

Center for Aircraft Structural Life Extension

Providing Structural Integrity Technology to the Aerospace Community



FY06 T-37B Teardown Analysis Program Results and Fleet Impact

Gregory A. Shoales, CASTLE

John B. Pendleton, T-37 Chief Engineer/ASIP Manager

Sandeep R. Shah, CASTLE

U.S. AIR FORCE



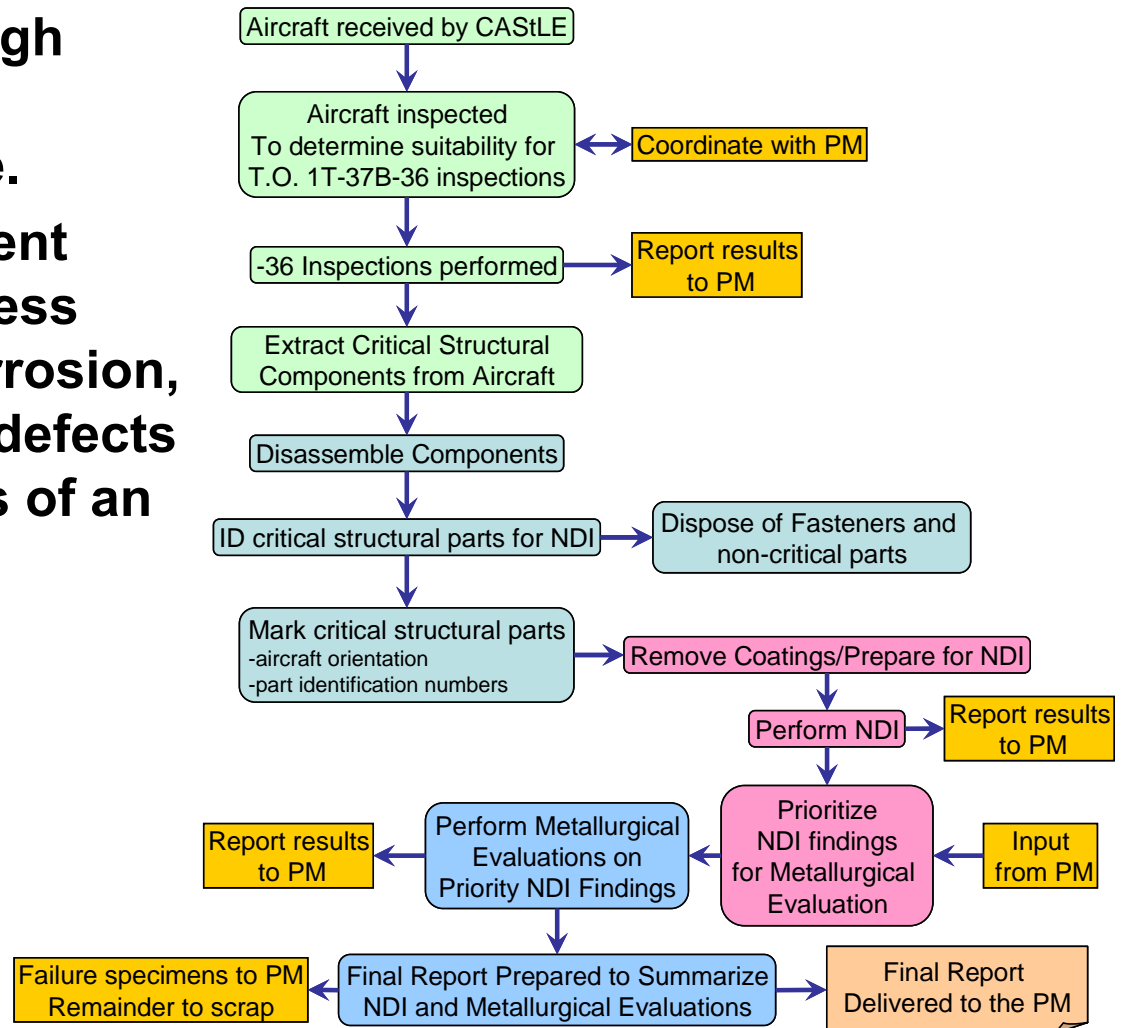
- **Program Overview**
- **Program Subjects**
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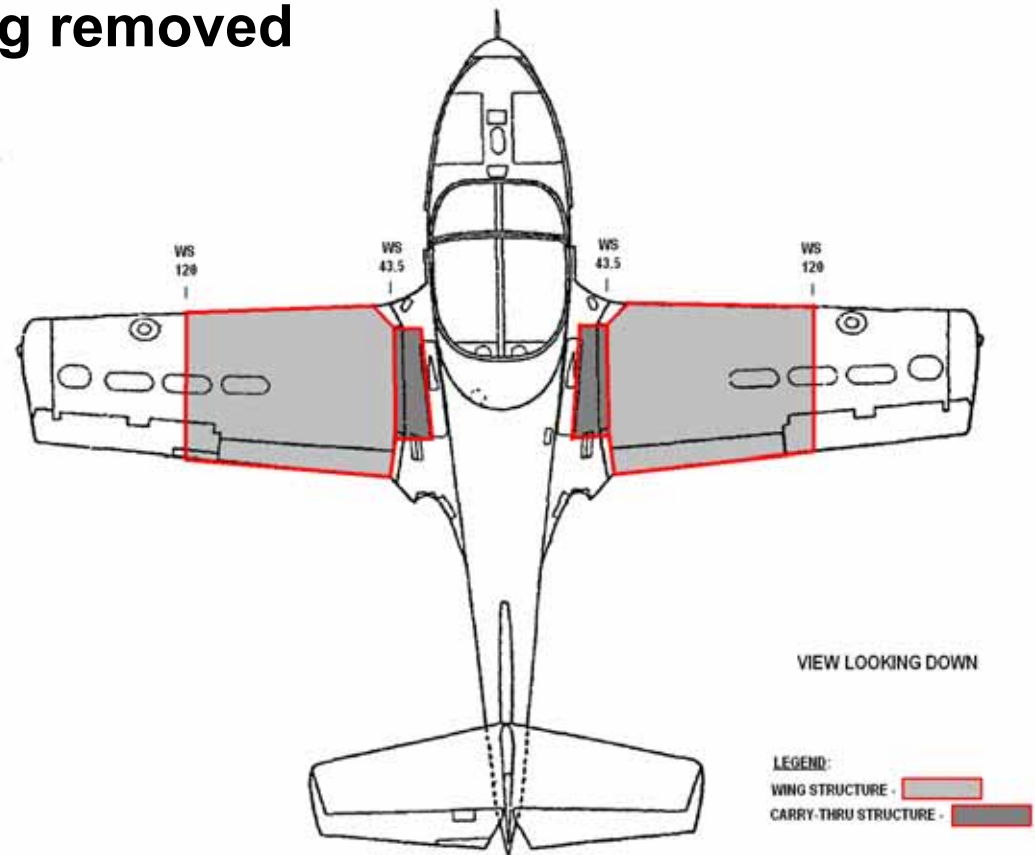
Program Overview



- Conduct a T-37B destructive teardown analysis of high flight hour wings and carry-through structure.
- Investigate and document evidence of fatigue, stress corrosion cracking, corrosion, and any other damage/defects that might result in loss of an aircraft during normal operation.



- 2 ship sets
 - Included portion of carry through structure
 - Outboard half of wing removed



- 2 additional ship sets
 - Entire wings
 - No carry through
- Documented service & mod history



NDI Indications



- **T.O. 1T-37B-36 Inspection**
 - Visual indication on upper aft spar cap
- **Part Level NDI Indications/Evaluation Prioritization**

SN	NDI Indications			Evaluations Completed			
	Left	Right	Total	Left	Right	Total	Percent
57-2297	46	40	86	34	21	55	64%
67-2243	102	72	174	39	39	78	45%
67-2257	32	34	66	23	24	47	71%
68-8071	64	39	103	64	39	103	100%
Sums	244	185	429	160	123	283	66%

- **NDI accomplished by Dan Laufersweiler, AFRL/RXSA**



Non-operational Damage Findings



- **Mechanical damage—41 findings**
 - **Scratch or deep gouge in hole bore**
 - **From manufacturing, disassembly, maintenance**
 - **Possible site to initiate continuing damage**
- **Material defect—1 finding**
 - **From porosity or hard inclusions**
 - **Also possible continuing damage site**



Operational Damage Findings



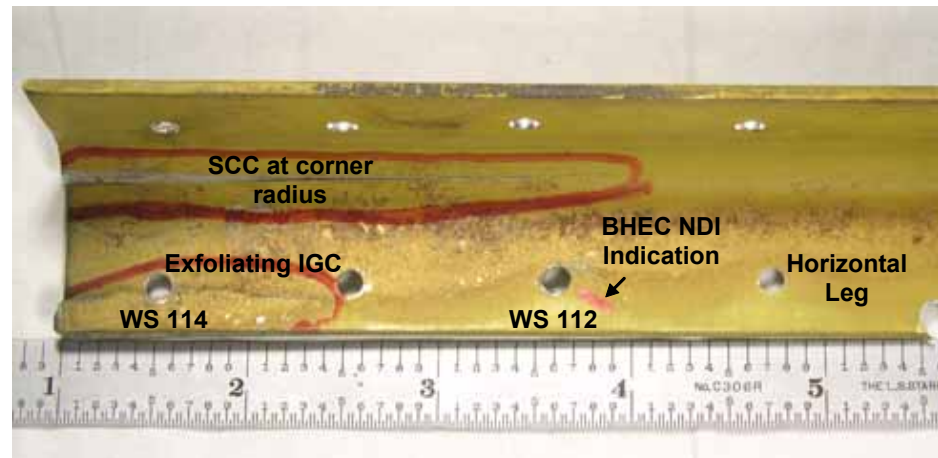
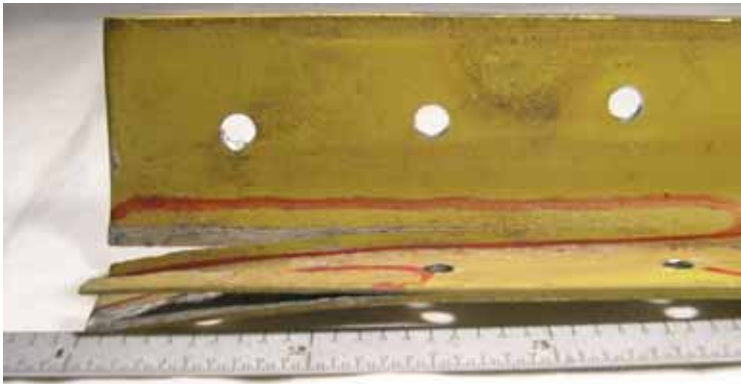
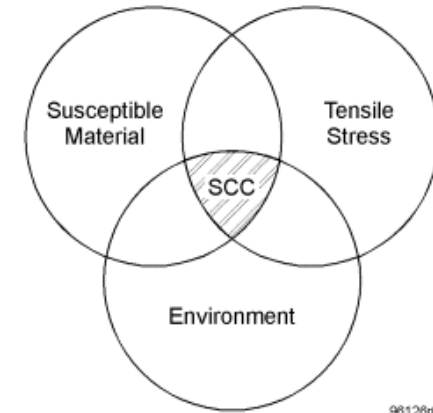
- **Environmentally assisted cracks/defects**
 - **Exfoliation corrosion—9 findings ←**
 - **Stress corrosion crack (SCC)—1 finding ←**
 - **Intergranular corrosion—12 findings**
 - **Deep hole bore pitting—6 findings**
- **Forward spar cap fatigue cracks (18 findings) ←**
- **Rib cap fatigue cracks—14 findings**
- **In-plane cracks—27 findings**
- **Surface corrosion—125 findings**

- Visual indication left upper aft spar cap of 1 aircraft



- Failure analysis finding
 - Exfoliation corrosion
 - Maximum of 47% thickness loss over 0.38 in²
 - Additional severe corrosion nearby

- 2.9 inch through crack
- Spar Cap Material: AA7075-T6
- Sustained Tensile Stress
 - Normal load bearing of spar cap
 - Evidence of residual stress

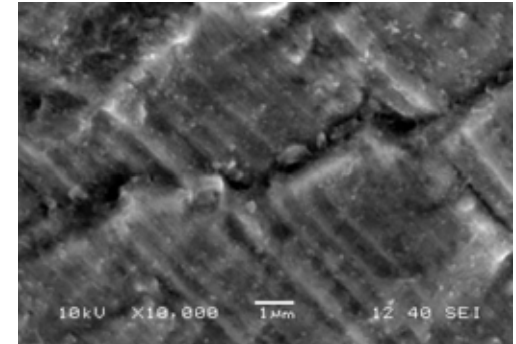


- Environment
 - Pooled water
 - Dark stains on spar caps observed on all aft spar caps

Operational Damage Finding

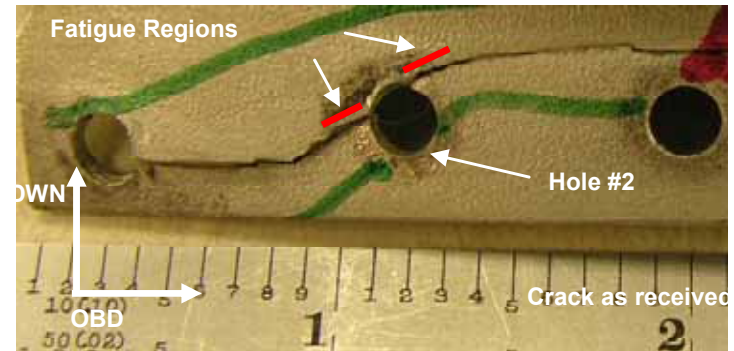
forward spar cap fatigue cracks

- Location: thin vertical leg which connects to spar web
- 18 findings at this location
 - 17 fatigue findings
 - Each with small fatigue region, ≤ 0.5 in
 - Final extension from overstress
 - One additional finding of overstress cracking only



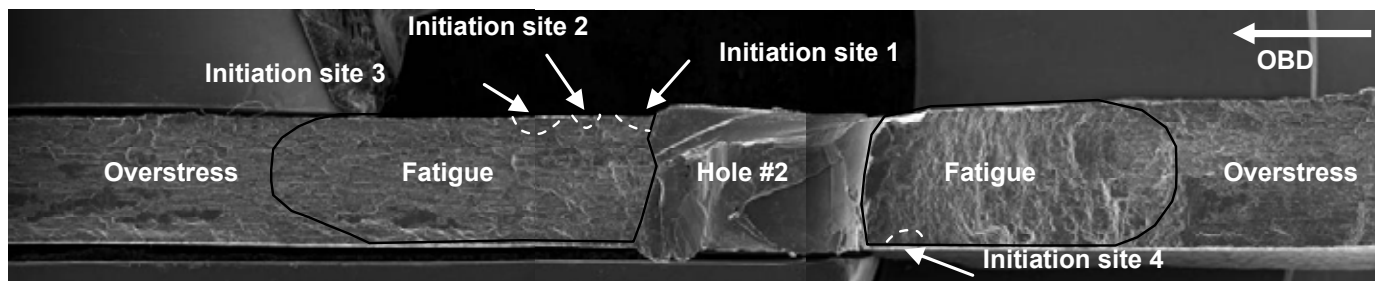
■ Specific initiation locations

- Radius between thick and thin vertical leg
- Fastener holes
 - 2:00 and 8:00 left wing
 - 5:00 and 11:00 right wing



■ Fractography

- Multiple surface initiation sites
- Cracks propagate in thickness direction
- Out of plane loading—8 to 13 ksi√in
- Due to relative motion between spar caps?





Operational Damage Finding

corrosion



- **Surface corrosion—125 findings**
- **Exfoliation corrosion—9 findings**
- **Overall Results**
 - **Thickness loss: less than 1% to 54%**
 - **Area affected: 0.001 to 3.6 in²**

- Database in Microsoft® Office Excel 2003 format
 - All indications
 - Indication location and NDI details
 - Links to macro photographs

Indication Location										Indication Type			
A/C SN	Part			Type	Coordinates (in)		Ship Side	Zone	Facing	Macro Figure(s) link	Source	Orientation	%FSH
	P/N	Nomenclature	Ref		WS/BL	FS							
57-2297	4022036-701	Spar Cap - LWR - AFT	67-2257	Spar Cap	101.5	167	LH	Vert	AFT	SN57-2297/DSCN5669.JPG	FPI		
57-2297	4022036-701	Spar Cap - LWR - AFT	67-2257	Spar Cap	94	167	LH	Horz	AFT	SN57-2297/DSCN5668.JPG	FPI		
57-2297	4022202-1 (3of6)	Rib Cap - FWD - UPR	-4, Fig. 30-?	Rib Cap	71.75	144	LH	Vert		SN57-2297/DSCN5688.JPG	EC FPI	9:00	100
57-2297	4022426-5 (7of8)	Rib Cap - UPR	-4, Fig. 30-91	Rib Cap	91.5	141	LH	Horz		SN57-2297/DSCN5686.JPG	FPI		
57-2297	4022426-5 (7of8)	Rib Cap - UPR	-4, Fig. 30-91	Rib Cap	91.5	141.75	LH	Horz		SN57-2297/DSCN5686.JPG	EC	5:00	100
57-2297	4022036-701	Spar Cap - LWR - AFT	67-2257	Spar Cap	51	167	LH	Horz	AFT	SN57-2297/DSCN5667.JPG	EC	1:00	30
57-2297	4022035-1	Spar Cap - LWR - AFT	67-2257	Spar Cap	46.5	167	LH	Vert	FWD	SN57-2297/DSCN5655.JPG	EC FPI	9:00	35
57-2297	4022035-1	Spar Cap - LWR - AFT	67-2257	Spar Cap	90.25	167	LH	Horz	FWD	SN57-2297/DSCN5656.JPG	EC FPI	8:00	75
57-2297	4022986-501	Spar Cap - LWR - FWD	67-2257	Spar Cap	46	130.5	LH	Vert		SN57-2297/DSCN5662.JPG	EC	3:00	100

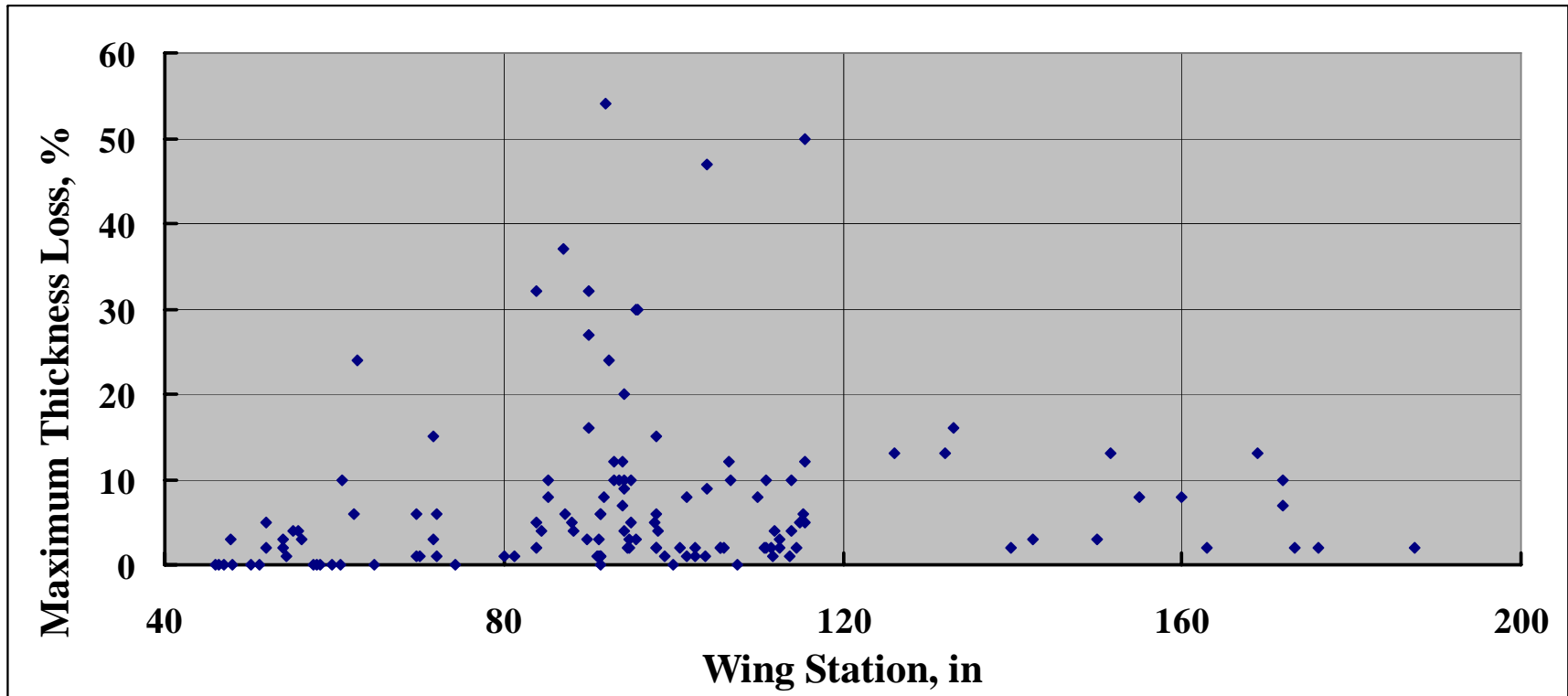
■ Key finding data

Evaluation Finding									
Type	Dimensions (in)				Corrosion Dimnesions		Through Crack	Faying Side Nucelation?	Report File Link
	c	a	b	max	%thick loss	Area (sq in)			
surface corrosion					8	0.283			<i>corrosion grind-out measurements only</i>
surface corrosion					7	0.0552			<i>corrosion grind-out measurements only</i>
fatigue crack	2.1	0.063		2.1			Y	ukn	SN57-2297 L RC FWD UPR FS144
fatigue crack	1.72	0.063	0.003	1.72			Y	unk	SN57-2297 L RC UPR FS141
fatigue crack	0.024	0.02		0.024			N	Y	SN57-2297 L RC UPR FS142
no defect									SN57-2297 L SC AFT LWR AFTSIDE WS51
in-plane crack	0.059		0.0113	0.059			N	N	SN57-2297 L SC AFT LWR FWDSIDE WS46
IG crack	0.021	0.028	0.04	0.04			N	unk	SN57-2297 L SC AFT LWR FWDSIDE WS90
unknown							N	Y	SN57-2297 L SC FWD LWR WS46A

- Searchable via standard Excel tools
 - Query tables, specific graphs
 - Can be imported into most database software

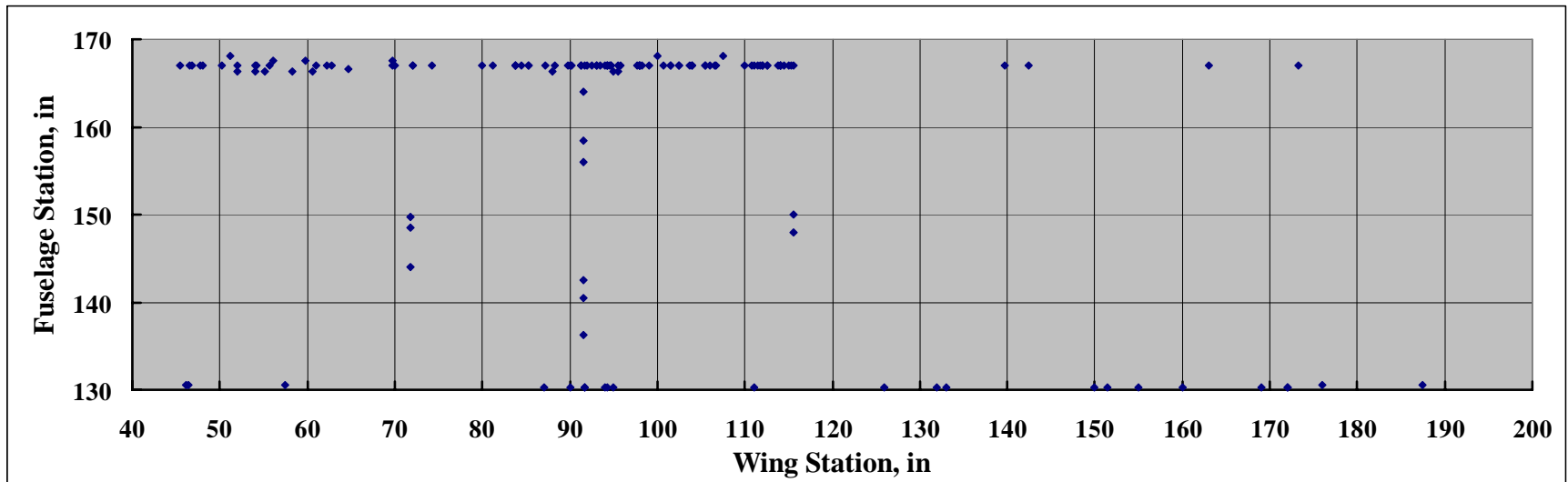


query example: corrosion severity vs. location



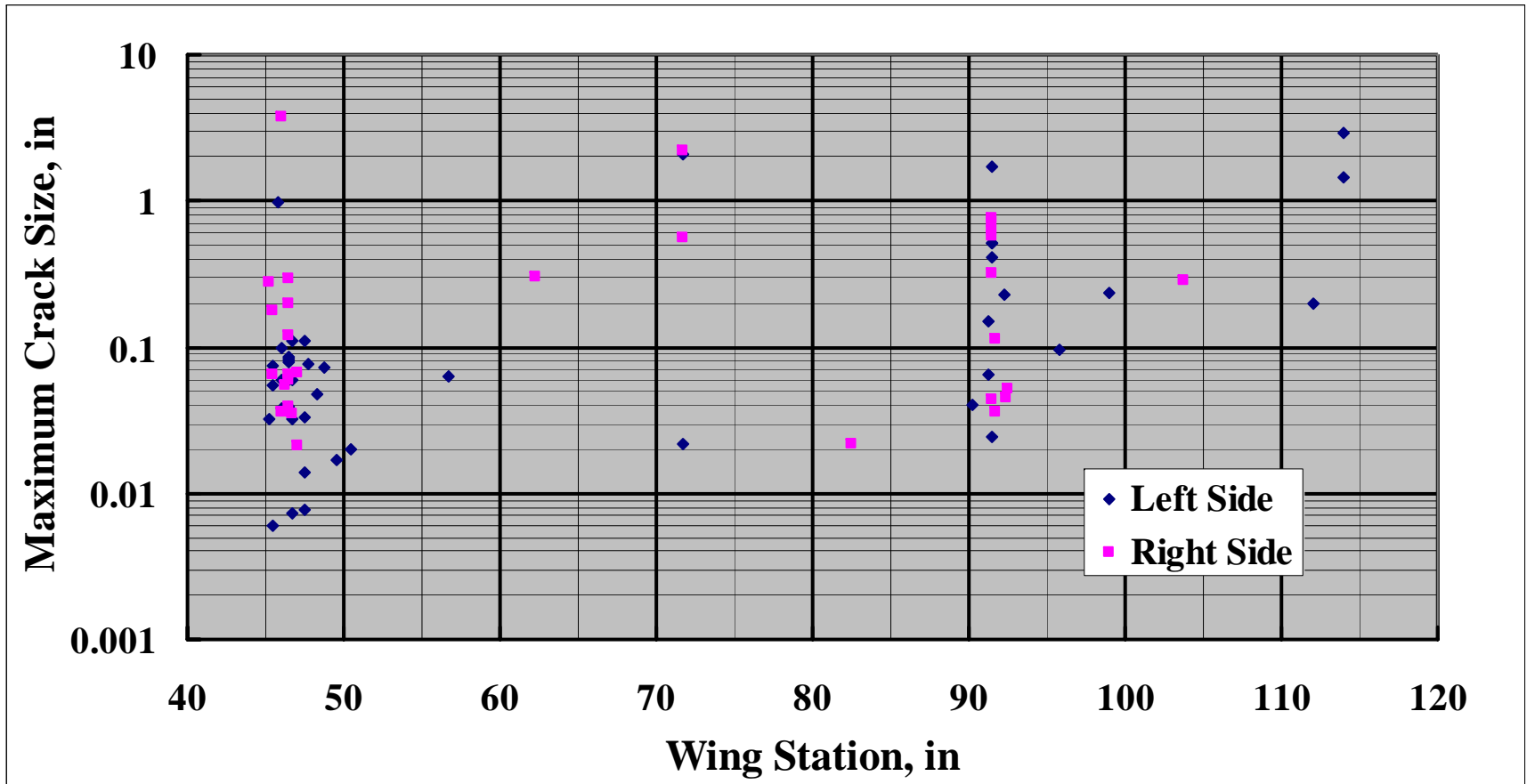


query example: corrosion FS vs. WS location





query example: crack size vs. WS location





Conclusions & Recommendations



- **Most complete inspection of T-37B structure to date**
 - 4 wing sets
 - 429 NDI indications
 - 283 detailed metallurgical evaluations
- **Data used with other sources for fleet management**
- **Findings at DTA locations**
 - Compare to predictions
 - Assess the validity of those predictions
- **Corrosions findings**
 - Evaluate impact to structural strength
 - Evaluate corrosion prevention and control program

- Indications from TO 1T-37B-36 inspections
 - Data to help assess inspections
 - Actual results compared to indication
- Compare to findings from FY07 program





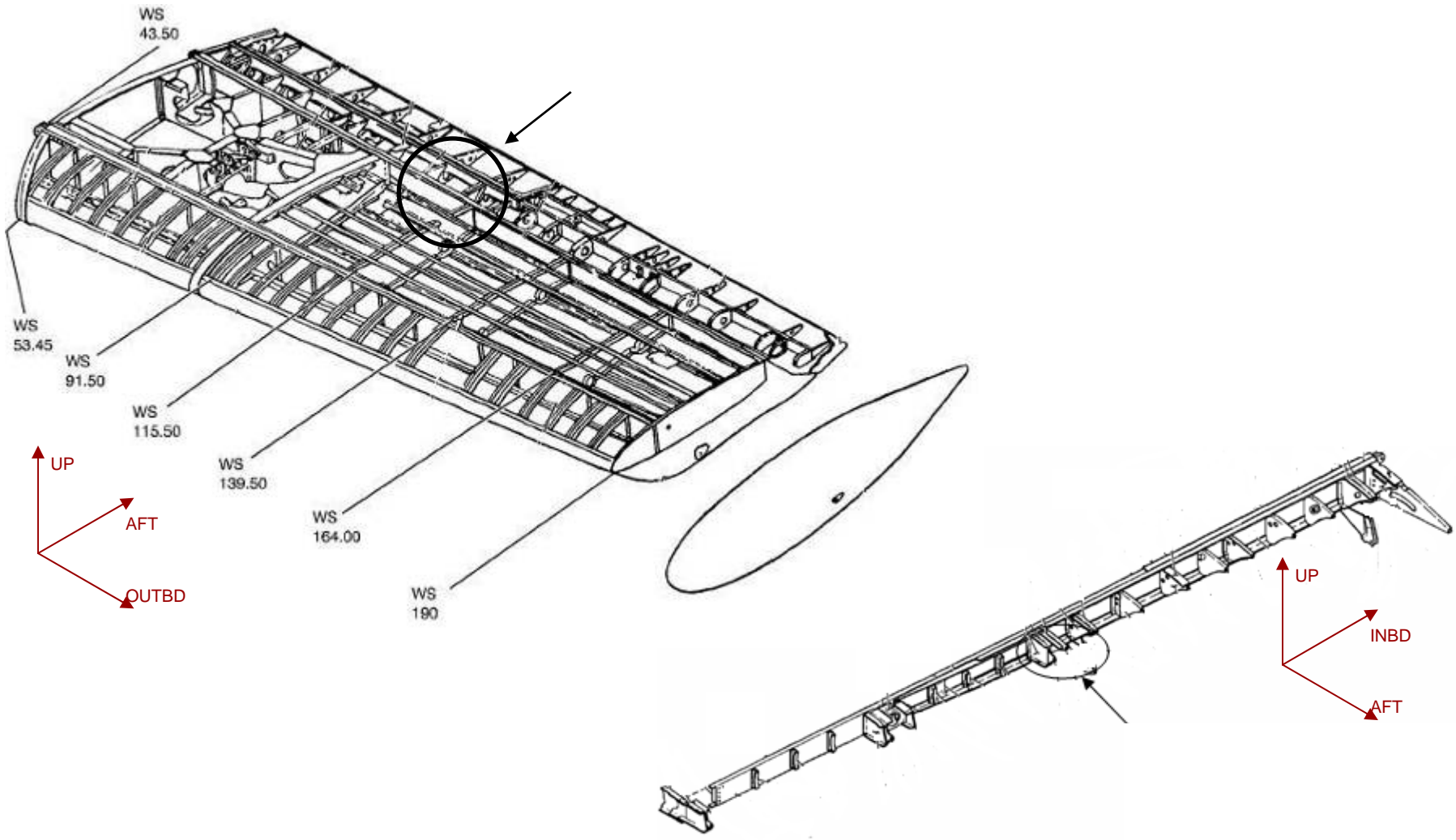
Fleet Impact



Fleet Impact lower rear spar cap



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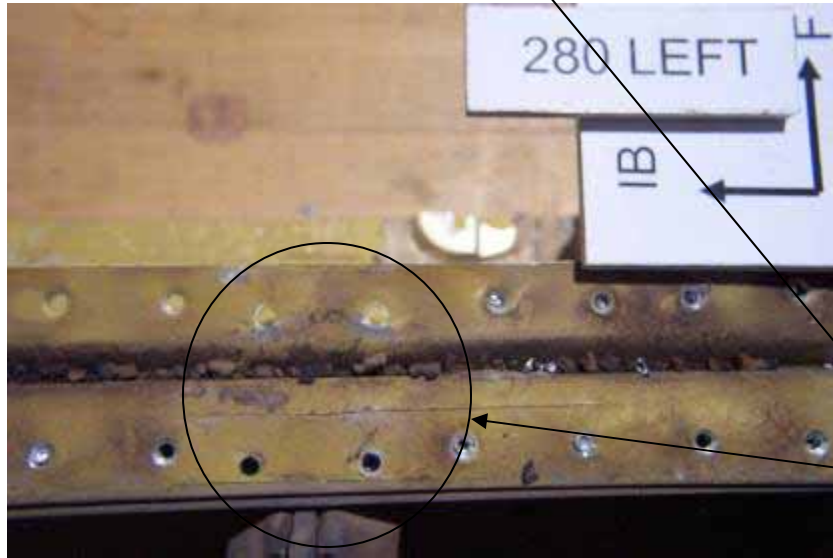
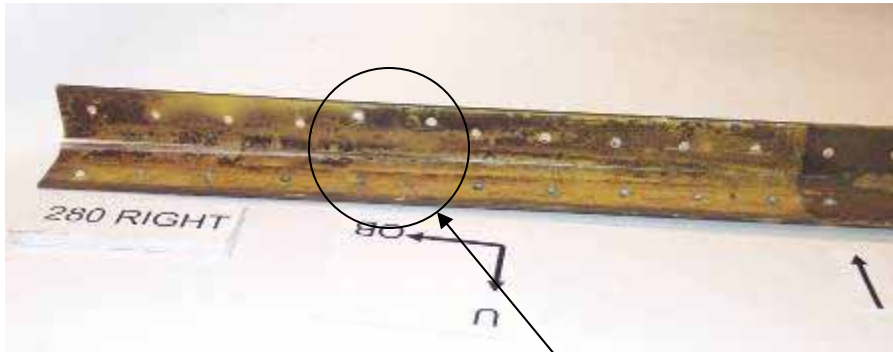




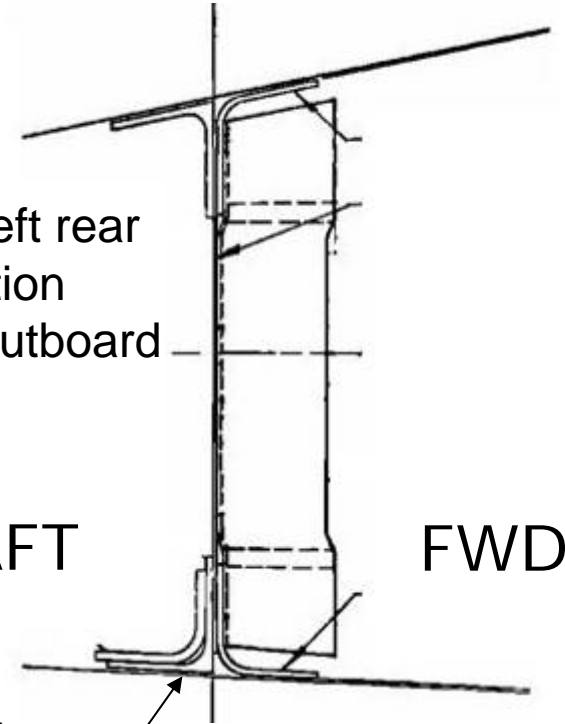
Fleet Impact lower rear spar cap



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View of left rear
spar section
looking outboard



Crack location on
horizontal flange

Location of outboard flap
attachment fitting – WS111.5



Fleet Impact

lower rear spar cap



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- **Spanwise cracks in the Lower Rear Spar Cap Aft Extrusion Angle (AL 7075-T6 Alloy) between WS105 and WS117**
 - Failure analysis and fractography determined cause of crack to be **STRESS CORROSION (SC)**
 - No past projects (202's, 107's, etc.) found dealing with cracking in this area – We've never inspected in this area before
- **FY05 Wing Teardown inspected 4 high time wings**
 - L/H Crack approx. 12" (centered on flap fitting attachment)
 - R/H Crack approx. 6" (centered on flap fitting attachment)
 - Sheppard AFB
- **FY06 Wing Teardown inspected 4 high time wings (3 included area of interest)**
 - L/H Crack approx. 3" (at outboard end of extrusion)
 - Randolph AFB



Fleet Impact

lower rear spar cap



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- **Presence of SC Cracks and Crack Growth Rates are difficult to predict**
 - Influence of time on crack presence/growth is small – one aircraft had ~22000 hrs, the other had ~16000 hrs
 - SCC is not flight hour dependent (there is a time component)
 - Analysis shows a 21 inch SC crack could cause buckling failure
 - Probability is unknown but could be high
- **Important to have data**
 - Thought it was primarily influenced by flap fitting
 - Additional data showed the fitting was not primary driver
- **Presence of SC cracking in this area among the rest of the fleet is unknown**
 - Being treated as a fleet issue – 2 out of 7 planes
- **It is possible that the stress corrosion crack could turn and become a fatigue crack**
 - Probability is very small - but unknown
- **Engineering analysis shows a fatigue crack inboard of WS108 could result in separating a portion of the spar cap**
 - Long crack growth life ~10,000 hrs, to be updated with new DTA FY08



Fleet Impact

lower rear spar cap



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- **X-Ray Inspection**
 - Will be able to see under splice without disassembly
 - Process already validated/verified for FY06 ACI
 - 2.75 hr duration
 - Further val/ver completed on wing section with cracked piece built in – minor mods to process/instructions
 - Done because of suspected POI/POD issues
- **Surface Eddy Current**
 - Surface Eddy Current inspection of spar cap inboard of Splice Overlap (WS105.75) – EC will catch cracks longer than 11”
 - Flap off
 - 1.25 hr duration for disassembly, inspection, reassembly, flap control check
 - Hill NDI did Val/Ver of the inspection process in August '06 at Sheppard AFB
 - Better POI/POD



Fleet Impact

lower rear spar cap



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■ Inspections

- FY06 Analytical Condition Inspection (ACI) of 6 A/C
 - No findings
- Additional recurring -6/-36 TO inspection at next/each PE (500 hrs)
 - No findings to date (large percentage of fleet inspected)

■ Data Collection

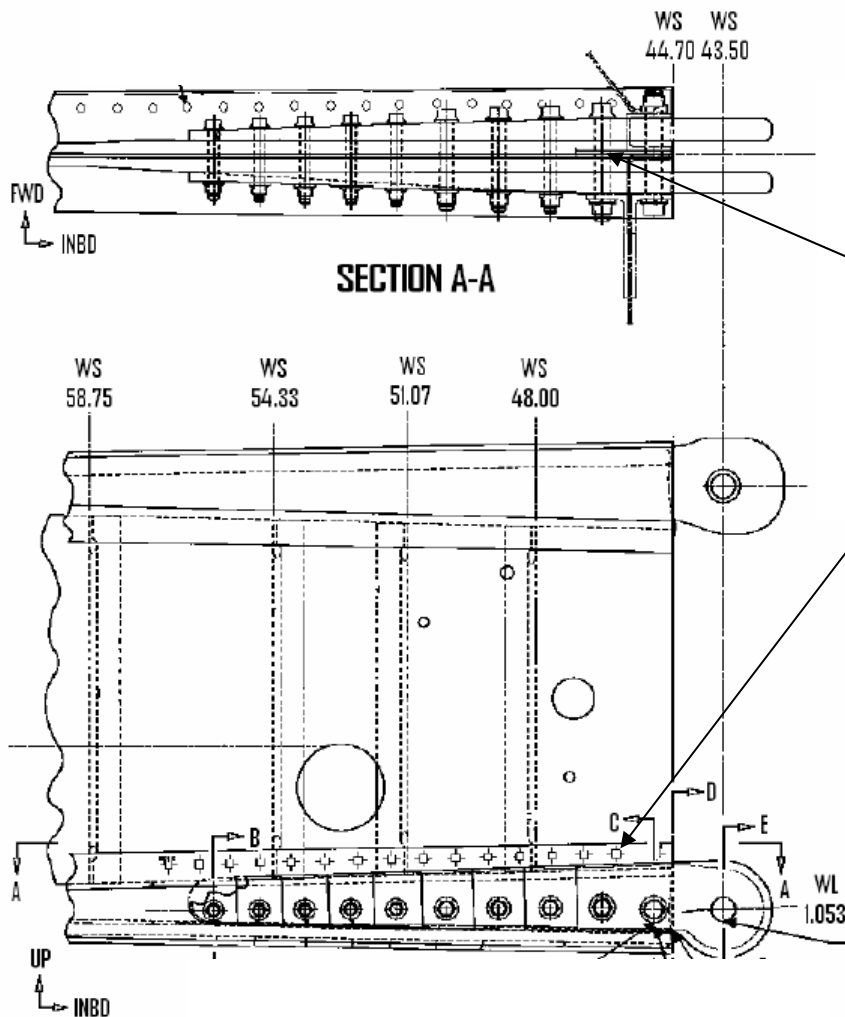
- Entire fleet will be inspected by end of CY07
- 107 process if more cracks found – Repair developed
 - Move to TCTO for inspection of entire fleet within 3 month time period



Fleet Impact lower forward spar cap



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Lower forward spar cap vertical flange web attachment tab cracking location (old Cessna FCL 5B)



Fleet Impact

lower forward spar cap



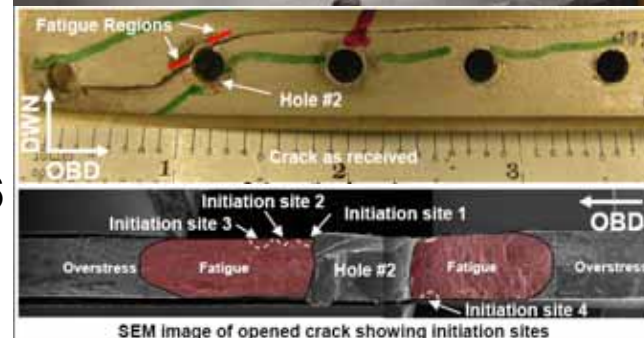
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- One crack found on 2003 teardown
 - Also showed up in fatigue tests
- Found on all planes in FY06 TD and one in FY07 TD
 - 6 out of 12 planes – fleet issue
- Area not inspected in the past
- Cannot be accessed from the leading edge side
- Can be accessed for inspection by eddy current with difficulty from small access panel in landing gear bay
 - Routing of multiple tubes increases difficulty

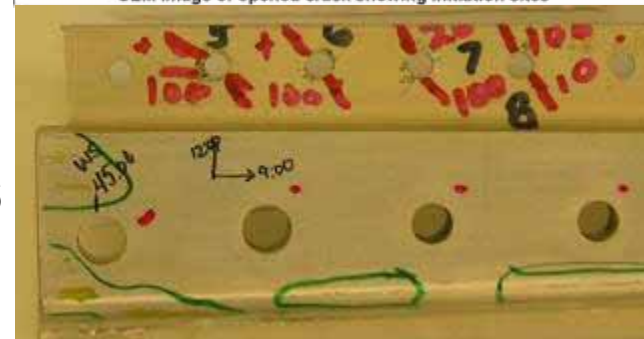
2003



FY06



FY06





Fleet Impact

lower forward spar cap



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- **Result of Web shear load being transferred into fastener bearing & tension of thinner section of vertical flange at attachment holes and fillet radius**
- **Possibly a self arresting crack as it approaches the thicker section of the vertical flange**
 - **Two wing fatigue tests cracked at this location (~1988)**
 - **Crack grew to 4 inches and arrested at second web stiffener**
 - **FY06 teardown crack is identical to this**
- **Crack could turn vertically to sever the spar cap**
 - **Analysis shows positive margin for redundant load path through SLEP steel wing attachment fittings if spar cap should crack vertically**
 - **Crack propagation life is long -- ~30,000 hrs – new DTA w/ FY08 funding**
- **Additional fleet wide inspection at next/each 500 hr PE**
 - **Eddy current around first 4 fasteners and in fillet radius - from aft side through access panel in landing gear bay – 1 hr**
 - **Crack could be detected from the front side once it reaches the radius transition into the thicker section**
 - **Inspection interval to be modified after new DTA**



Fleet Impact

rear spar corrosion



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- **Wing spar corrosion is a major issue**
 - **Rear Spar is primary location**
 - **Material load-bearing cross-section loss**
 - **Developing new visual inspection requirement**
 - **Should only require removal of 3 access panels**
 - **New fleet wide inspection at next/each 500 hr PE**
 - **Findings may require repair or replacement**
 - **Significant corrosion findings from FY07 teardown**
 - **Material loss not as severe as on FY06 teardown**

- **FY07 Teardown revealed a new FCL at aft banjo fitting – empennage attachment to fuselage**



■ Conclusions and Recommendations

- Destructive Teardown Inspections are critical for safe fleet management through to retirement
- Need to examine various locations repeatedly and comprehensively to get breadth and depth of data
- Based on findings, DTA, Risk Assessment:
 - Update active FCLs – add and possibly remove
 - Implement new inspections
 - Modify existing inspections
 - Both methodology and intervals
- Corrosion is a major issue with potential for significant reductions in load-bearing capability
 - Prevention, Inspection, Control, Repairs



Questions?