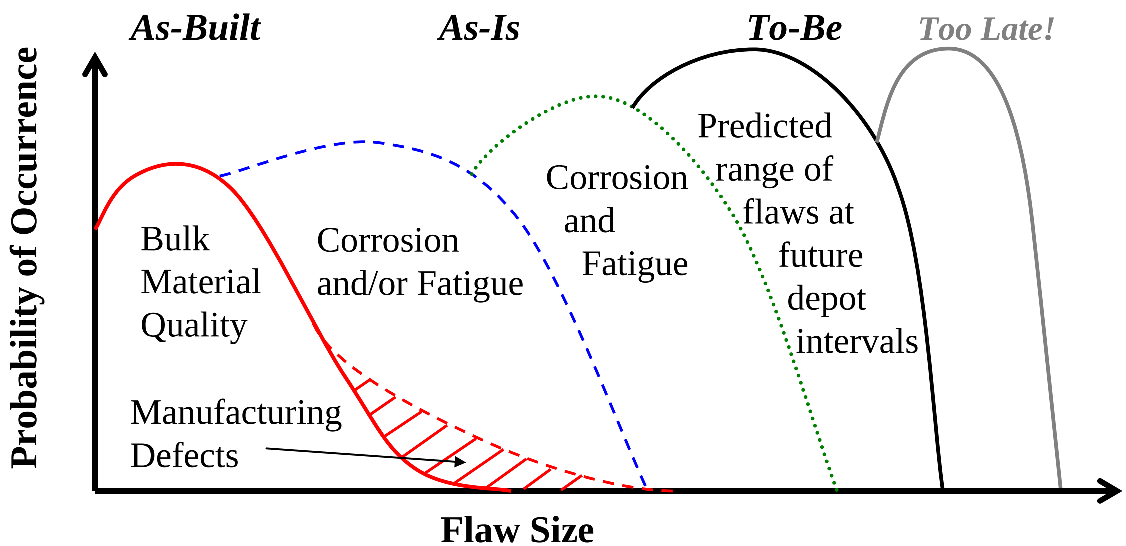


- Even with conservative approach, the largest site is 0.624 mm
  - 90% are less than 0.254 mm
  - 48% are less than 0.127 mm

Initiation Feature	%	Dimensions (mm)		
		Minimum	Maximum	Average
Corrosion Pit	80%	0.022	0.624	0.135
Mechanical Damage	20%	0.040	0.326	0.156
Percentage of Initiation Sites on Faying Surface				31%

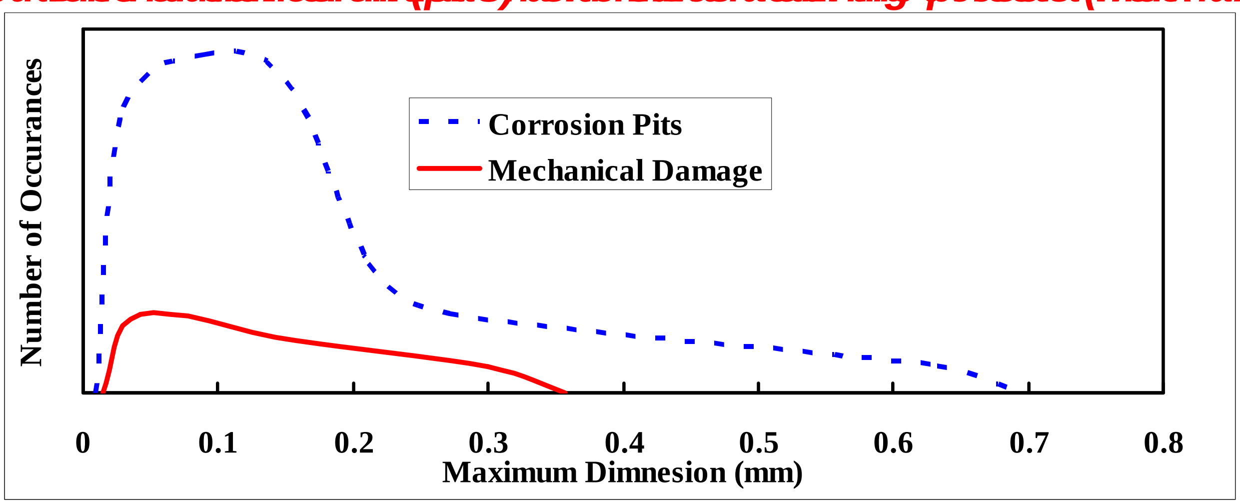
Initiation Site Size Distribution

literature compared to the present work



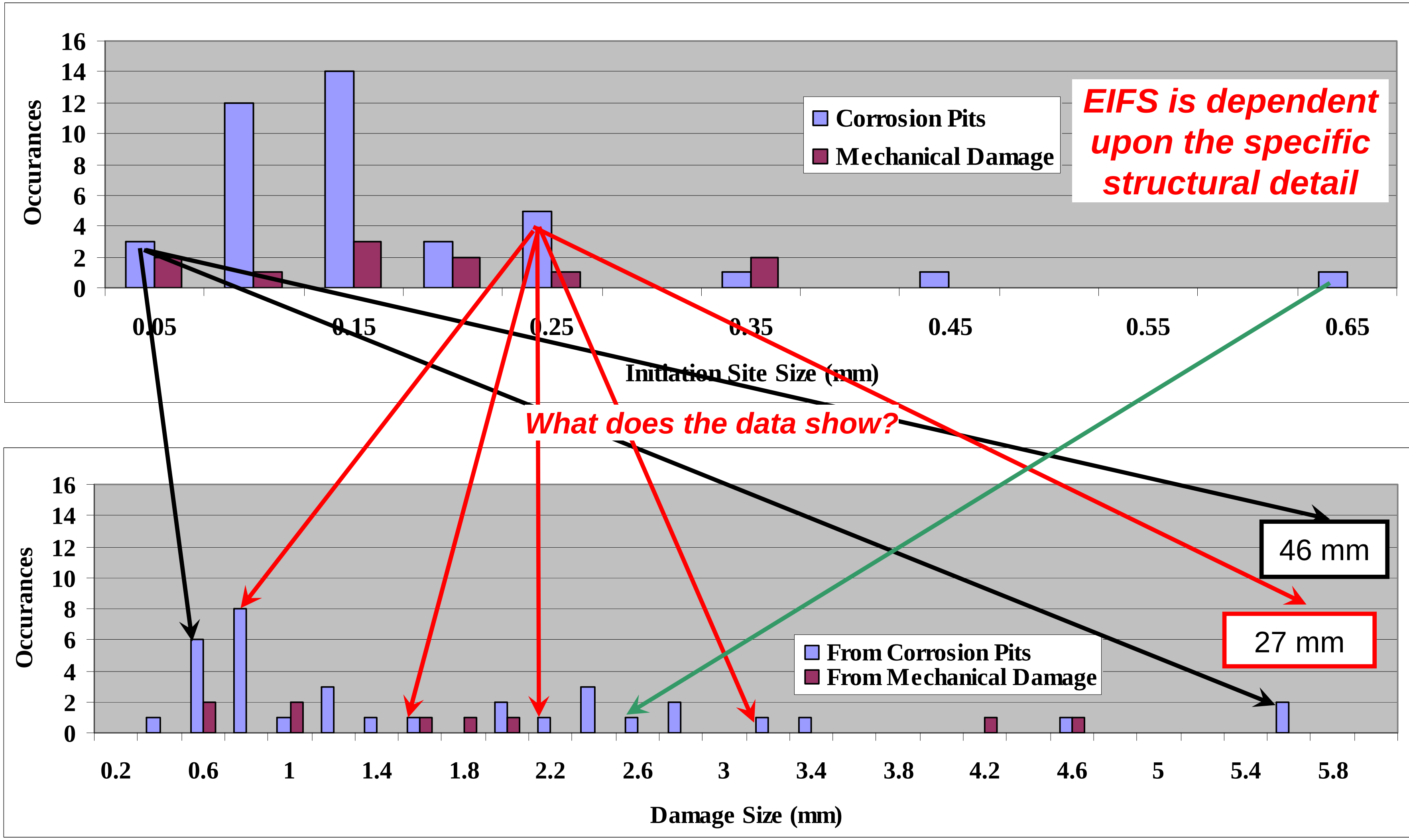
Similar distribution of initiation site sizes for the present work

Distribution of corrosion (pits) and manufacturing defects (mechanical damage)



Initiation Site Size Distribution

compared to damage finding scale



Distribution of damage size does not track with distribution of corresponding initiation site size

Future Work

- Holistic life data has historically not been the analysis emphasis of teardown programs
- Future programs shall place special emphasis on:
  - Identifying initiating feature characteristics (type, location and dimensions)
  - Tracking the progression of damage from each identified feature
- CAStLE's current program represents significantly more teardown data than the combination of the eight aircraft discussed herein