Candidate Inspection Information for MAPOD Demonstration

Model Assisted POD Working Group Meeting
September 22-23, 2005
Orlando, FL

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

B727 Teardown Database

- "DESTRUCTIVE EVALUATION AND EXTENDED FATIGUE TESTING OF A RETIRED PASSENGER AIRCRAFT (B727)"
- FAA R&D Contract No. DTFA03-02-C-00044
- Retired Delta 727-200 fuselage
- The objectives are:
  - **Assess the capabilities** of existing and emerging NDT methods
  - **Characterize the multiple site damage (MSD)** in fuselage
  - **Increase/induce the MSD** in selected sections through extended fatigue testing
  - **Develop analysis methods** that predict the state of MSD at any point in time
  - **Create searchable database** and distribute for public use

Acknowledgements

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FAA AANC (Sandia)

David Moore, Floyd Spencer

Gov't, academia, industry partnership

Program Overview/Outline

Background and Preparation
- Selection of Aircraft/Areas
- Aircraft Information Report
- Specimen Removal & Test Plan

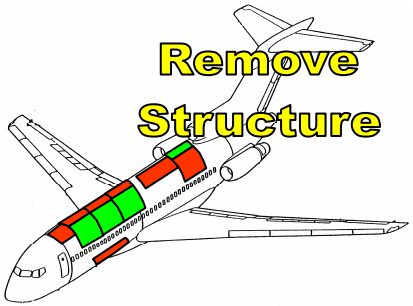
Inspection Capability Assessment
- Conduct Field Inspection
- Conduct Post Removal Inspection
- Emerging NDT
- Assess Inspection Capability

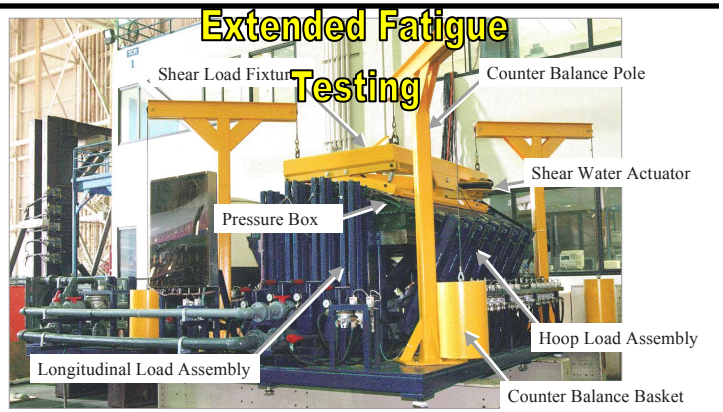
Damage Characterization
- Crack locations/shapes/orientations
- Contributing factors to cracking
- Reconstructed crack histories (SEM)

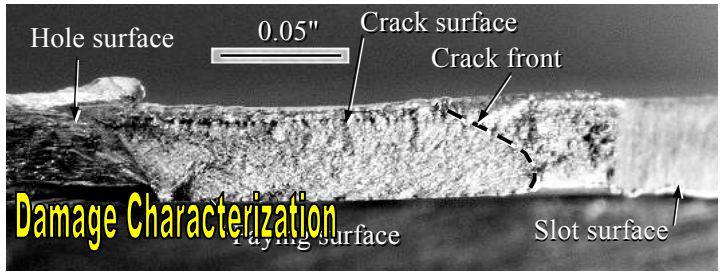
Data Analysis
- Spectra development
- Initial flaw distributions

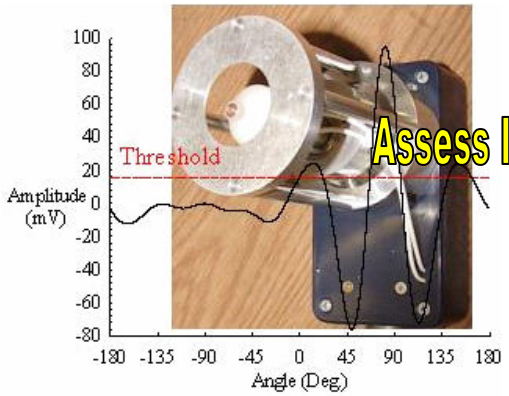
Extended Fatigue Testing
- Preparation of Panels
- Develop Test Plans
- Conduct Fatigue Tests

Documentation and Database





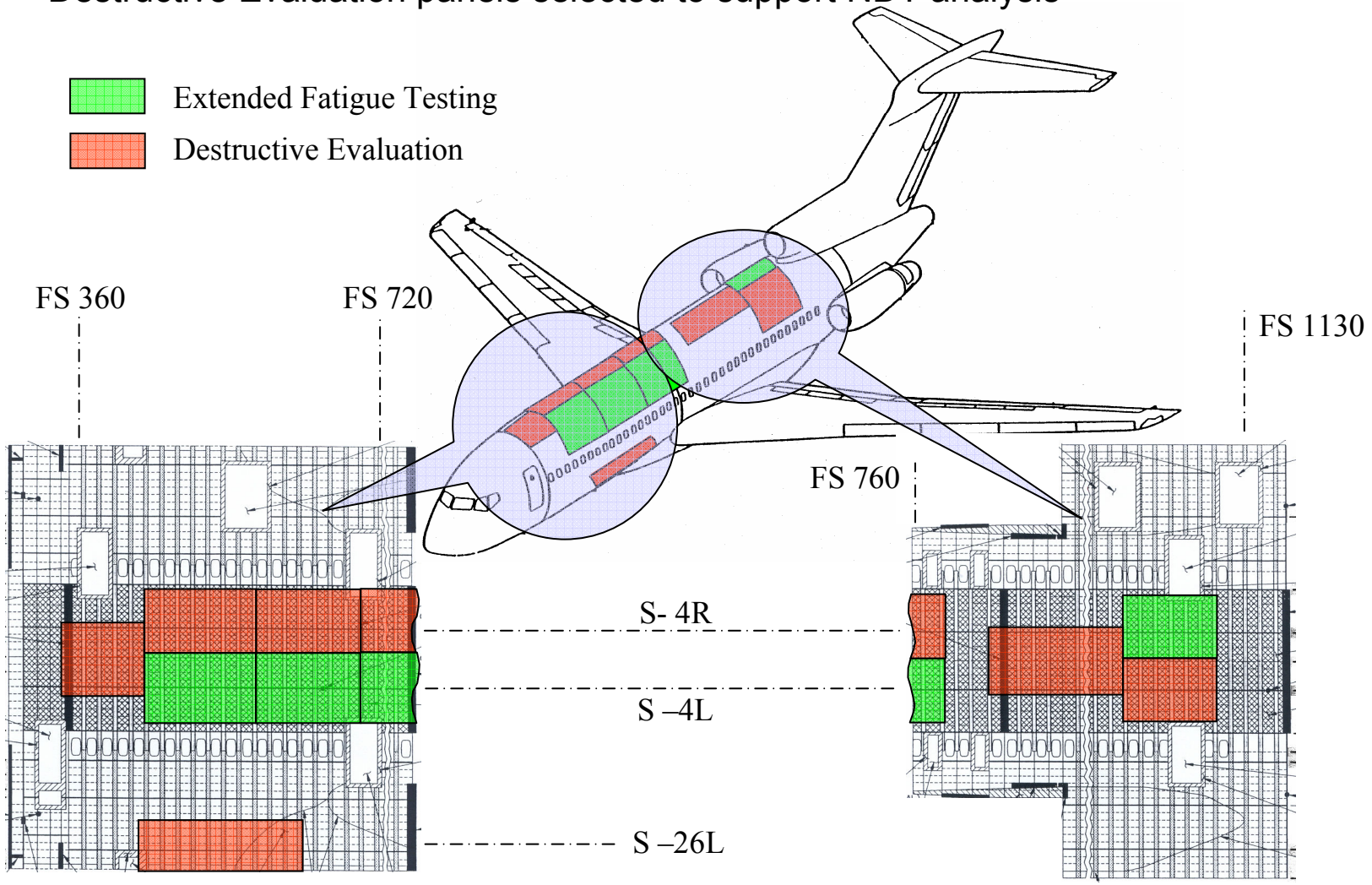




NDT = only a portion of project scope

Selection of Areas

- Extended Fatigue Test panels showed no NDT indications
- Destructive Evaluation panels selected to support NDT analysis

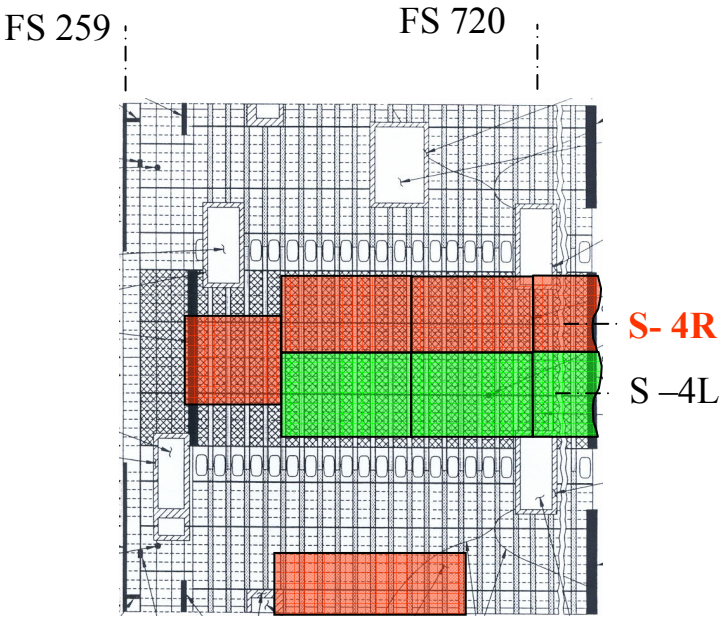


NDT Results drove panel selections

Initial Findings using Conventional NDT

- Number of fasteners with crack indications using MFEC, LFEC and DVI

	Field Inspections			Post Removal Inspections		
Stations	MFEC	LFEC	DVI	MFEC	LFEC	DVI
420-440	1	0	0	1	0	0
440-460	1	0	0	1	0	0
480-500	1	1	0	0	1	0
500-520	3	0	1	7	0	1
520-540	8	4	6	8	4	6
540-560	12	1	10	11	2	10
560-580	6	0	1	12	0	1
580-600	10	0	0	13	0	0
600-620	5	2	3	4	2	0
620-640	5	0	5	6	0	5
640-660	0	0	0	2	0	0
660-680	4	1	0	2	0	0
680-700	1	1	0	1	0	0
700-720	6	0	0	8	0	0
720-720A	9	2	3	9	3	3
720A-720B	8	1	0	8	1	0
720B-720C	13	4	0	14	5	0
720C-720D	4	1	0	5	1	0
720D-720E	3	0	1	3	0	2
720E - 720F	0	0	0	1	0	0
Totals	**100**	**18**	**30**	**116**	**19**	**28**



Conclusion: Field and Post-removal results are the same;

Candidate A/C was good selection

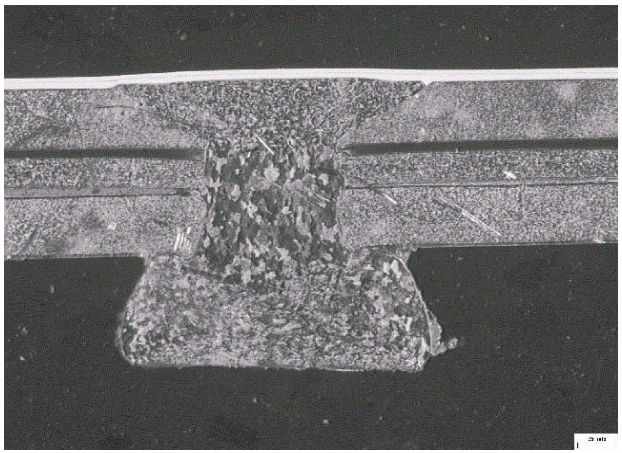
Emerging NDT

- 20 techniques evaluated; 2 techniques declined participation
- Collaboration of Delta, FAA-AANC, FAA-TC, Boeing selected methods

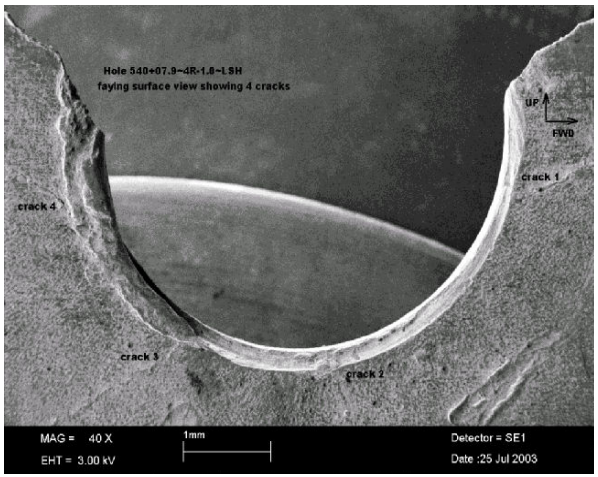
Technology	Company
Detailed Visual	Generally accepted practices
Low Frequency Eddy Current (LFEC) Sliding Probe	Boeing NDTM
Medium Frequency Eddy Current (MFEC)	Boeing NDTM
Automatic Couplant Ejection System (ACES)	SAIC
C-Scan Eddy Current with Sliding Probe	Delta Air Lines
Conventional Film Radiography	Generally accepted practices
Digital Radiography	Virtual Media Imaging (VMI)
Eddy Current Array Probe	R/D Tech
Eddyscan	Nortec (Staveley)
Giant Magnetoresistive Sensor (GMR)	NASA Langley
High Frequency Ultrasonic Array	USUT Labs
Magneto Optical Imaging (MOI)	PRI
MAUS Trescan	NDT Solutions
MAUS Rotoscan	Boeing, St. Louis
Mobile Automated Scanner (MAUS) Rasterscan	Boeing, St. Louis
Meandering Winding Magneometer (MWM) sensor	Jentek
Remote Field Eddy Current	IMTT
Self-Nulling Rotating Probe (Rivet Check)	Foerster & FAA AANC
Structural Anomaly Mapping (SAM)	Honeywell
Turbo Magneto Optical Imaging (MOI)	PRI & Boeing, Seattle

Variety of NDT Techniques explored, compared to current NDT

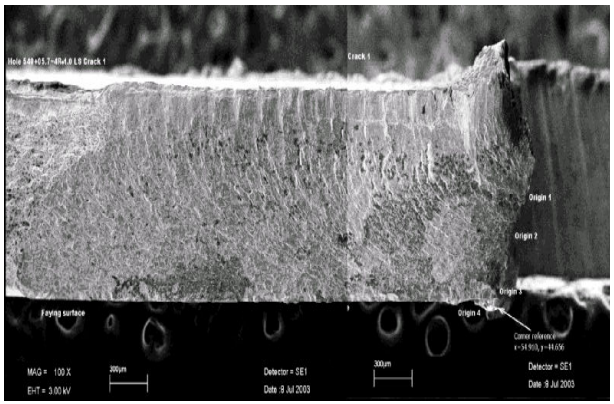
Damage Characterization



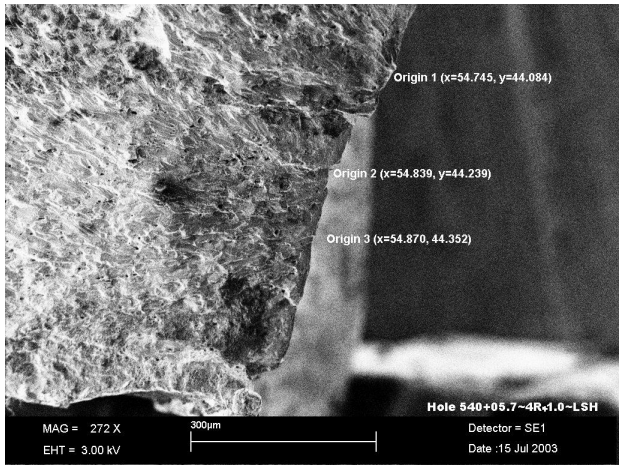
Stereo-micrograph of typical rivet cross-section



Typical stereo-micrograph of faying surface showing multiple cracks



Fractograph mosaic of fracture surface



SEM fractograph of crack origins near hole corner

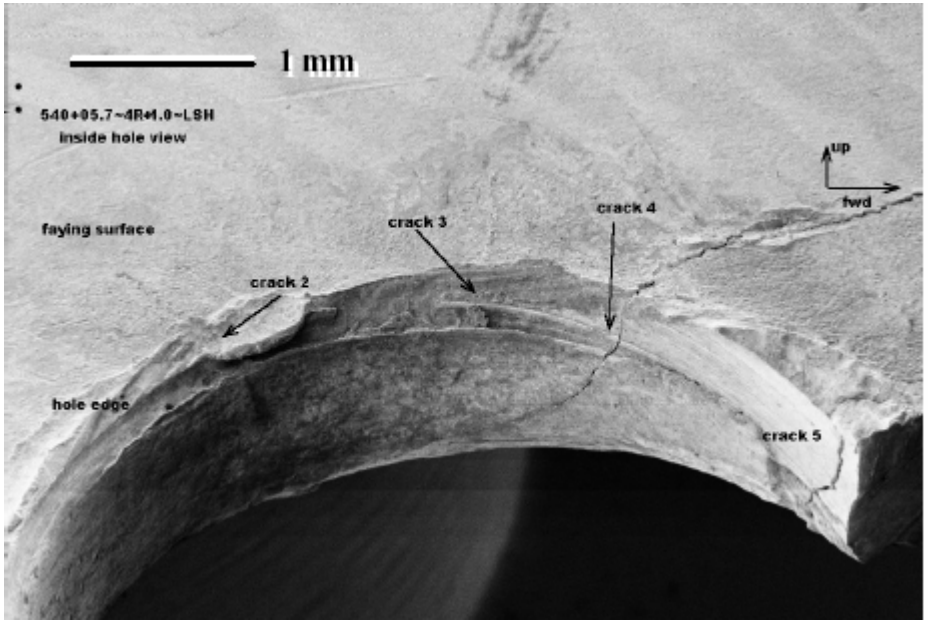
The objective is to characterize the state of damage at DSG.

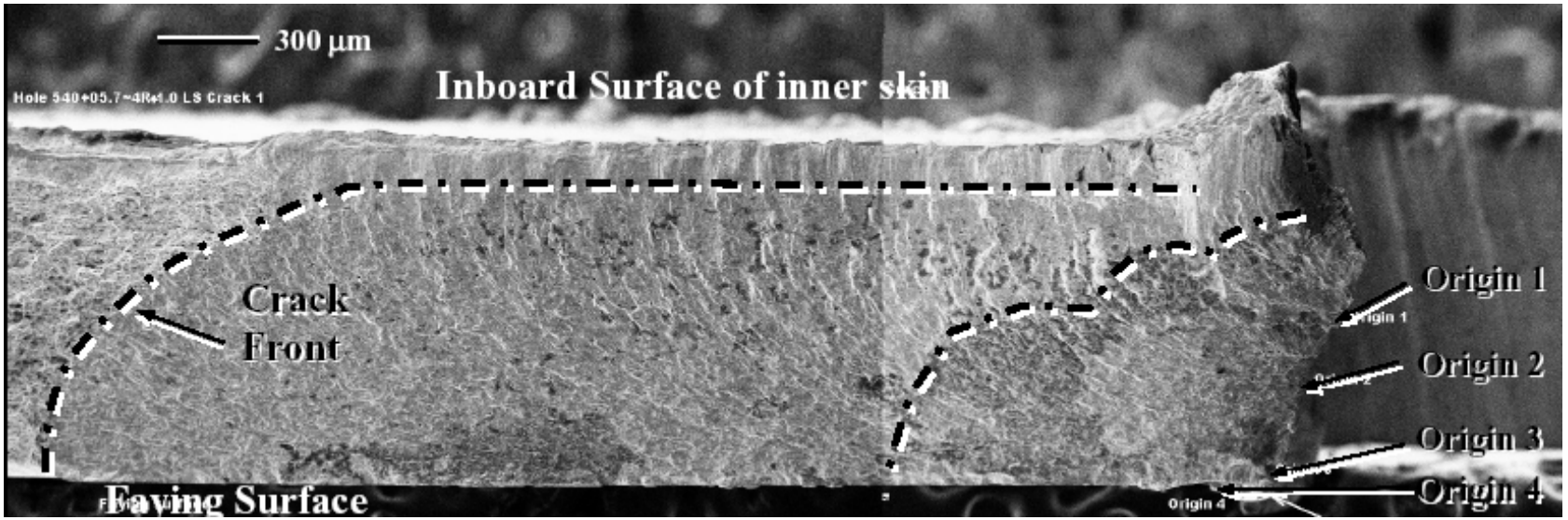
- Destructive evaluation of over 150 fastener sites, including the NDT indications.
- Accomplished crack length vs flight cycle reconstruction on 50 cracks using SEM.
- Have measured parameters for crack initiation model, e.g driven head size, hole quality, crack length and direction.

Microscopic examination of damage at Design Service Goal

Damage Characterization

- Characterization of cracks along 4R:
  - Multiple cracks forming a starburst
  - Multiple crack origins: rivet hole and faying surface
  - Eventually form a contiguous crack
  - Crack tunneling under clad layer
- Effect on NDT:
  - Internal Visual/HFEC methods would not detect until breakthrough (0.250-0.300”)
  - Consistency of sealant between layers

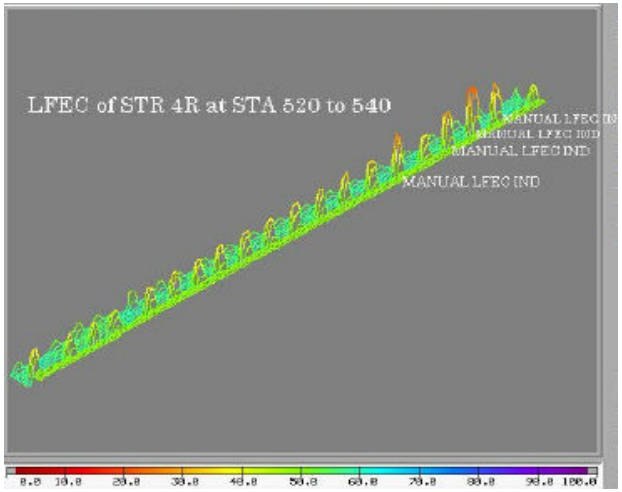




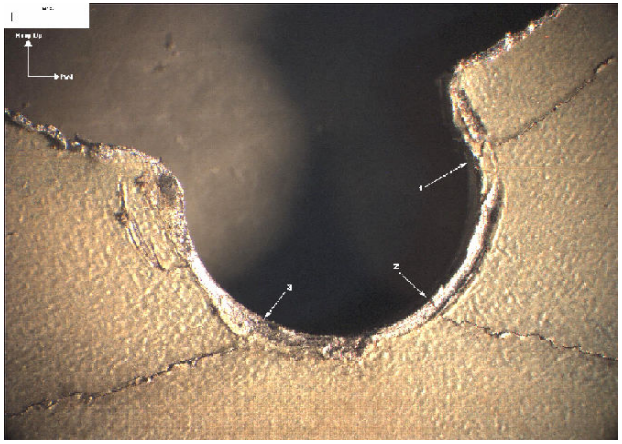
Findings significantly affect NDT Inspections

Inspection Capability Assessment

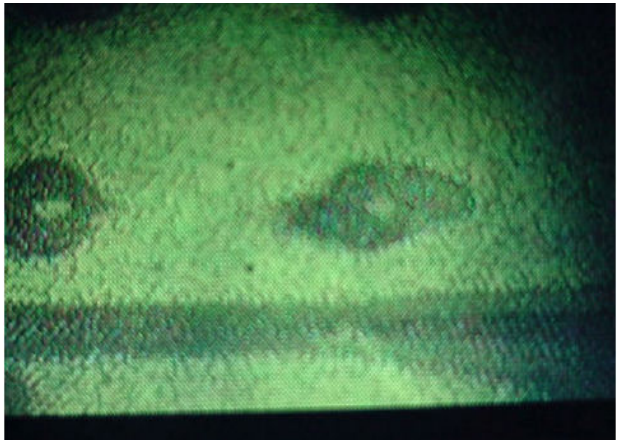
External MOI NDT under controlled conditions after panel removal.



Lower row S-4R cracks as depicted by an emerging NDT method - external LFEC on SAIC automated scanner.



Microscopic examination of cracking during Damage Characterization.



Lower row S-4R cracks as depicted by an emerging NDT method - external MOI.

The objective is to assess the capabilities the selected NDT used in this study to find and characterize damage.

- Results of the Field and Pre-Teardown inspections to be compared to crack measurements from Damage Characterization.
- Developed system to rate emerging NDT's readiness for airline use.

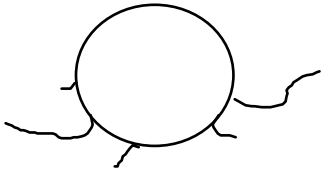
Combining Damage Characterization and NDT results

Factors Affecting POD Analysis

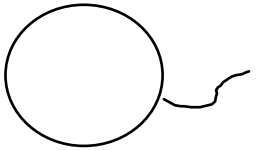
- Inspection Sites or “Opportunities”

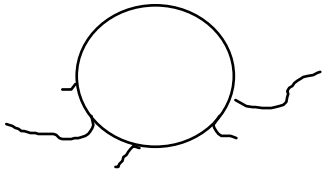
Actual D/C Results

NDT Analysis

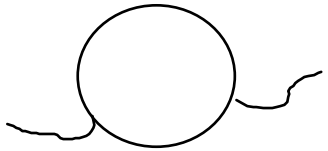


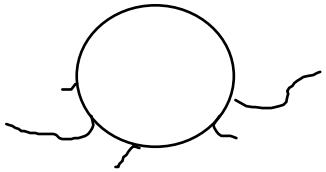
“Single opportunity” = One crack on one side of fastener



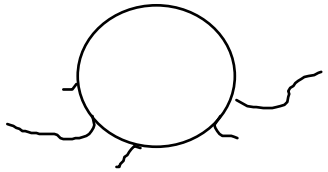


“Two opportunities” = Largest crack on each side (fwd/aft) of fastener



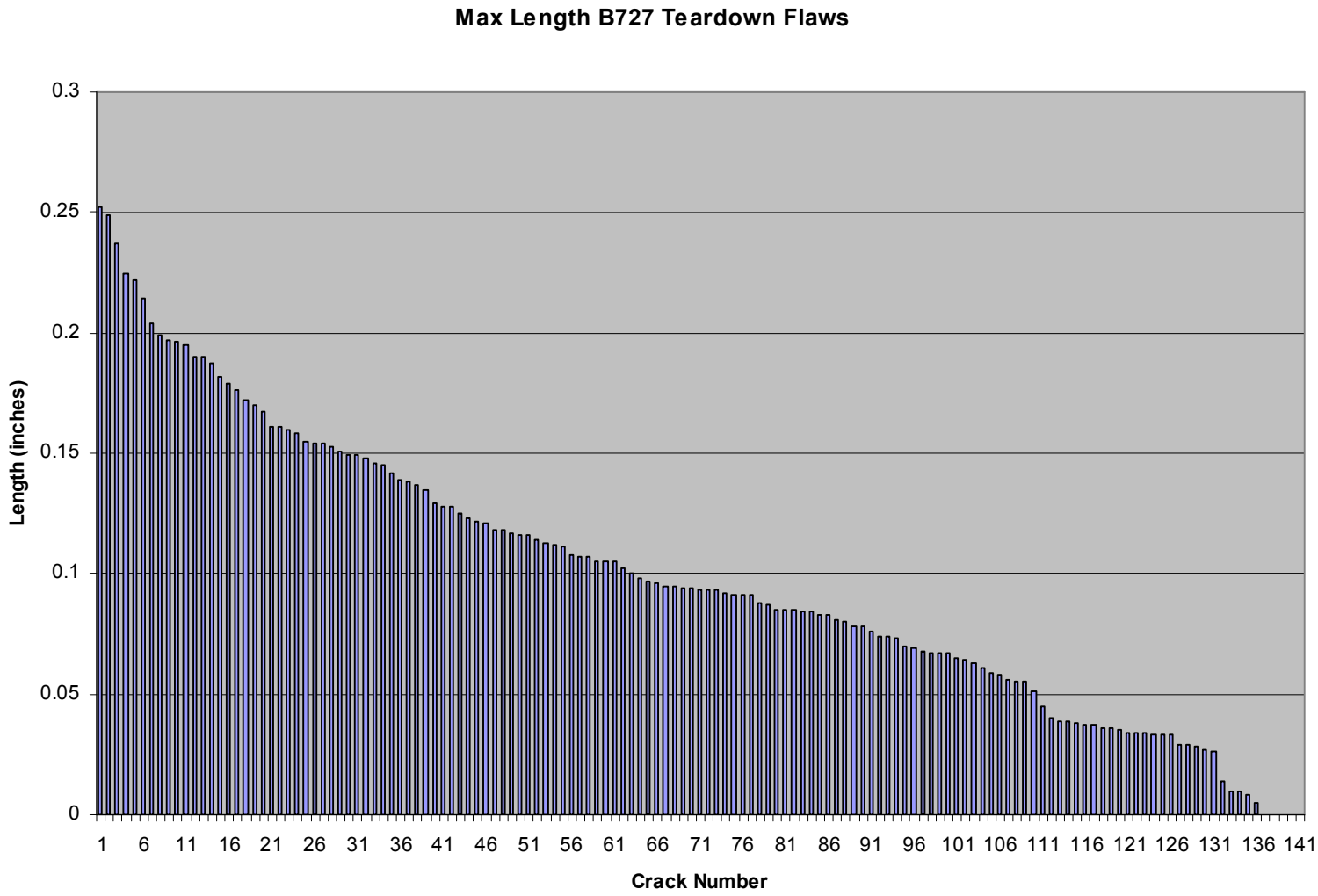


Multiple Opportunities = All cracks counted



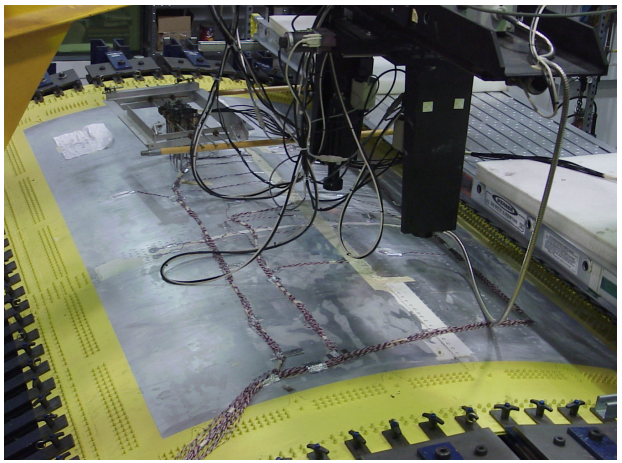
Definition of inspections sites affects POD analysis

Flaw Distribution from B727 Teardown Panels

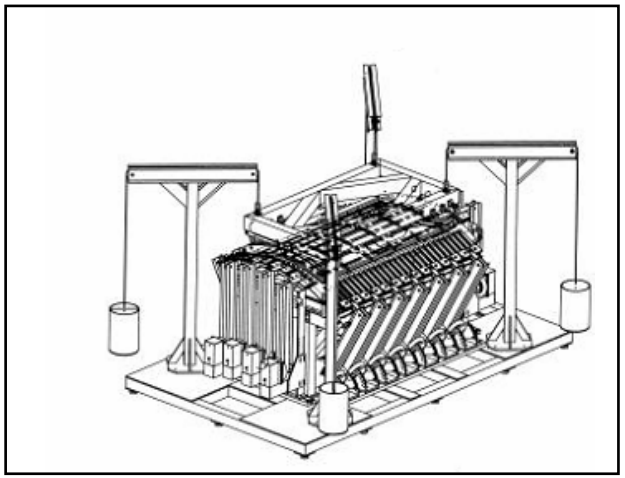


Next Steps: Extended Fatigue Testing on FAA's FASTER

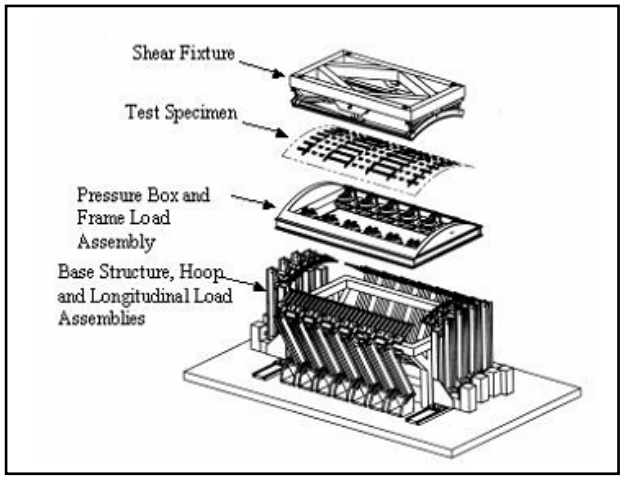
FASTER fixture prior to panel installation. Shows top of pressure box, hoop loader, and shear fixture counterweight frames



FT2 test panel installed. Remote external cameras shown. Remote internal underwater camera is also in use



Panel installed with shear fixture



Exploded view

The objective is to continue the growth of MSD in a realistic way.

- FASTER applies internal pressure, plus hoop, longitudinal, and shear loads to curved panel test article made from crown.

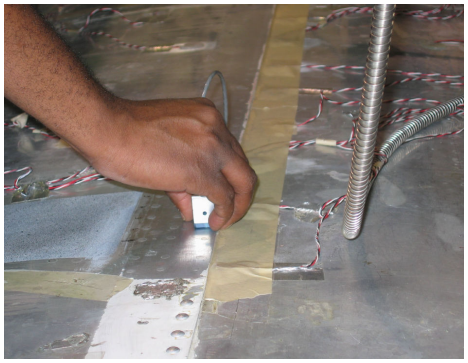
Test will provide:

- Crack initiation and growth rates, link-up.
- Critical MSD distribution when FAR's not met.
- Cycles from conservative analytical failure criteria to actual failure.

Unique machine used to simulate additional service cycles

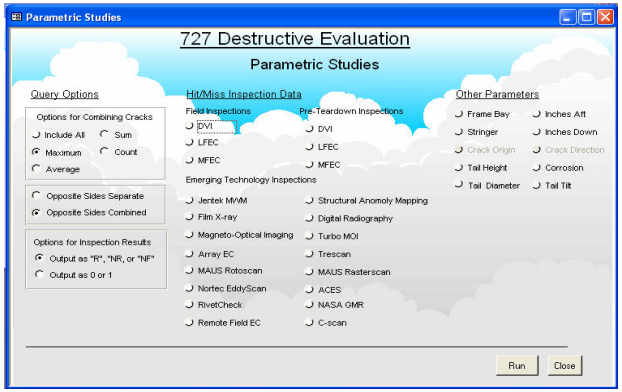
Next Steps: FASTER NDT Test Support

- NDT support of FASTER testing includes both “Standard” and “Emerging” methods
  - Standard: DVI (internal/external), External LFEC, Internal MFEC, Internal HFEC (clips)
  - Emerging: Rivetcheck, MOI, Jentek MWM, USUT in use as Emerging techniques
    - Selected from ranking on techniques based on inspections in ATL
    - Giant Magnetoresistive Sensor (GMR), Turbo-MOI also chosen for tests; Unavailable for long-term use
- Inspections support the different phases of FASTER test
  - Initial Crack detection (MSD definition)
  - Crack growth measurements (and monitor new cracks)
- Visual inspections almost daily, NDT weekly
- All data put into database



NDT also an integral part of FASTER testing

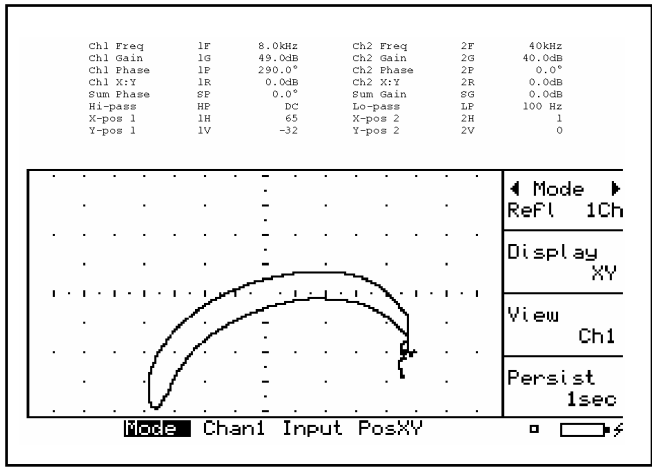
Final Report and Database



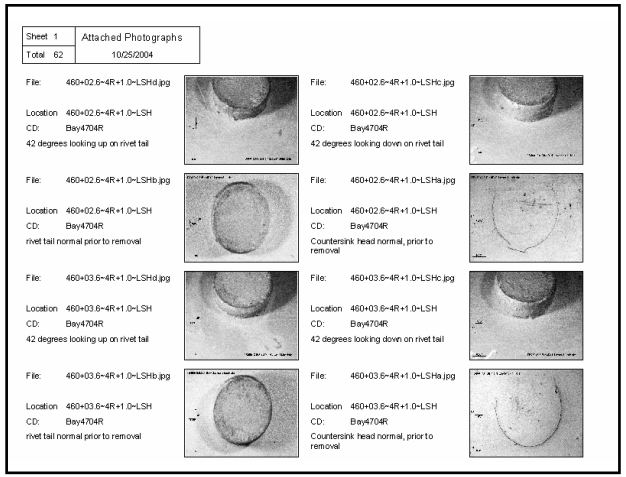
Form to create parametric study

Objective is to catalogue the large volume of data in a useful way.

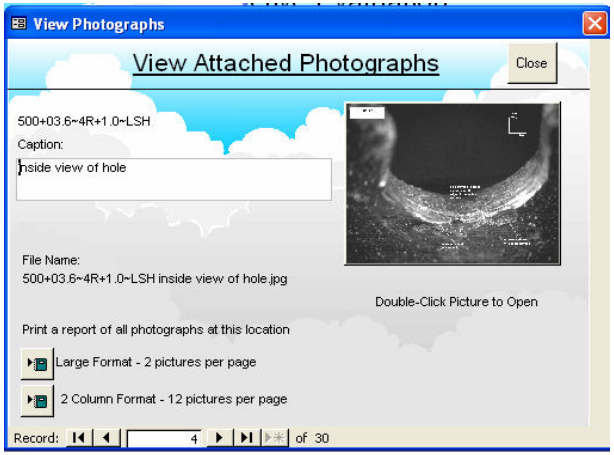
- Data from the quarterly reports combined into a large 5 volume final report.
- MS Access database is best way to capture and distribute data:
  - Captures data relationships between inspection, characterization, and photographs
  - Prefabricated queries and reports
  - Designed for portability, to be distributed in industry



NDT screen capture (signal analysis or a-hat versus a analysis is possible)



Report of photographs from single location



Form to browse graphical results from Boolean search of picture captions

Wealth of data, well organized; Will be made available to the public soon!

Current Status

- FAA and Delta Airlines have agreed that the MAPOD Working Group is an excellent first use for the B727 Teardown Database
- Delta is performing a quality control check of the database to ensure accuracy of information
- Fatigue Test panel is being processed at FASTER, but no cracks to date
- Beta-test version of Database being reviewed by Sandia/AANC for usability