POSITRON SYSTEMS™

Health Management and Life Remaining Assessment for Aerospace Components

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Positron Systems

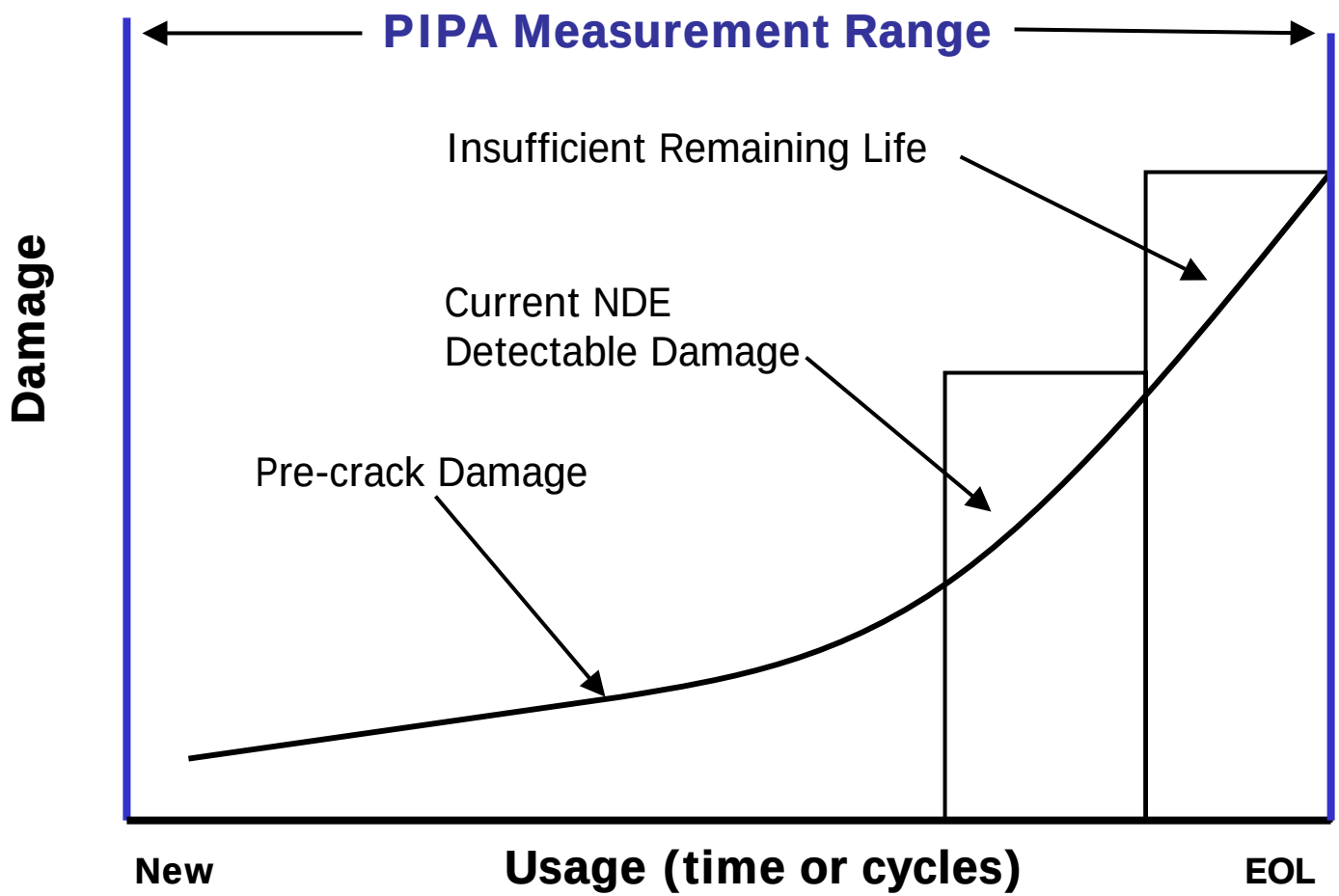
Briefing Topics

- Technology Overview
- Applications
- Discussion

Induced Positron Annihilation Unique Capabilities

- Atomic level, microstructural diagnostics
- Near-surface material characterization
- Multi-layer, thick structure damage detection
- Detects multiple damage mechanisms
- Service life remaining determination
- Works in variety of materials

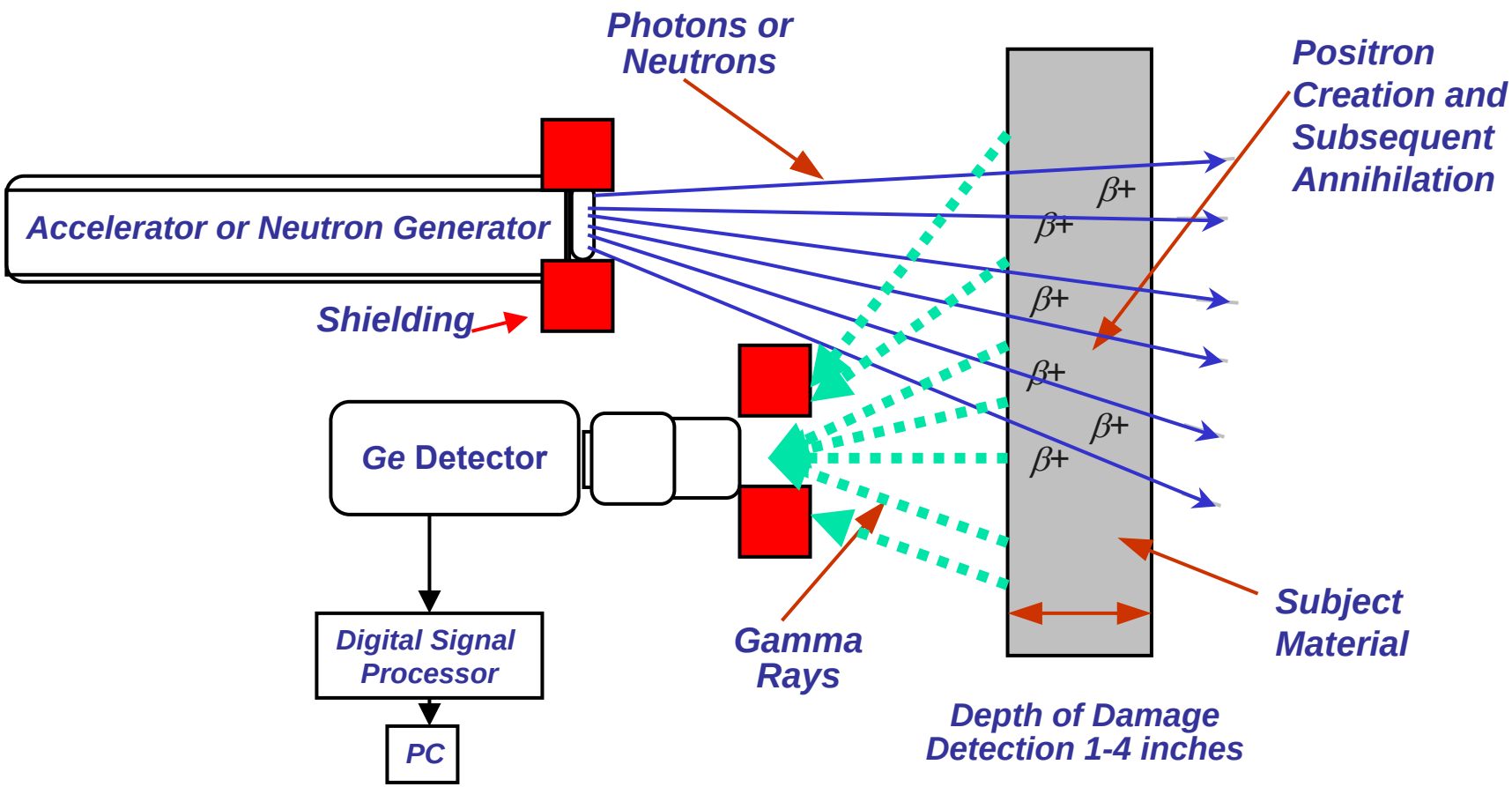
Advanced Measurement Capability



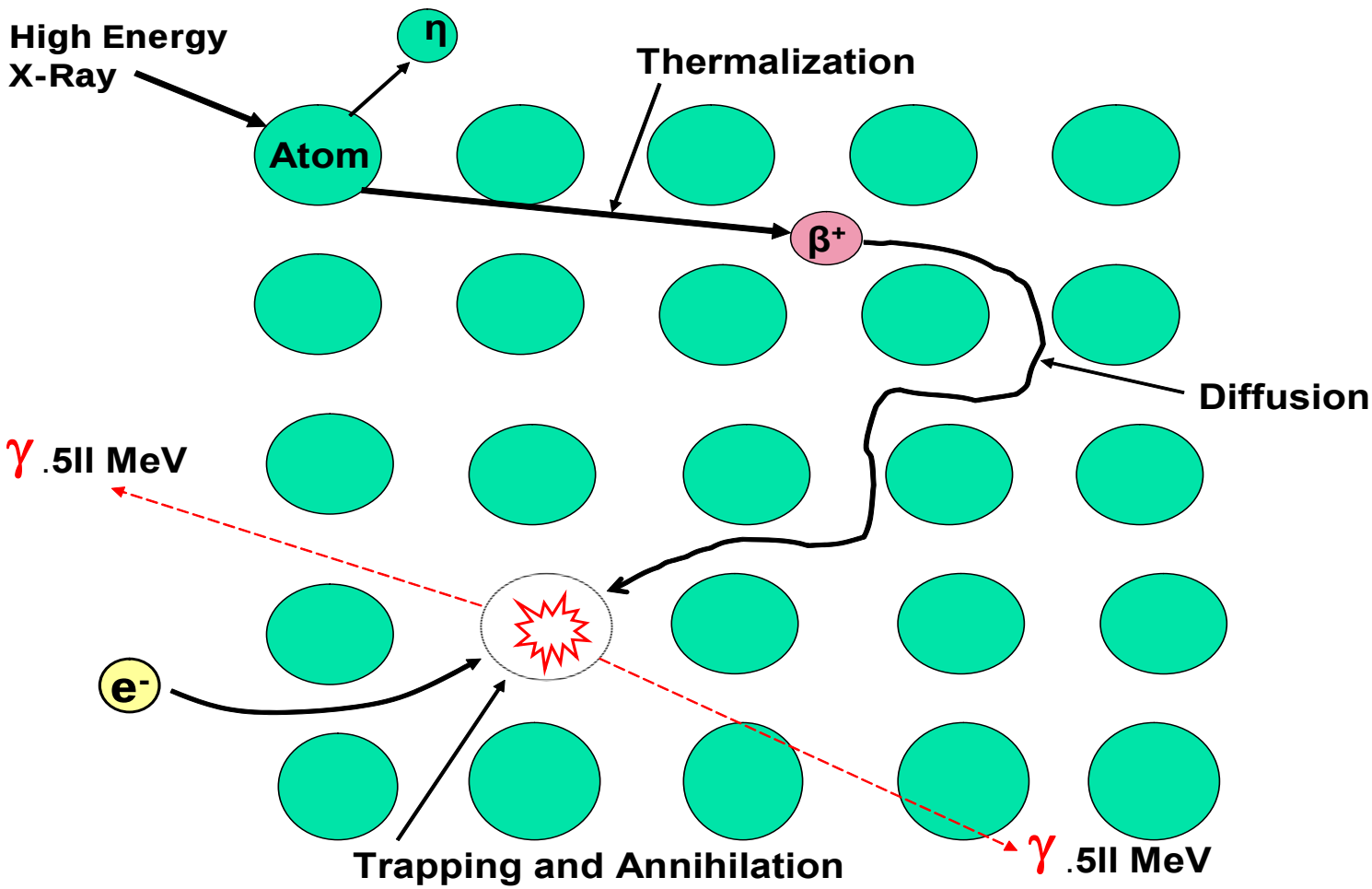
Positron Systems' Technologies

- Photon Induced Positron Annihilation (PIPA)
  - Larger equipment, faster volumetric (bulk) analysis
  - Mobile capability
- Distributed Source Positron Annihilation (DSPA)
  - Small size, near-surface analysis, can be configured as a probe
  - Mobile capability
- Neutron Induced Positron Annihilation (NIPA)
  - In development
  - Smaller than PIPA, highly portable, bulk analysis

Photon/Neutron Induced Positron Annihilation

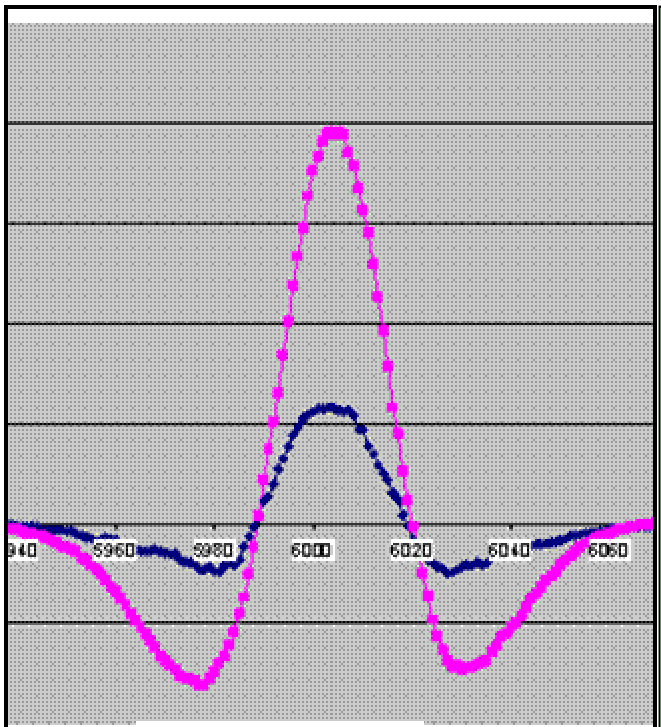


Positron Life Cycle

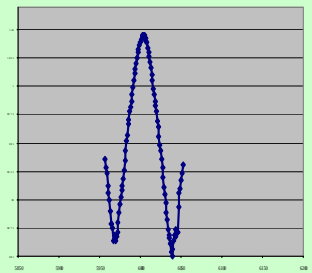
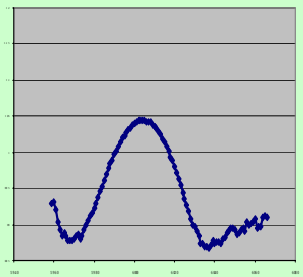


Annihilation gammas are measured. Energy level is indicative of dislocation density.

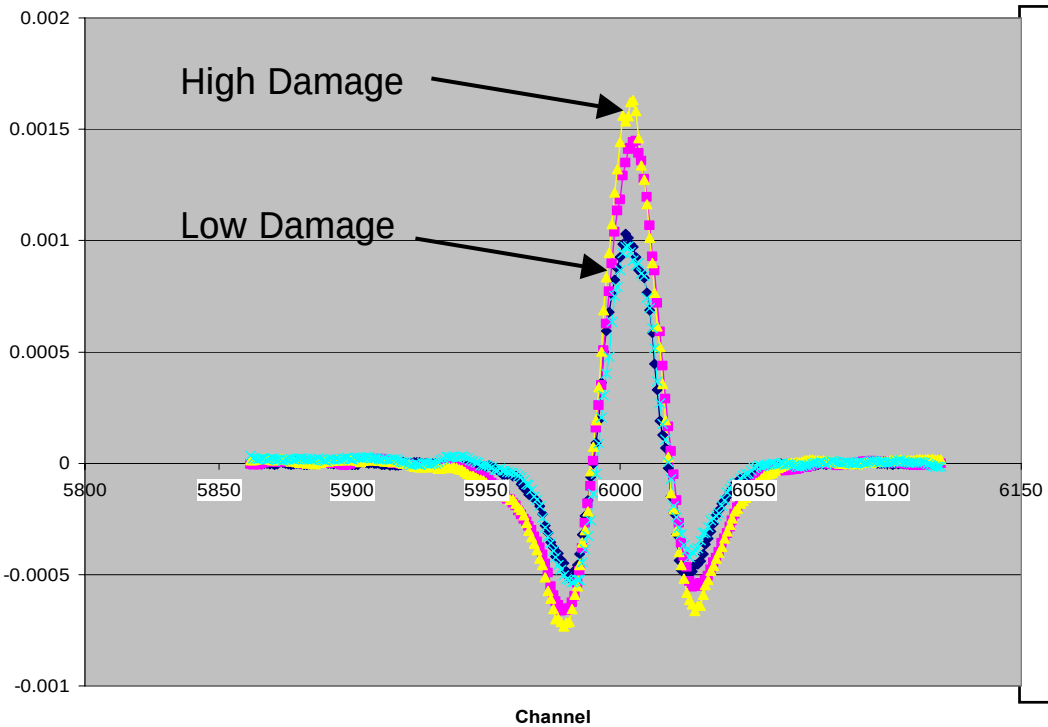
Damage to Peak Shape Relationship

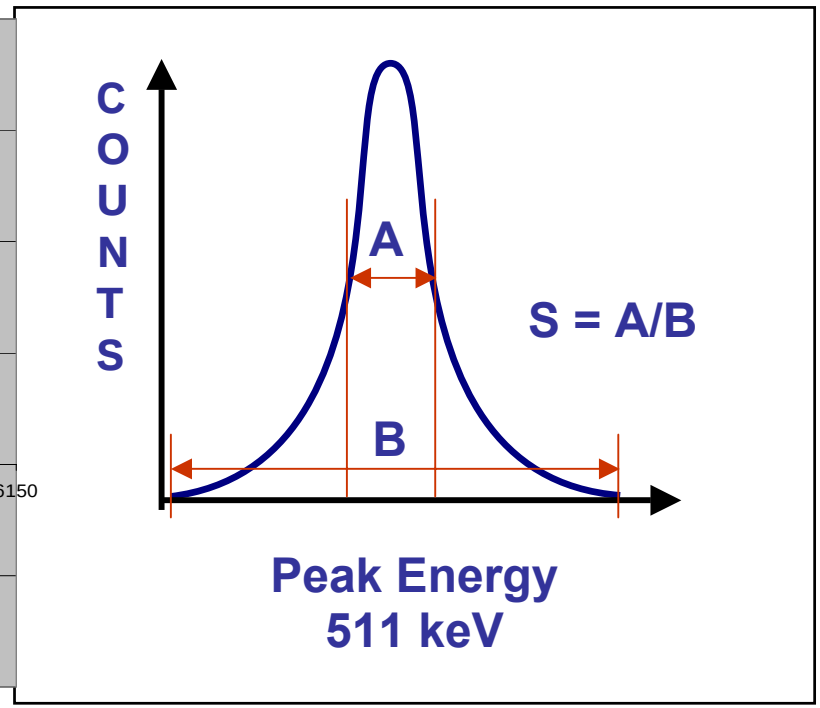


Defect Type

Void	**Increasing**	
Microvoid		
Divacancy	**S Parameter**	
Monovacancy		
Bulk Material	**Decreasing**	

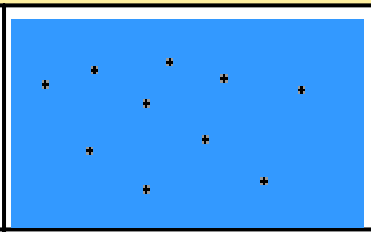
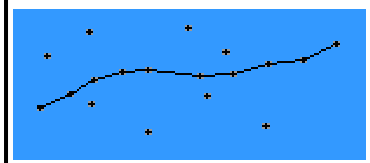
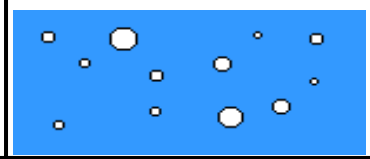
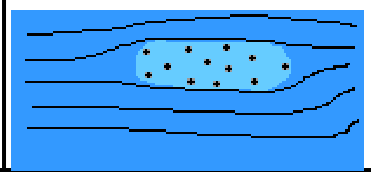
Doppler Broadened S Parameter Analysis



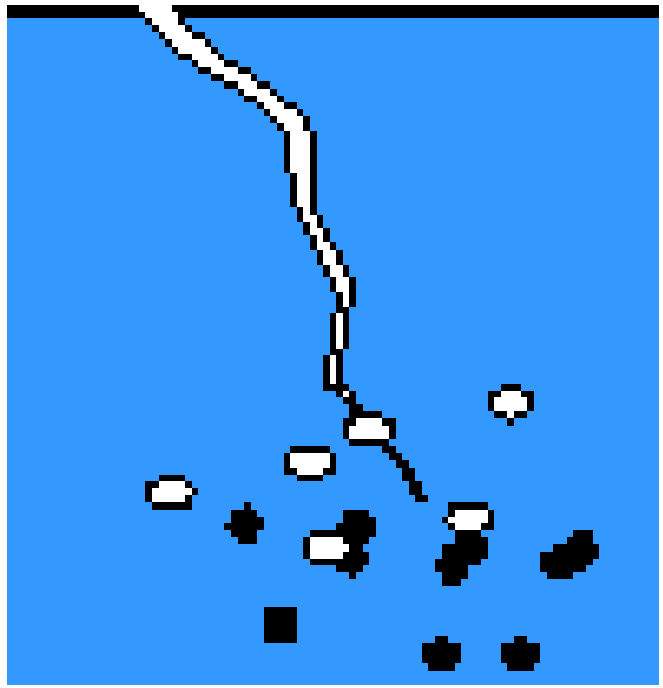


- Counts within the 511 keV gamma ray energy level are compared against total counts
- The line-shape parameter, “S” is indicative of damage levels

Positron Trapping Defects

Defect Type		Size	Materials
Atomic Vacancies		0.1 nm	Metals
Dislocations		1 nm - 10 μm	Metals
Voids		0.1 nm - 1 μm	Metals
Holes		0.1 nm - 10 μm	Polymers

Defects range from single- atom vacancies through macroscopic voids and holes.

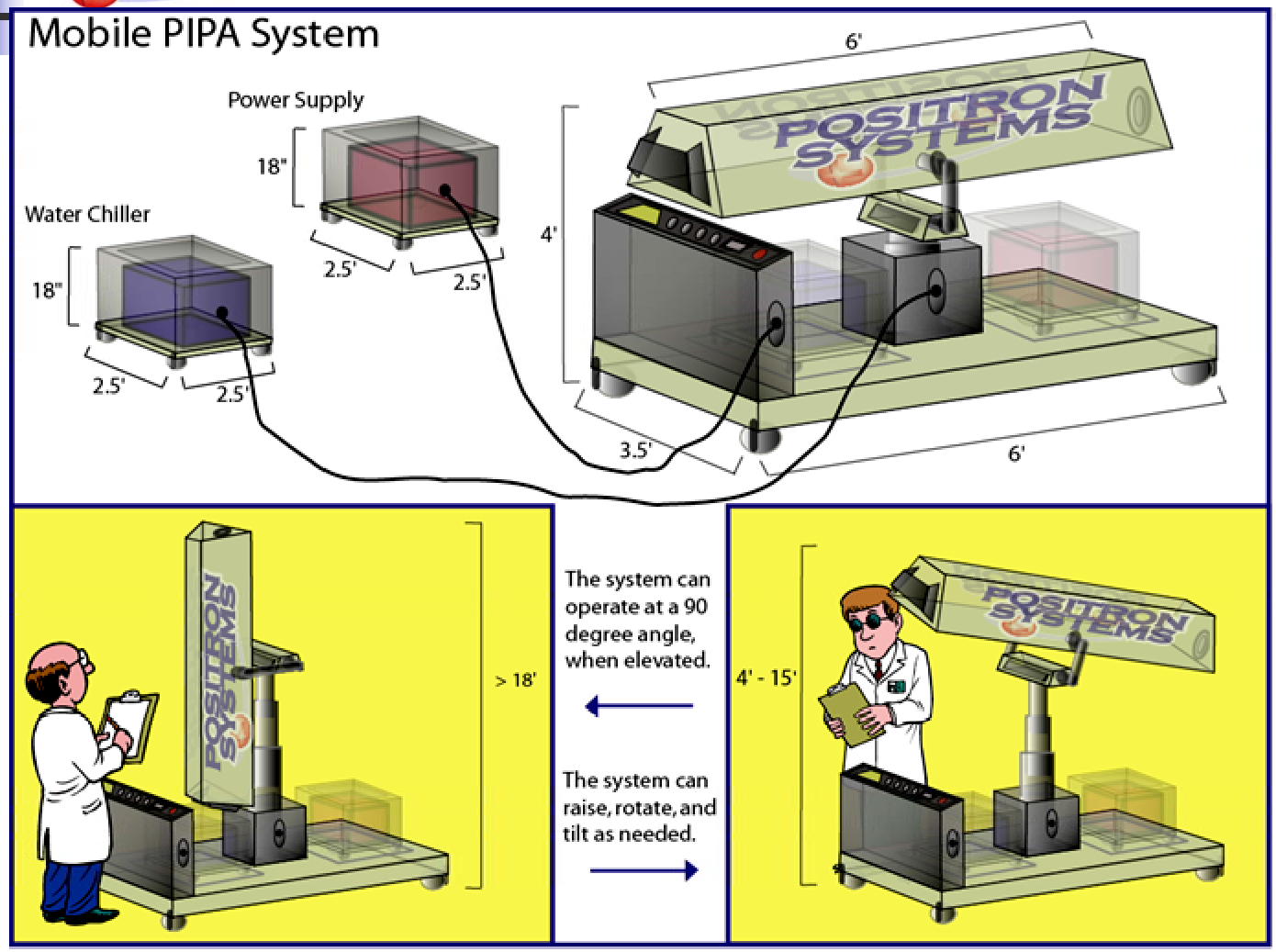


Stress Crack Tip

Key Principles of PIPA Summary

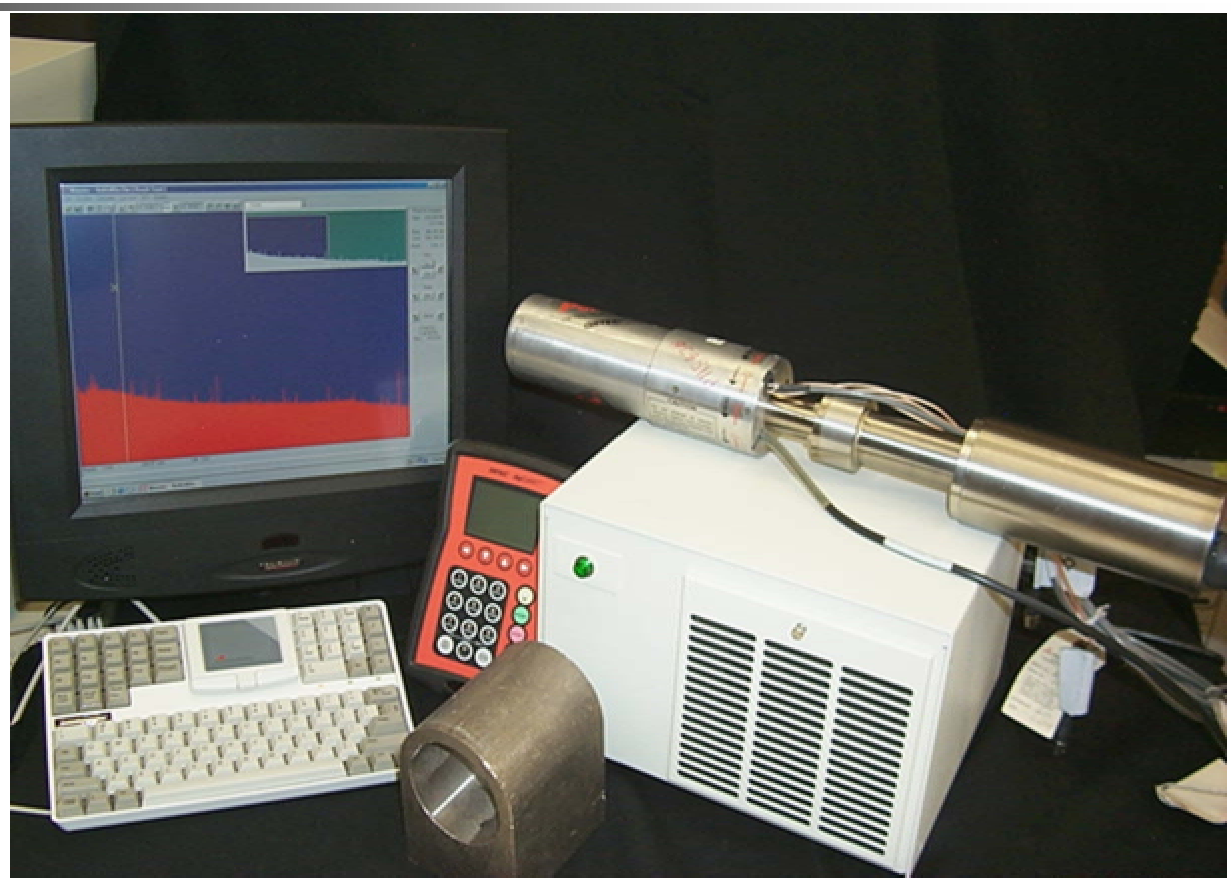
- **Highly Sensitive Probe—Positive charge causes positrons to be repelled by protons, probing 10^5 lattice sites**
- **Trapped at Defects—Attractive potential exists at open-volume defects because there are less positive charged nuclei**
- **Conservation of Momentum—higher ratio of low momentum free electrons causes a unique annihilation energy (5ll keV) at defects (Doppler broadened analysis)**
- **Longer Life—Lower atomic (electron) density in defect areas mean the positrons live longer—defect sizes and types**
- **Composition / impurities—Differences encountered in atomic structure provide different annihilation "characteristics"**

Mobile PIPA System Concept



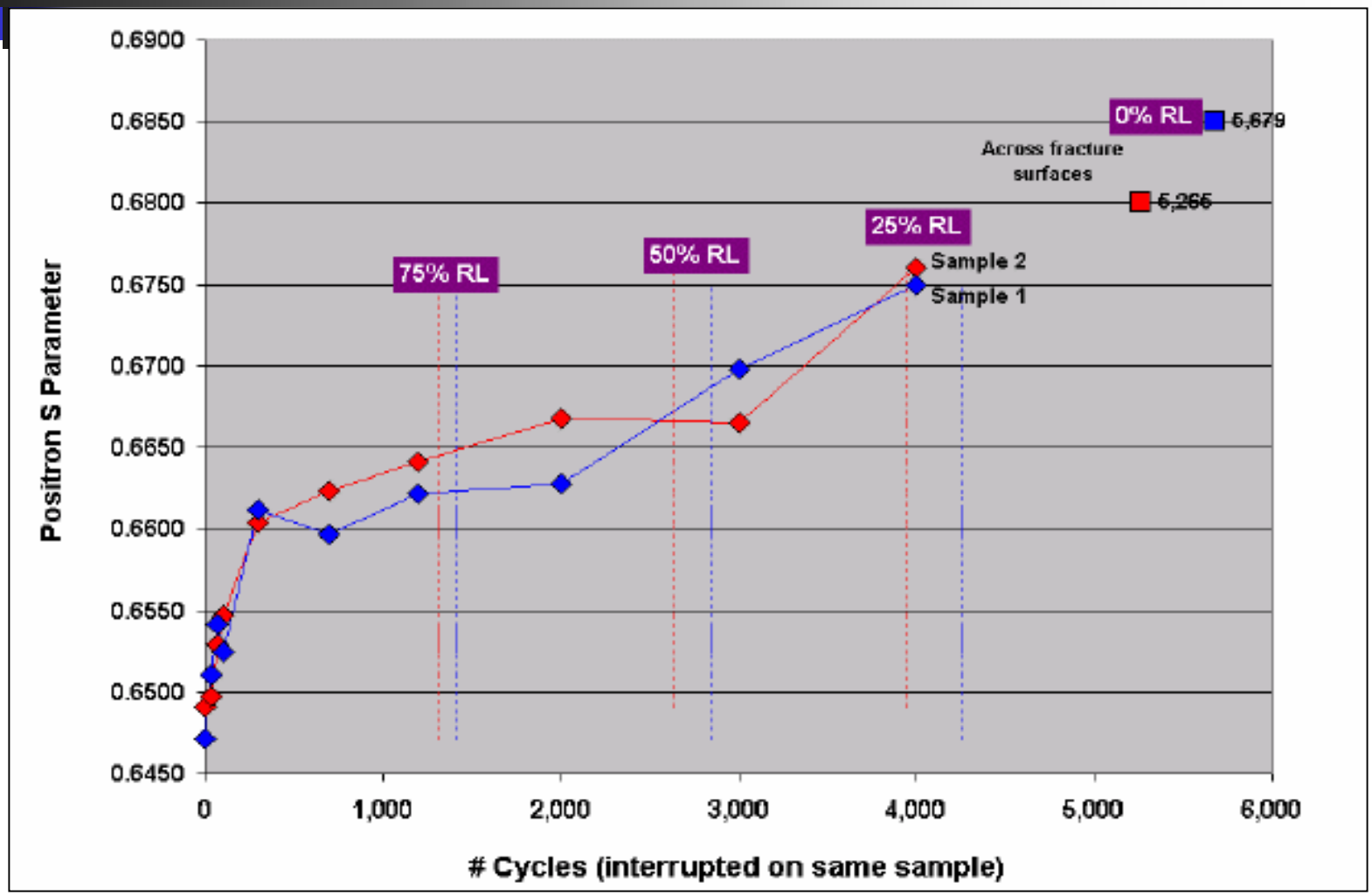
Developmental NIPA System

Neutron Generator



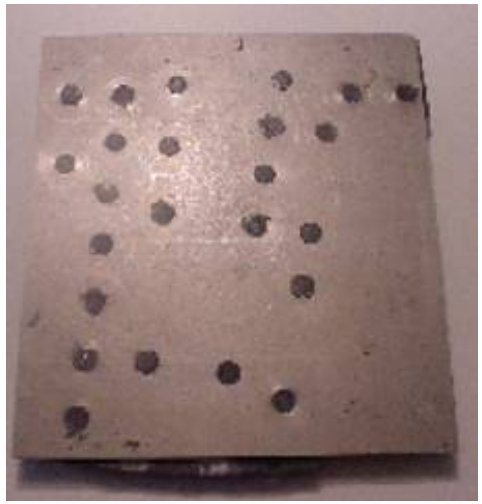
Borescope Size Generator

Remaining Life Assessment

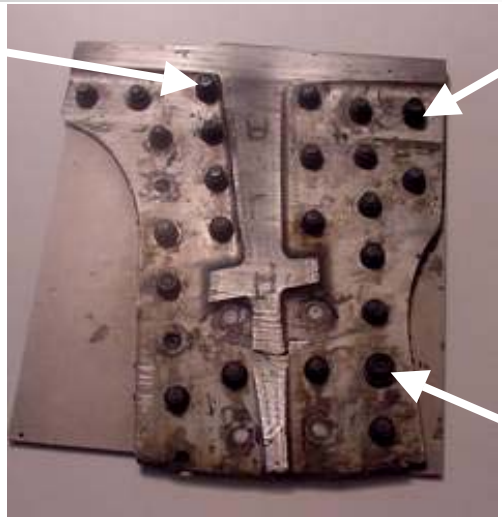


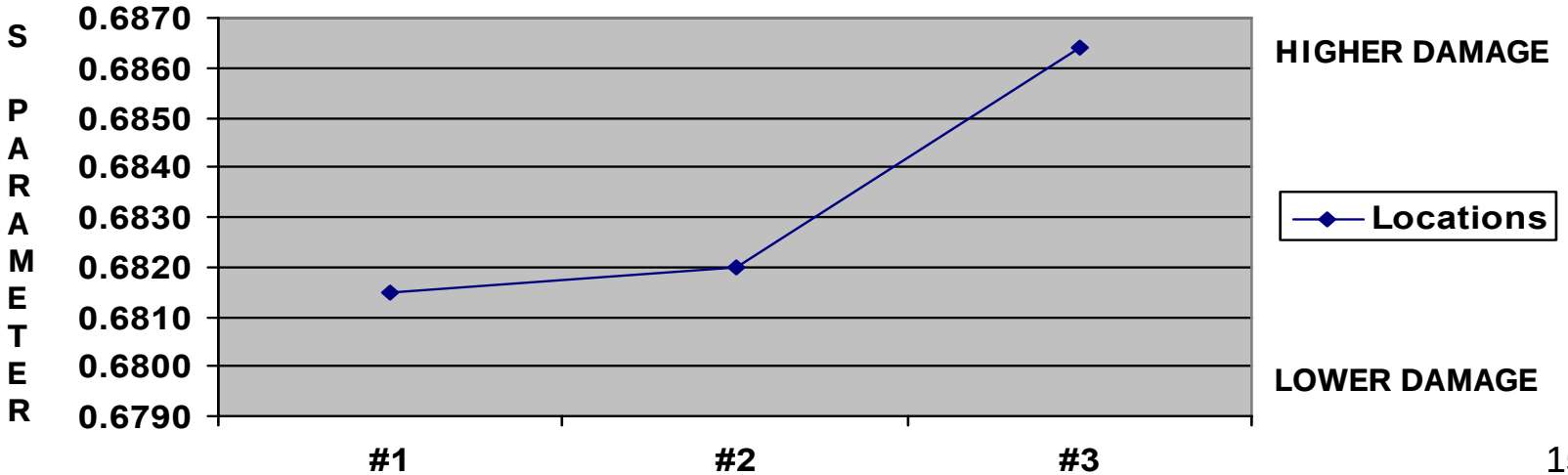
Multi-Layer Crack Detection

Outer Wing

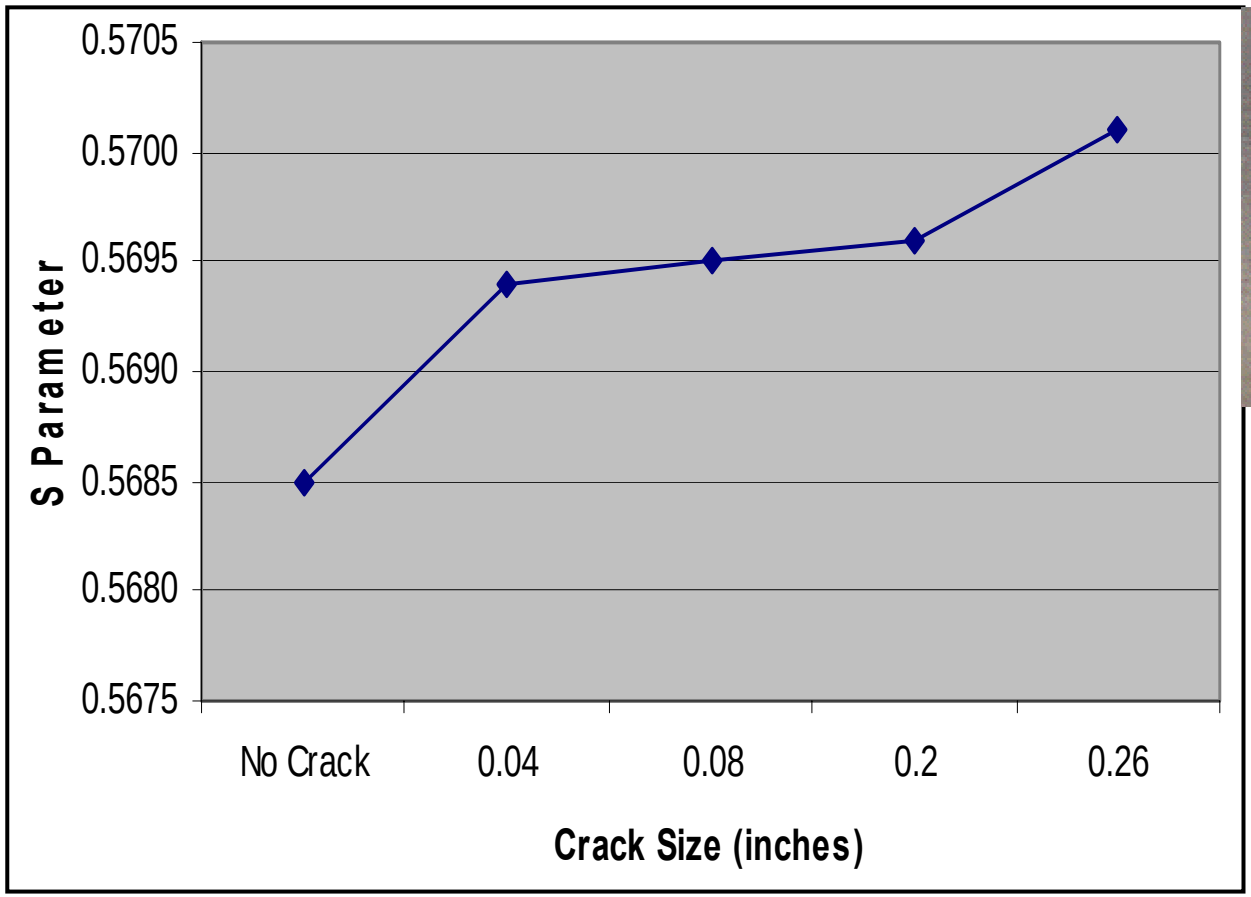


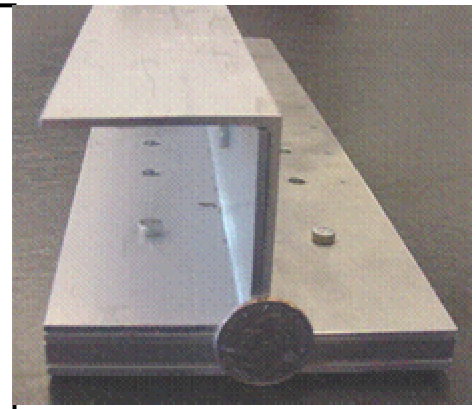
Inside Wing





Initial Multi-Layer Crack Response

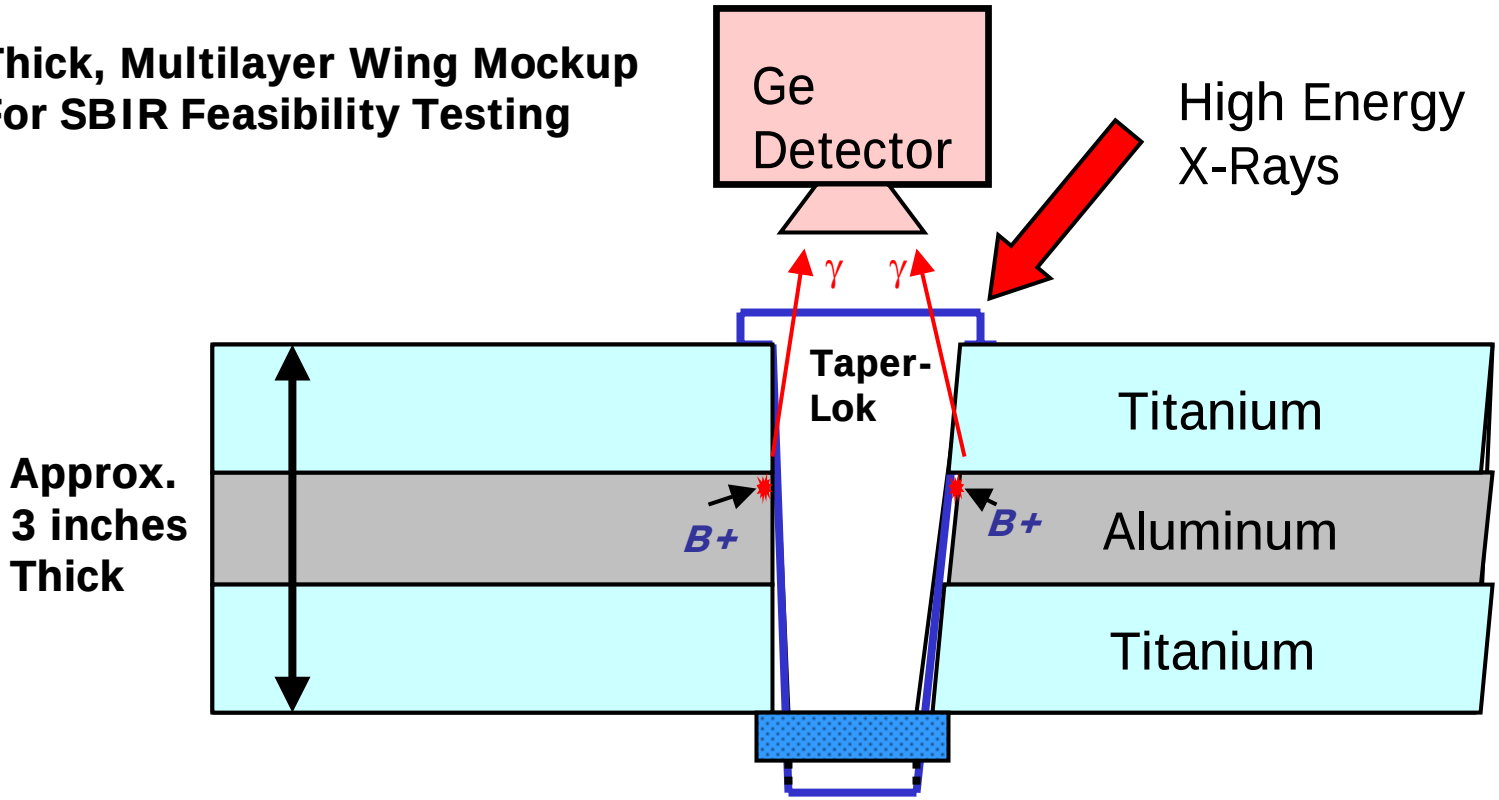




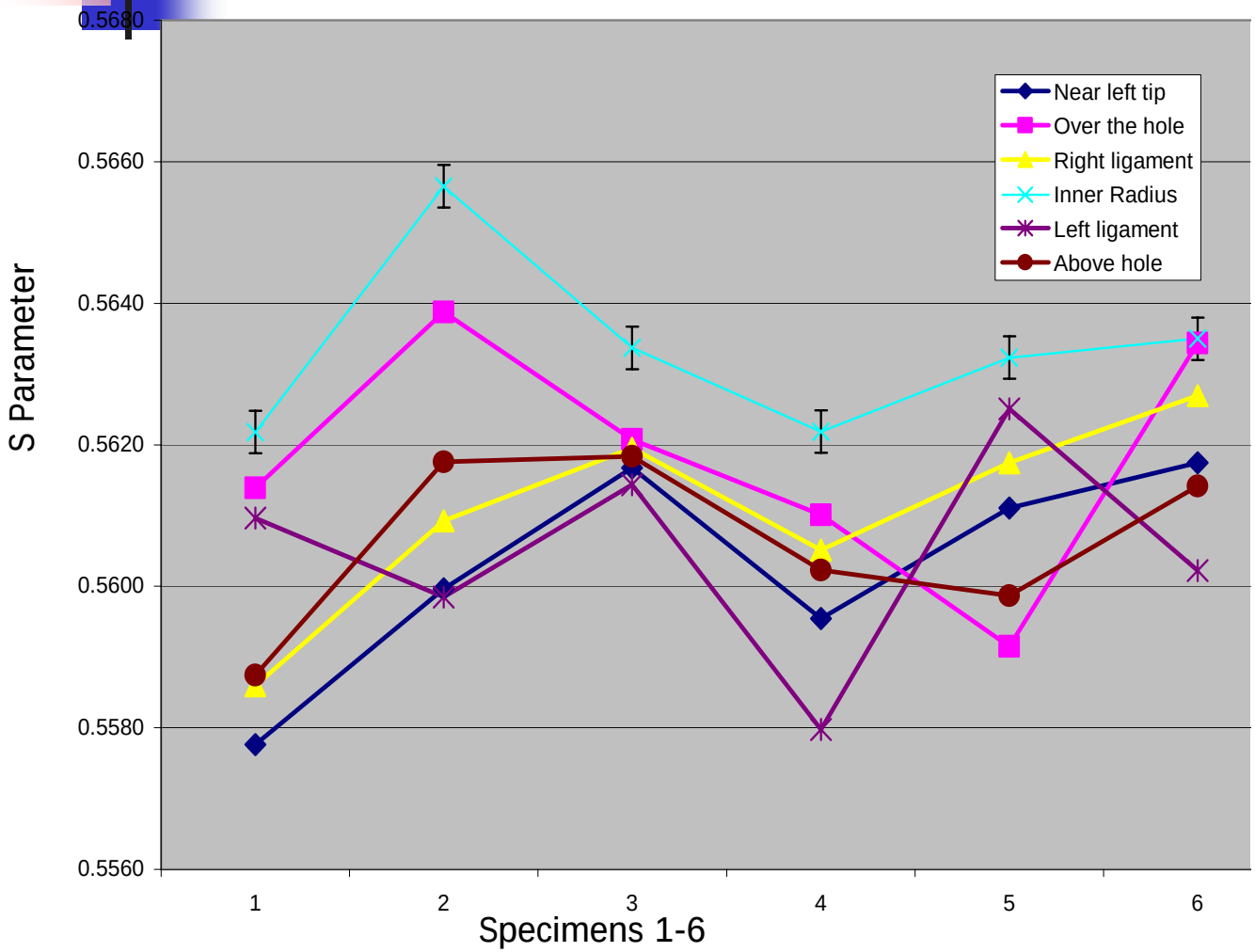
Taper-Lok SBIR Project

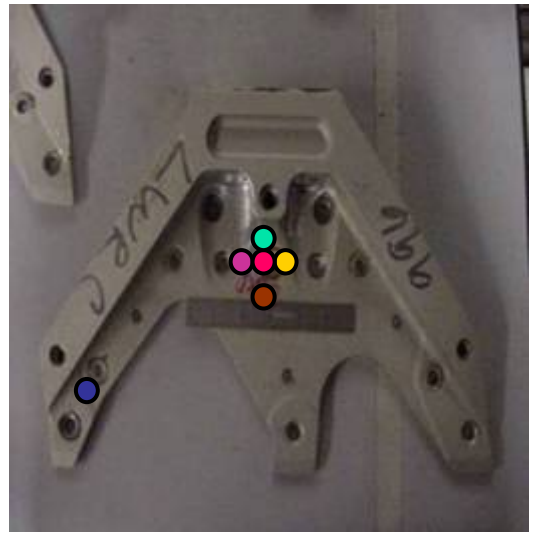
Taper-Lok Hole Damage Detection

Thick, Multilayer Wing Mockup For SBIR Feasibility Testing



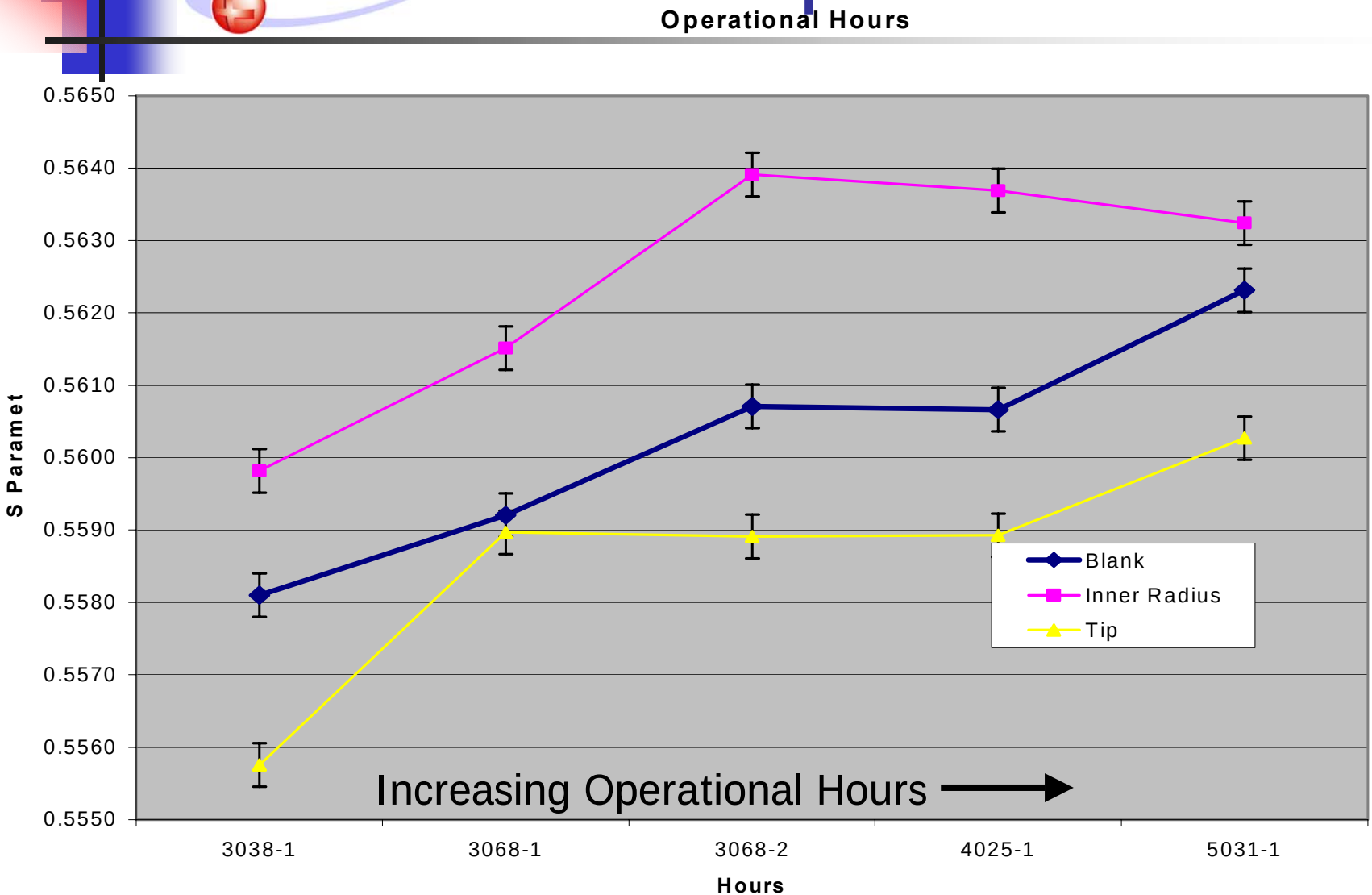
Wing Attach Fitting Damage Assessment



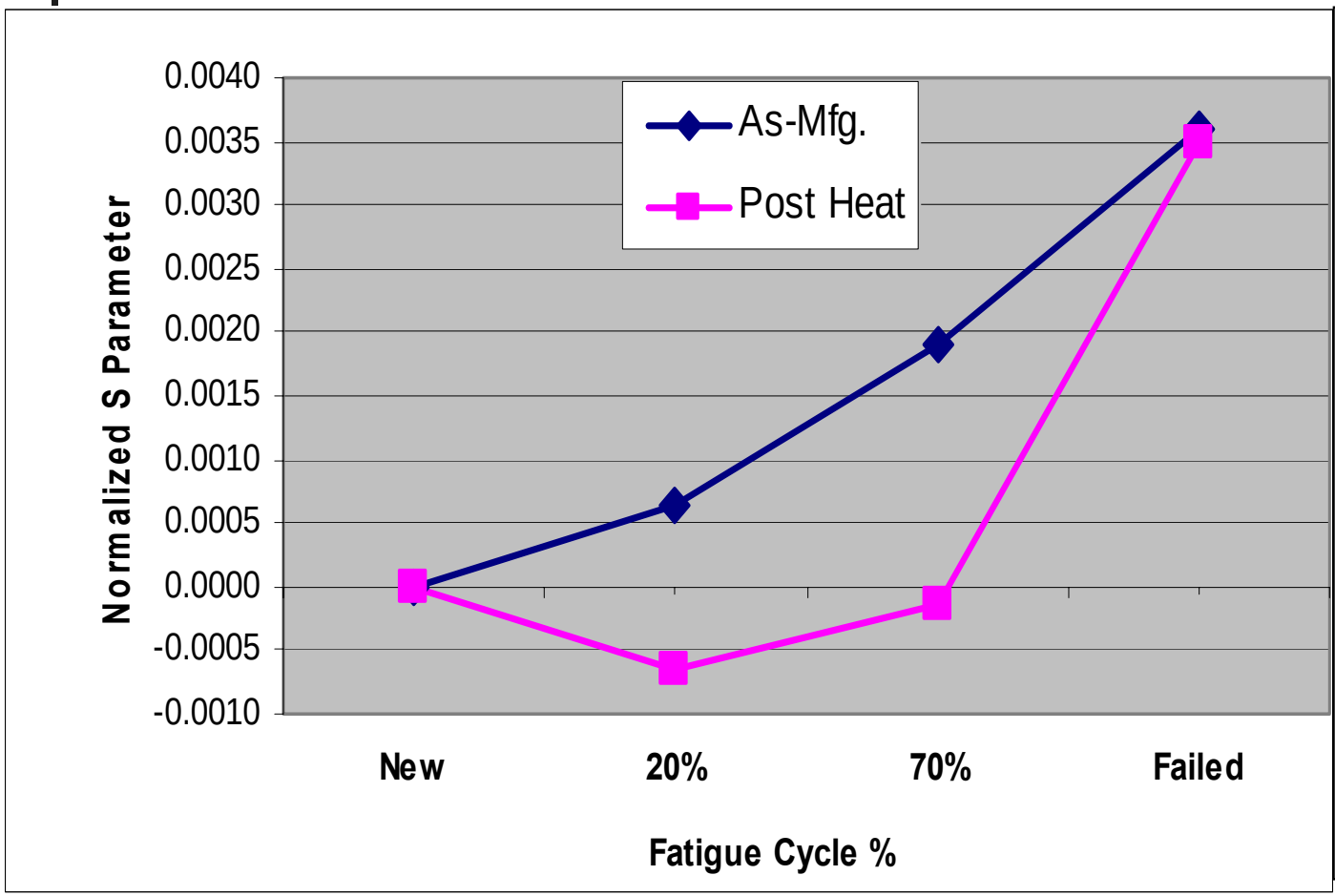


WAF

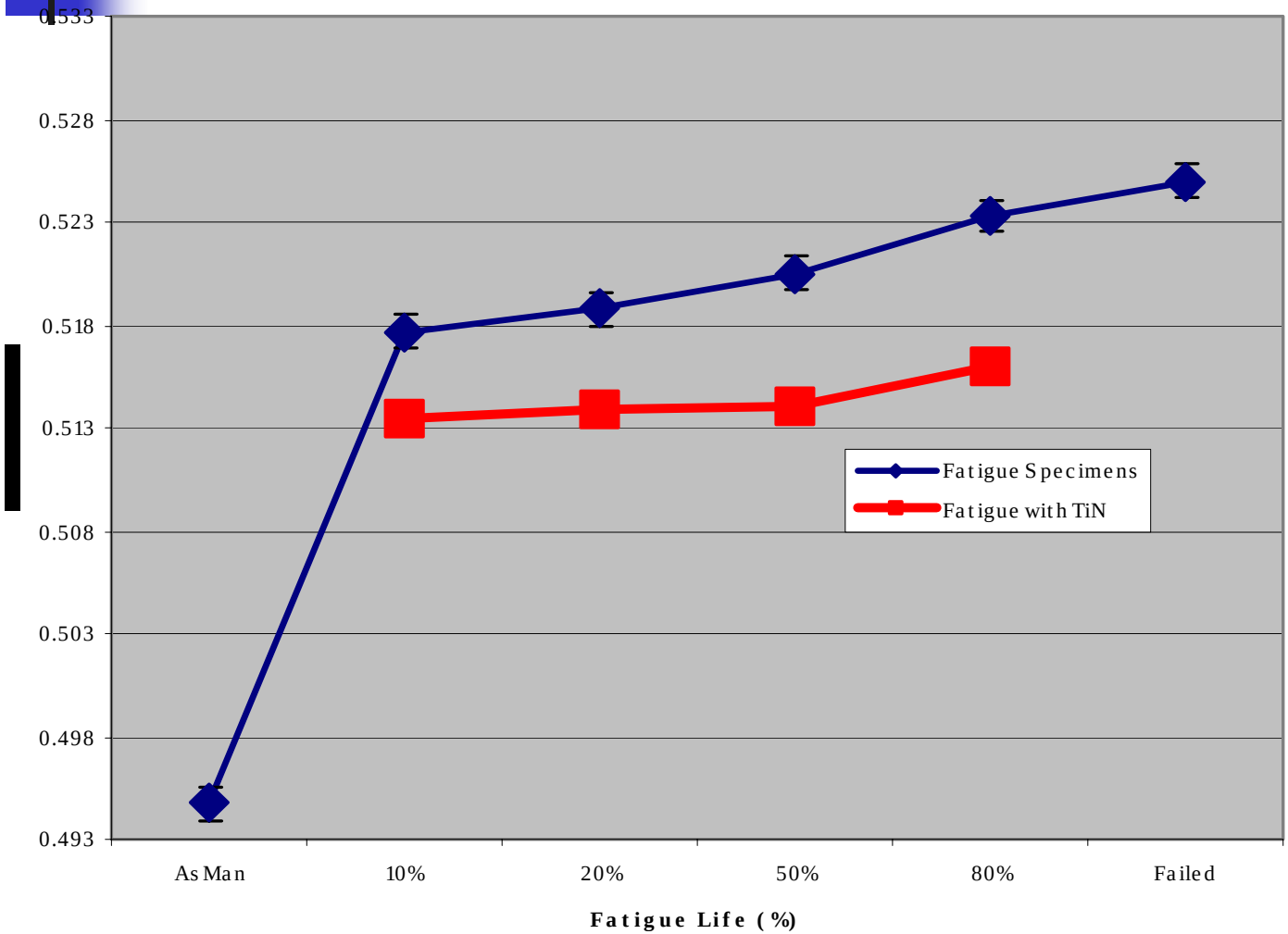
WAF Damage with Operational History



Nickel-Based Superalloy Thermal Treatment Analysis

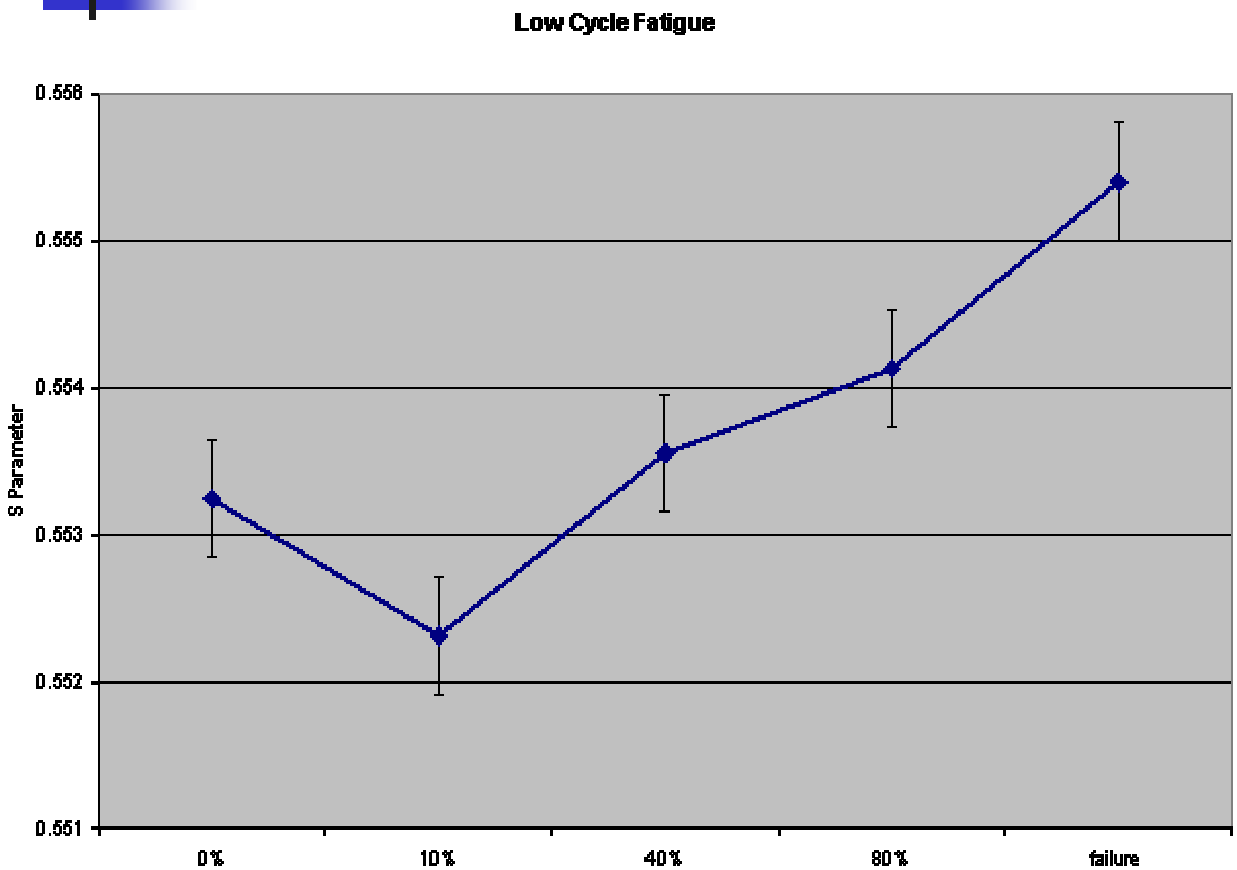


Titanium Fatigue HAI Specimens



Fatigue specimens with and without simulated HAI

Low Cycle Fatigue DSPA Analysis

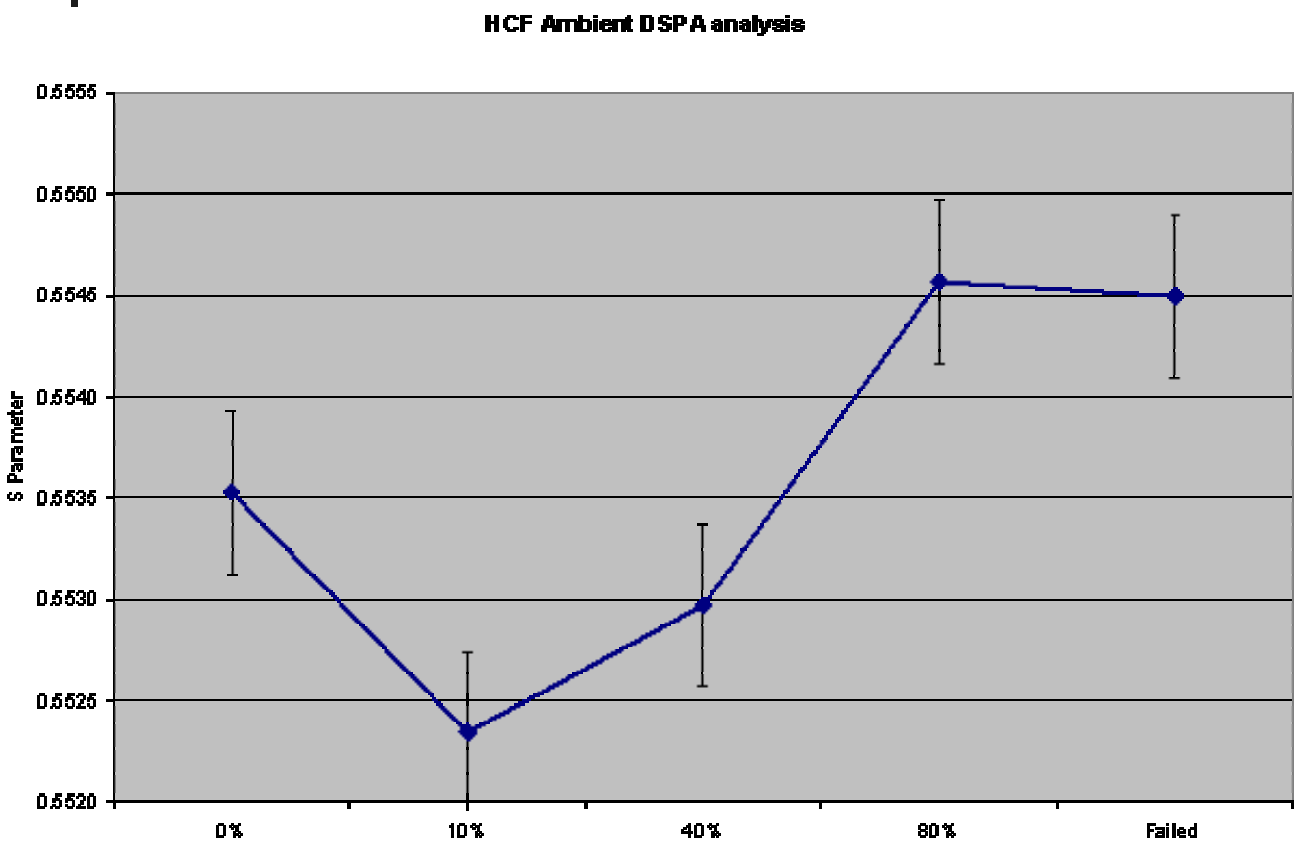


Fatigue Cycles

7475-T3751 AL

Test Coupons

High Cycle Fatigue DSPA Analysis



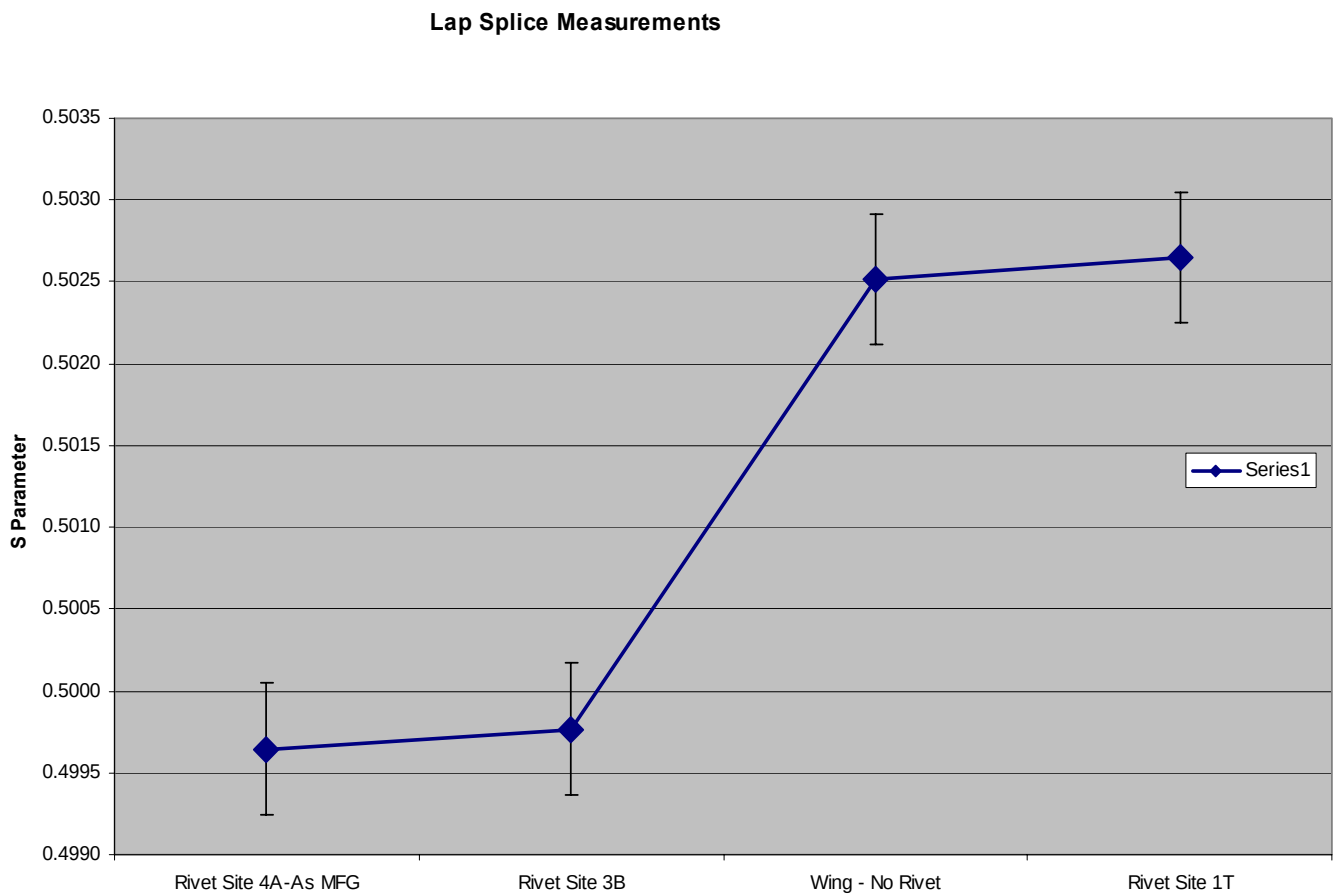
Fatigue Cycles

7475-T3751 AL
Test Coupons

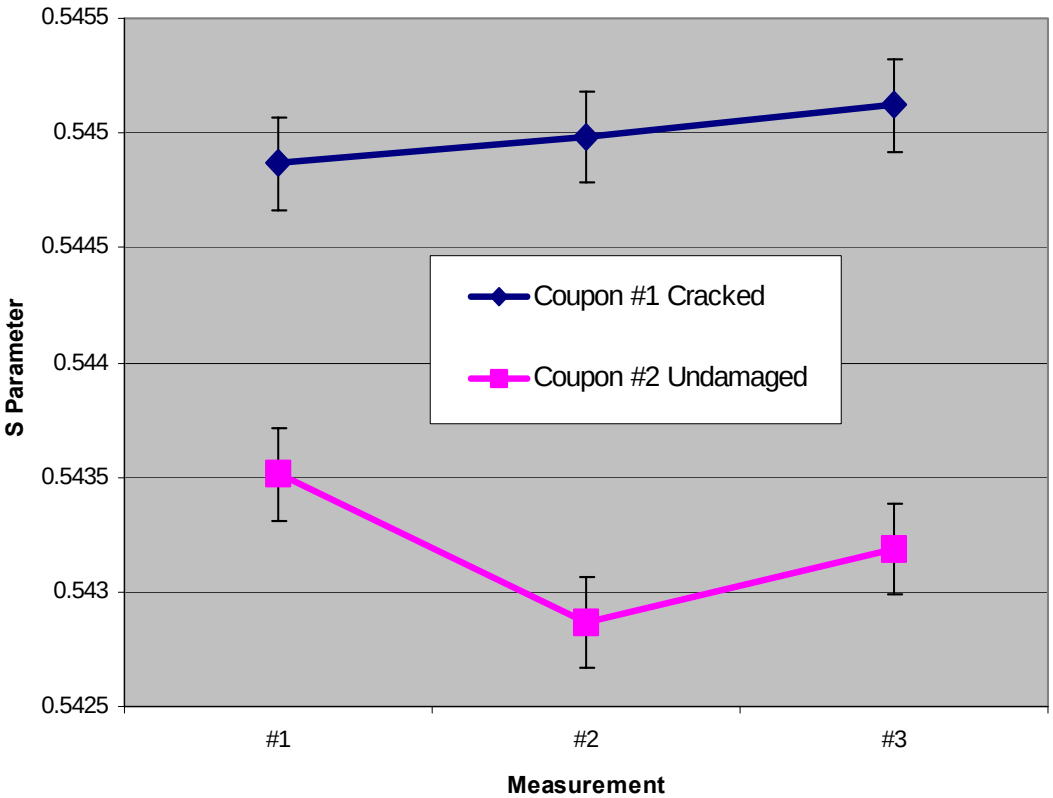
Sandia Surface Skin Analysis

- Initial measurements inconclusive on large area specimens with surface damage
- Typical range .0020 - Initial reduction from as manufactured complicates blind sample studies
- Much broader dynamic range for lap splice measurements

Sandia Lap Splice Analysis Significant Differences

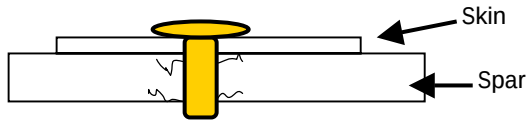


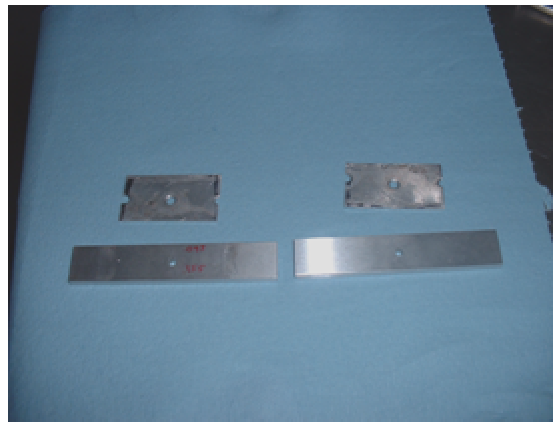
Cessna Coupon Initial Feasibility Demonstration



Crack Lengths 0.093 & 0.155 in.

0.035 & 0.042 in.





Positron Systems' Solution

- Portable equipment in development
  - Maintenance hanger configuration
- Validate initial findings with further testing
- Develop inspection criteria and sufficient database with statistical uncertainties for pass/fail and remaining life estimates
- Certify inspection process

Technology Value

- NDE, Life Prediction, Failure Analysis
- Early damage detection—"From Day One"
- "Cradle to Grave" system health management
- Field portable
- In-situ, thick, multilayer damage detection
- Minimize disassembly/coating removal
- Multiple damage mechanism detection capability
- Works in metals, polymers, ceramics, composites

Test & Analysis Center

Idaho Accelerator Center Expansion

Confidential

POSITRON SYSTEMS™

Questions?