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Survey of Transport Airplane Structural Repairs, Alterations and Modifications (RAMs)

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Presentation Outline

- Motivation & Outcomes – Support Widespread Fatigue Damage (WFD) Rulemaking
- Review of 1990s Airworthiness Assurance Working Group (AAWG) Repair Survey (tasked by the Aviation Rulemaking Advisory Committee (ARAC))
- Airplane Models and Number of Repairs, Alterations and Modifications (RAMs)
- Data Mining - Service Difficulty Reporting Database
- Field Survey Activities – Process, Schedule, and Status
- Teardown Activities - Process, Schedule, and Status
- Field Survey & Teardown Database - Process, Schedule, and Status
- Questions

Project Motivation

- Goal: provide data to better understand the risks that Repairs, Alterations and Modifications (RAMs) may pose for developing widespread fatigue damage (WFD).
- Widespread Fatigue Damage (WFD)
  - Simultaneous cracks
  - Multiple (repeating) structural locations
    - Multiple Site Damage (MSD)
    - Multiple Element Damage (MED)
  - Sufficient size and density so structure can no longer carry load
- WFD Rule - Notice of Proposed Rulemaking issued April 2006
  - Requirement for design approval holders to evaluate baseline airplane structure and certain repairs, alterations, and modifications for WFD
  - Public comments suggest RAMs should be removed
  - No recorded accidents attributed to WFD in properly installed RAMs
  - Adverse service experience limited to baseline airplane structure
  - Aging Airplane Safety Rule & Damage Tolerance Data for Repairs and Alterations Rule requires surveys and damage tolerance evaluations be performed on RAMs

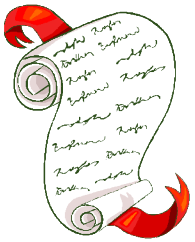
Project Motivation

- General agreement among industry stakeholders - low risk of WFD occurring in RAMs
- FAA determined WFD assessments should focus on baseline structure only
  - Establishing a limit of validity (LOV) of the engineering data
  - LOV supports the structural maintenance program for airplane models
- This and other changes are described in a technical document that was published in the Federal Register on November 7, 2008
- The FAA is further assessing whether additional regulatory actions are needed to address RAMs that may pose a risk of developing WFD
- This Survey of RAMs is providing data to support FAA WFD rule making

Expected Outcomes of the Current RAMs Survey

1. Determine the (average) number of RAMs per airplane
2. Determine the size(s) of repairs.
3. Determine the average age of each RAM (relative to design service goal).
4. Determine the location of each RAM (relative to fatigue sensitivity).
5. Determine the source of RAM data (Structural Repair Manual, Designated Engineering Representative or Manufacturer Engineering).
6. Determine the reason for each RAM (i.e. the causal factor).
7. Determine if any subsequent damage occurred (especially fatigue cracking).

Project Tasking

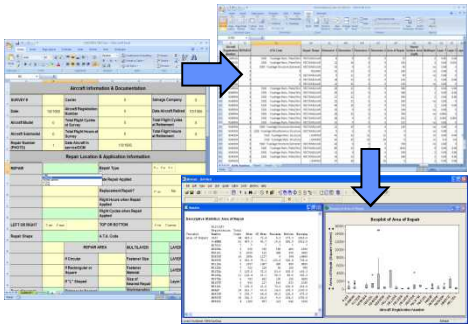


Task 1. Work Plan and Review Prior AAWG Survey

Task 2. Survey Aviation Safety Data

Task 3. Field Survey of Repairs, Alterations & Modifications

Task 4. Teardown Inspections of Retired Repairs, Alterations & Modifications



Task 5. Documentation and Database Development

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Review of Past AAWG Repair Survey

- The AAWG conducted a focused survey of repairs placed on airplanes
  - 1992 Fuselage Repair Survey of Stored Airplanes
  - 1994 Repair Survey of In-service Airplanes
  - Final Report published on 12/12/1996
  - Surveys performed by OEM, Operator & FAA personnel

- Quick external only survey that placed each repair into Category A, B or C
  - Category A: A permanent repair for which the baseline zonal inspections are adequate to ensure continued airworthiness (inspectability) equivalent to unrepaired surrounding original structure.
  - Category B: A permanent repair that requires supplemental inspections to ensure continued airworthiness.
  - Category C: A temporary repair that will need to be reworked or replaced prior to an established time limit. Supplemental inspections may be necessary to ensure continued airworthiness prior to this limit.

AAWG Fuselage Repair Survey Statistics

AIRPLANE MODEL	AIRPLANES SURVEYED ('92/'94/TOTAL)	REPAIR CLASSIFICATION		
		REPAIRS REQUIRING NO ADDITIONAL ACTION (CATEGORY A) ('92/'94/TOTAL)	REPAIRS REQUIRING SUPPLEMENTAL INSPECTIONS (CATEGORY B OR C) ('92/'94/TOTAL)	TOTAL REPAIRS SURVEYED ('92/'94/TOTAL)
727	6 / 7 / 13	39 / 100 / 139	66 / 109 / 175	105 / 209 / 314
737	5 / 4 / 9	41 / 17 / 58	49 / 66 / 115	90 / 83 / 173
747	2 / 5 / 7	13 / 37 / 50	32 / 130 / 162	45 / 167 / 212
DC-8	0 / 3 / 3	0 / 56 / 56	0 / 43 / 43	0 / 99 / 99
DC-9	6 / 4 / 10	21 / 37 / 58	32 / 16 / 48	53 / 53 / 106
DC-10	0 / 4 / 4	0 / 12 / 12	0 / 21 / 21	0 / 33 / 33
A-300	9 / 0 / 9	17 / 0 / 17	18 / 0 / 18	35 / 0 /35
L-1011	2 / 0 / 2	12 / 0 / 12	16 / 0 / 16	28 / 0 / 28
F-28	0 / 8 / 8	0 / 10 / 10	0 / 41 / 41	0 / 51 / 51
TOTAL	30 / 35 /65	143 / 269 / 412	213 / 426 / 639	356 / 695 / 1051

AAWG Repair Survey Summary & Conclusions

- Survey was based on AAWG Repair Criteria with OEM size & proximity limits
- Teams inspected 65 airplanes
- Teams inspected 1051 repairs (40% Category A & 60% Category B/C)
- Repairs general of good quality and done per the SRM
- Category B/C repairs mostly due to size/proximity criteria

- Confirmed need for Repair Assessment Evaluations (current RAP programs)
- No immediate repair safety concerns observed
- Operators needed repair assessment procedures from OEMs
- Older airplanes generally have more repairs
- Repair assessment training needed for operators & FAA PMIs
- Majority of repairs on the fuselage pressure shell

Objectives of AAWG Repair Survey

SCOPE OF REPAIR SURVEYS

- External visual observation of external lower fuselage plating repairs.
- Inspections designed to be conducted quickly, with no more than a work stand and light.
- Repairs which clearly do not meet existing Structural Repair Manual guidance will be reported to the operator.

PURPOSE OF REPAIR SURVEYS

- Gain first-hand observations of typical repairs.
- Sample of numbers, types, proximity, condition of repairs, etc.
- Identify SRM quality repairs that may require additional attention to ensure continued airworthiness.
- Observe any repairs which are below SRM standards.
- Develop a qualitative opinion of the team's concern for repairs as a safety issue, if any.

DISPOSITION OF SURVEY FINDINGS

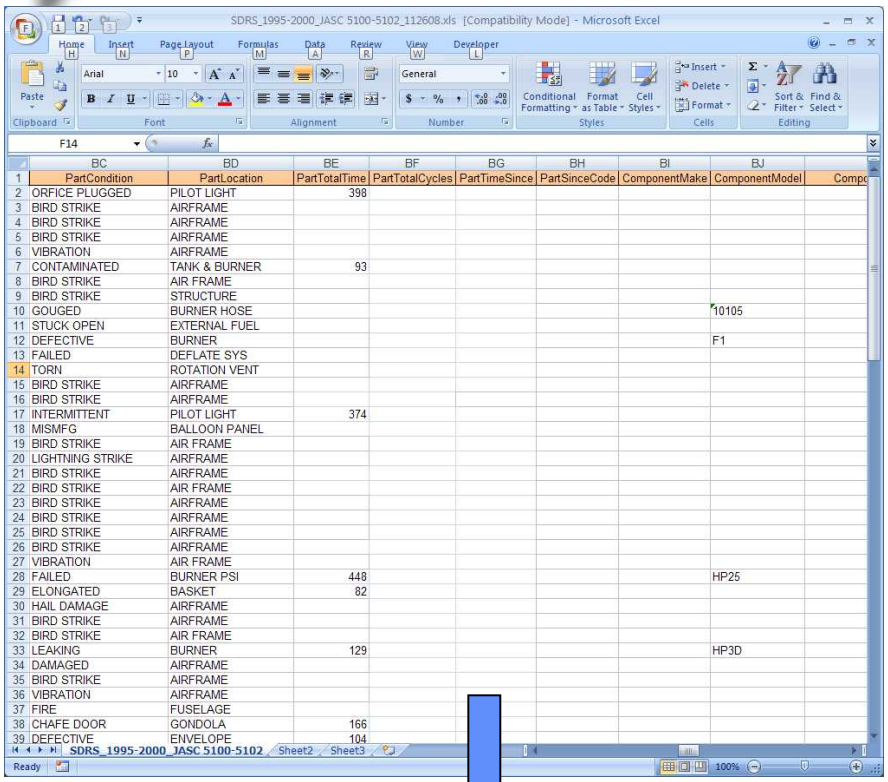
- Document the observations in a standard way that can be combined for all OEMs.
- Make recommendations for further effort as appropriate.

Objectives of Current RAMs Survey

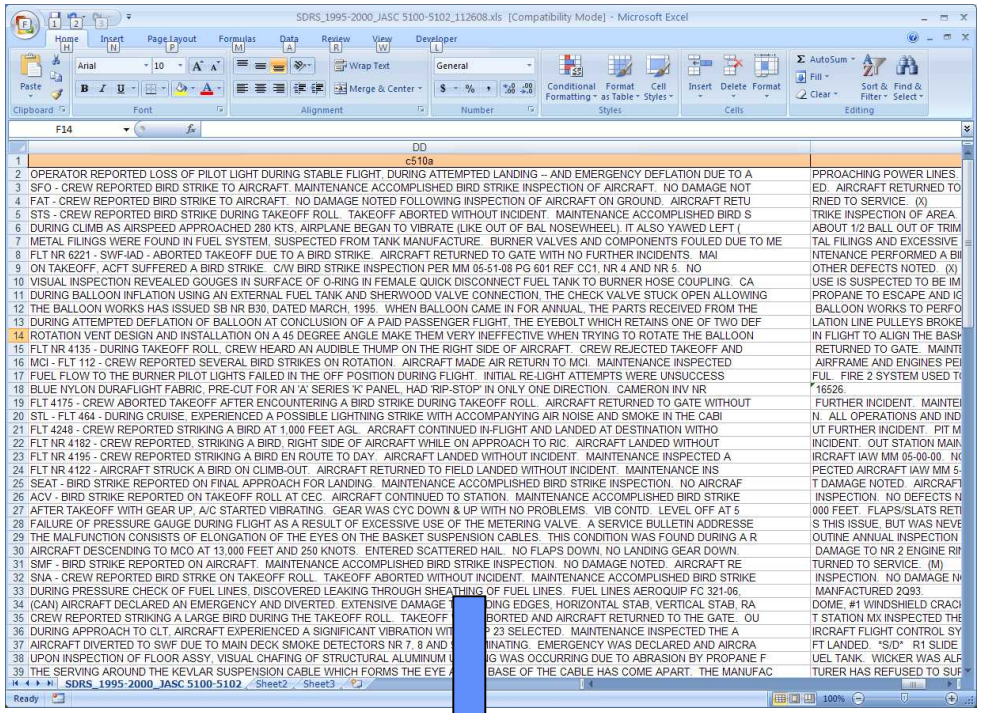
- **Determine if there is a risk of WFD occurrence associated with RAMs**

- Determine the average number of RAMs per airplane
- Determine the size(s) of repairs.
- Determine the average age of each RAM relative to design service goal.
- Determine the location of each RAM (relative to fatigue sensitivity).
- Determine the source of RAM data (SRM, DER, ECO?).
- Determine the reason for each RAM (i.e. the causal factor).
- Determine if any subsequent damage occurred (especially fatigue cracking).

Survey of Service Difficulty Reporting Database



	BC	BD	BE	BF	BG	BH	BI	BJ
1	PartCondition	PartLocation	PartTotalTime	PartTotalCycles	PartTimeSince	PartSinceCode	ComponentMake	ComponentModel
2	ORFICE PLUGGED	PILOT LIGHT	398					
3	BIRD STRIKE	AIRFRAME						
4	BIRD STRIKE	AIRFRAME						
5	BIRD STRIKE	AIRFRAME						
6	VIBRATION	AIRFRAME						
7	CONTAMINATED	TANK & BURNER	93					
8	BIRD STRIKE	AIR FRAME						
9	BIRD STRIKE	STRUCTURE						
10	GOUGED	BURNER HOSE						10105
11	STUCK OPEN	EXTERNAL FUEL						
12	DEFECTIVE	BURNER						F1
13	FAILED	DEFLATE SYS						
14	TORN	ROTATION VENT						
15	BIRD STRIKE	AIRFRAME						
16	BIRD STRIKE	AIRFRAME						
17	INTERMITTENT	PILOT LIGHT	374					
18	MISMFG	BALLOON PANEL						
19	BIRD STRIKE	AIR FRAME						
20	LIGHTNING STRIKE	AIRFRAME						
21	BIRD STRIKE	AIRFRAME						
22	BIRD STRIKE	AIR FRAME						
23	BIRD STRIKE	AIRFRAME						
24	BIRD STRIKE	AIRFRAME						
25	BIRD STRIKE	AIRFRAME						
26	BIRD STRIKE	AIRFRAME						
27	VIBRATION	AIR FRAME						
28	FAILED	BURNER PSI	448					HP25
29	ELONGATED	BASKET	82					
30	HAIL DAMAGE	AIRFRAME						
31	BIRD STRIKE	AIRFRAME						
32	BIRD STRIKE	AIR FRAME						
33	LEAKING	BURNER	129					HP3D
34	DAMAGED	AIRFRAME						
35	BIRD STRIKE	AIRFRAME						
36	VIBRATION	AIRFRAME						
37	FIRE	FUSELAGE						
38	CHAFE DOOR	GONDOLA	166					
39	DEFECTIVE	ENVELOPE	104					



	DD
1	c510a
2	OPERATOR REPORTED LOSS OF PILOT LIGHT DURING STABLE FLIGHT. DURING ATTEMPTED LANDING -- AND EMERGENCY DEFLATION DUE TO A
3	SFO - CREW REPORTED BIRD STRIKE TO AIRCRAFT. MAINTENANCE ACCOMPLISHED BIRD STRIKE INSPECTION OF AIRCRAFT. NO DAMAGE NOT
4	FAT - CREW REPORTED BIRD STRIKE TO AIRCRAFT. NO DAMAGE NOTED FOLLOWING INSPECTION OF AIRCRAFT ON GROUND. AIRCRAFT RETU
5	STS - CREW REPORTED BIRD STRIKE DURING TAKEOFF ROLL. TAKEOFF ABORTED WITHOUT INCIDENT. MAINTENANCE ACCOMPLISHED BIRD S
6	DURING CLIMB AS AIRSPEED APPROACHED 280 KTS, AIRPLANE BEGAN TO VIBRATE (LIKE OUT OF BAL NOSEWHEEL). IT ALSO YAWED LEFT (
7	METAL FILINGS WERE FOUND IN FUEL SYSTEM. SUSPECTED FROM TANK MANUFACTURE. BURNER VALVES AND COMPONENTS FOULED DUE TO ME
8	FLT NR 6221 - SWF-IAD - ABORTED TAKEOFF DUE TO A BIRD STRIKE. AIRCRAFT RETURNED TO GATE WITH NO FURTHER INCIDENTS. MAI
9	ON TAKEOFF, ACFT SUFFERED A BIRD STRIKE. C/W BIRD STRIKE INSPECTION PER MM 05-51-08 PG 601 REF CC1, NR 4 AND NR 5. NO
10	VISUAL INSPECTION REVEALED GOUGES IN SURFACE OF O-RING IN FEMALE QUICK DISCONNECT FUEL TANK TO BURNER HOSE COUPLING. CA
11	DURING BALLOON INFLATION USING AN EXTERNAL FUEL TANK AND SHERWOOD VALVE CONNECTION, THE CHECK VALVE STUCK OPEN ALLOWING
12	THE BALLOON WORKS HAS ISSUED SB NR B30, DATED MARCH, 1995. WHEN BALLOON CAME IN FOR ANNUAL, THE PARTS RECEIVED FROM THE
13	DURING ATTEMPTED DEFLATION OF BALLOON AT CONCLUSION OF A PAID PASSENGER FLIGHT, THE EYEBOLT WHICH RETAINS ONE OF TWO DEF
14	ROTATION VENT DESIGN AND INSTALLATION ON A 45 DEGREE ANGLE MAKE THEM VERY INEFFECTIVE WHEN TRYING TO ROTATE THE BALLOON
15	FLT NR 4135 - DURING TAKEOFF ROLL, CREW HEARD AN AUDIBLE THUMP ON THE RIGHT SIDE OF AIRCRAFT. CREW REJECTED TAKEOFF AND
16	MCI - FLT 112 - CREW REPORTED SEVERAL BIRD STRIKES ON ROTATION. AIRCRAFT MADE AIR RETURN TO MCI. MAINTENANCE INSPECTED
17	FUEL FLOW TO THE BURNER PILOT LIGHTS FAILED IN THE OFF POSITION DURING FLIGHT. INITIAL RE-LIGHT ATTEMPTS WERE UNSUCCESS
18	BLUE NYLON DURAFLIGHT FABRIC, PRE-CUT FOR AN 'A' SERIES 'K' PANEL, HAD 'RIP-STOP' IN ONLY ONE DIRECTION. CAMERON INV NR
19	FLT 4175 - CREW ABORTED TAKEOFF AFTER ENCOUNTERING A BIRD STRIKE DURING TAKEOFF ROLL. AIRCRAFT RETURNED TO GATE WITHOUT
20	STL - FLT 464 - DURING CRUISE, EXPERIENCED A POSSIBLE LIGHTNING STRIKE WITH ACCOMPANYING AIR NOISE AND SMOKE IN THE CABI
21	FLT 4248 - CREW REPORTED STRIKING A BIRD AT 1,000 FEET AGL. ARCRAFT CONTINUED IN-FLIGHT AND LANDED AT DESTINATION WITHO
22	FLT NR 4182 - CREW REPORTED, STRIKING A BIRD, RIGHT SIDE OF AIRCRAFT WHILE ON APPROACH TO RIC. AIRCRAFT LANDED WITHOUT
23	FLT NR 4195 - CREW REPORTED STRIKING A BIRD EN ROUTE TO DAY. AIRCRAFT LANDED WITHOUT INCIDENT. MAINTENANCE INSPECTED A
24	FLT NR 4122 - AIRCRAFT STRUCK A BIRD ON CLIMB-OUT. AIRCRAFT RETURNED TO FIELD LANDED WITHOUT INCIDENT. MAINTENANCE INS
25	SEAT - BIRD STRIKE REPORTED ON FINAL APPROACH FOR LANDING. MAINTENANCE ACCOMPLISHED BIRD STRIKE INSPECTION. NO AIRCRAF
26	ACV - BIRD STRIKE REPORTED ON TAKEOFF ROLL AT CEC. AIRCRAFT CONTINUED TO STATION. MAINTENANCE ACCOMPLISHED BIRD STRIKE
27	AFTER TAKEOFF WITH GEAR UP, A/C STARTED VIBRATING. GEAR WAS CYC DOWN & UP WITH NO PROBLEMS. VIB CONTD. LEVEL OFF AT 5
28	FAILURE OF PRESSURE GAUGE DURING FLIGHT AS A RESULT OF EXCESSIVE USE OF THE METERING VALVE. A SERVICE BULLETIN ADDRESSE
29	THE MALFUNCTION CONSISTS OF ELONGATION OF THE EYES ON THE BASKET SUSPENSION CABLES. THIS CONDITION WAS FOUND DURING A R
30	AIRCRAFT DESCENDING TO MCO AT 13,000 FEET AND 250 KNOTS. ENTERED SCATTERED HAIL. NO FLAPS DOWN, NO LANDING GEAR DOWN
31	SMF - BIRD STRIKE REPORTED ON AIRCRAFT. MAINTENANCE ACCOMPLISHED BIRD STRIKE INSPECTION. NO DAMAGE NOTED. AIRCRAFT RE
32	SNA - CREW REPORTED BIRD STRIKE ON TAKEOFF ROLL. TAKEOFF ABORTED WITHOUT INCIDENT. MAINTENANCE ACCOMPLISHED BIRD STRIKE
33	DURING PRESSURE CHECK OF FUEL LINES, DISCOVERED LEAKING THROUGH SHEATHING OF FUEL LINES. FUEL LINES AEROQUIP FC 321-06.
34	(CAN) AIRCRAFT DECLARED AN EMERGENCY AND DIVERTED. EXTENSIVE DAMAGE [illegible]DING EDGES, HORIZONTAL STAB, VERTICAL STAB, RA
35	CREW REPORTED STRIKING A LARGE BIRD DURING THE TAKEOFF ROLL. TAKEOFF [illegible]BORTED AND AIRCRAFT RETURNED TO THE GATE. OU
36	DURING APPROACH TO CLT, AIRCRAFT EXPERIENCED A SIGNIFICANT VIBRATION WIT[illegible]P 23 SELECTED. MAINTENANCE INSPECTED THE A
37	AIRCRAFT DIVERTED TO SWF DUE TO MAIN DECK SMOKE DETECTORS NR 7, 8 AND [illegible]INATING. EMERGENCY WAS DECLARED AND AIRCRA
38	UPON INSPECTION OF FLOOR ASSY, VISUAL CHAFING OF STRUCTURAL ALUMINUM [illegible]G WAS OCCURRING DUE TO ABRASION BY PROPANE F
39	THE SERVING AROUND THE KEVLAR SUSPENSION CABLE WHICH FORMS THE EYE [illegible] BASE OF THE CABLE HAS COME APART. THE MANUFAC

Large Amounts of Missing Data.

Most useful information was found in the Comments Fields. Querying these fields for key phrases and indicators provided little additional data for trend analysis.

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TASK 2

Sandia National Laboratories

Scope of Current RAMs Survey

- Includes repairs, alterations and modifications on entire airplane
- Aircraft of interest were initially pre-amendment 25-96 design type
  - Recent changes have added all transport airplanes operated in US domestic fleet (~4600 airplanes) to the sample pool
- Airplane models of interest are similar to those in the 1996 AAWG repair survey, but somewhat expanded
  - Boeing 727, 737, 747, 757 & 767
  - McDonald Douglas DC-9 & MD 80/90 & DC-10/MD11
  - Airbus A300, A310, A318-319-320 series
- Number of RAMs should equal or exceed that from the 1996 AAWG Final Report on Continued Airworthiness of Structural Repairs
  - Greater than 65 airplanes and 1051 Repairs
  - Recent changes have increased number of airplanes & RAMs
    - 134 Airplanes
    - Approximately 2065 RAMs
- Focus on In-Service airplanes instead of retired airplanes
  - Records availability and access to RAM interior for visual inspection

Completed Field Inspections of RAMs at Operator Maintenance Locations

Gaining operator approval and coordinating these surveys requires a huge time commitment. Several levels of communication are typically required.

Location	Date	Airplanes
MX Base 1	12/2/08	DC-10, MD 10
MX Base 2	1/9/09	737/757/MD80
MX Base 3	1/14/09	757
MX Base 4	1/20/09	727
MX Base 5	2/10/09	737
MX Base 2	2/23/09	737/757/MD80
MX Base 6	3/16/09	757/767/A300/A310
MX Bases 8 & 9	4/20/09	DC-9, A320, 757, 767
MX Base 2	4/27/09	737

Planned Field Inspections of RAMs at Operator Maintenance Locations

Location	Date	Airplanes
MX Base 3	5/4/09	757
MX Base 5	5/11/09	737
MX Base 10	5/18/09	A320 series
MX Base 2	5/25/09	737NG
To Be Determined	June-Dec 09	

Plans are subject to change on short notice due to airplane scheduling needs of operators.

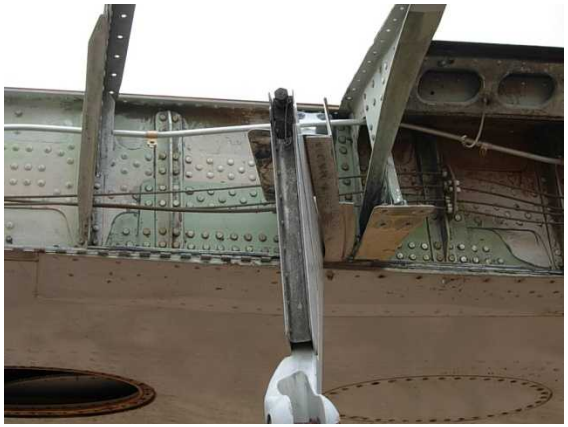
In-Service Airplanes RAMs Survey Target Airplanes

Sample Plan Sandia / Goal as of end of March 2009														
Aircraft Type	**OP1**	**OP2**	**OP3**	**OP4**	**OP5**	**OP6**	**OP7**	**OP8**	**OP9**	**OP10**	**OP11**	**OP12**	**OP13**	**Total Aircraft**
A300&310			1			3						2		6
A320Series			1					3	4		4		5	17
A330									1				1	2
B727						4								4
B737-Classic		1		1						10	1		2	15
B737-NG	1	2	2	4	2					6	1			18
B747									3		1	1		5
B757			3	1	3				1		2	2	1	13
B767			2	1	3						1	1	1	9
B777			1	1	1						1			4
DC-8F												3		3
DC10						5						1		6
MD-80&90	2		11		3				2					18
														134

An additional 14 “airplanes of opportunity” not shown

Teardown Inspections of Repairs from Salvage Yards - Specimens

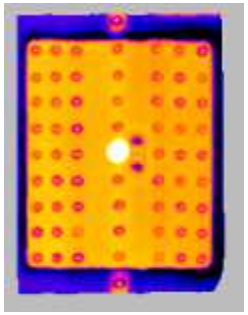
- **Examples of general structures of interest :**
  - **Passenger to freighter cargo door conversion surround frame.**
  - **Wing spar repair/modifications.**
  - **Fuselage lap joint replacement modifications.**
  - **Large area repairs on fuselage, wing and empennage structures.**
  - **Small repair clusters on fuselage, wing and empennage structures.**



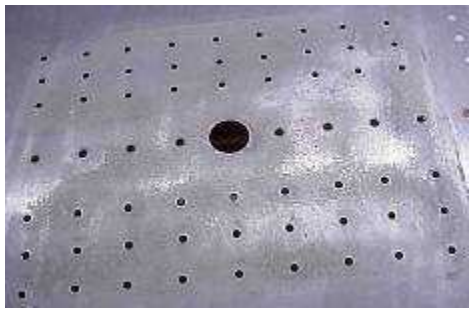
Teardown Inspections of Repairs from Salvage Yards - Protocol

1. RAMs cut from aircraft
2. RAM location on aircraft documented
3. RAM reason, engineering basis, flight hours and cycles determined
4. Nondestructive Inspective (NDI) deployed from outside of the airplane as appropriate
5. Partial Teardown and Eddy Current Bolt Hole Inspection
6. Complete Teardown to separate repair and skin layers, and remove sealant
7. In-depth NDI deployed to characterize the repair as appropriate
8. Direct visual inspections with stereo microscope

Repair

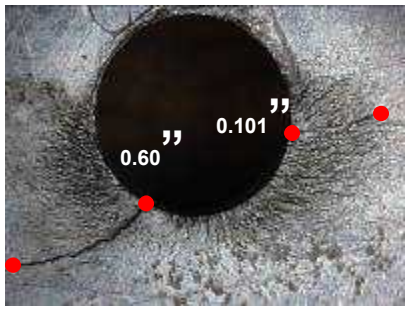


NDI



Teardown

NDI



Findings

Teardown Inspections of Repairs from Salvage Yards - Status

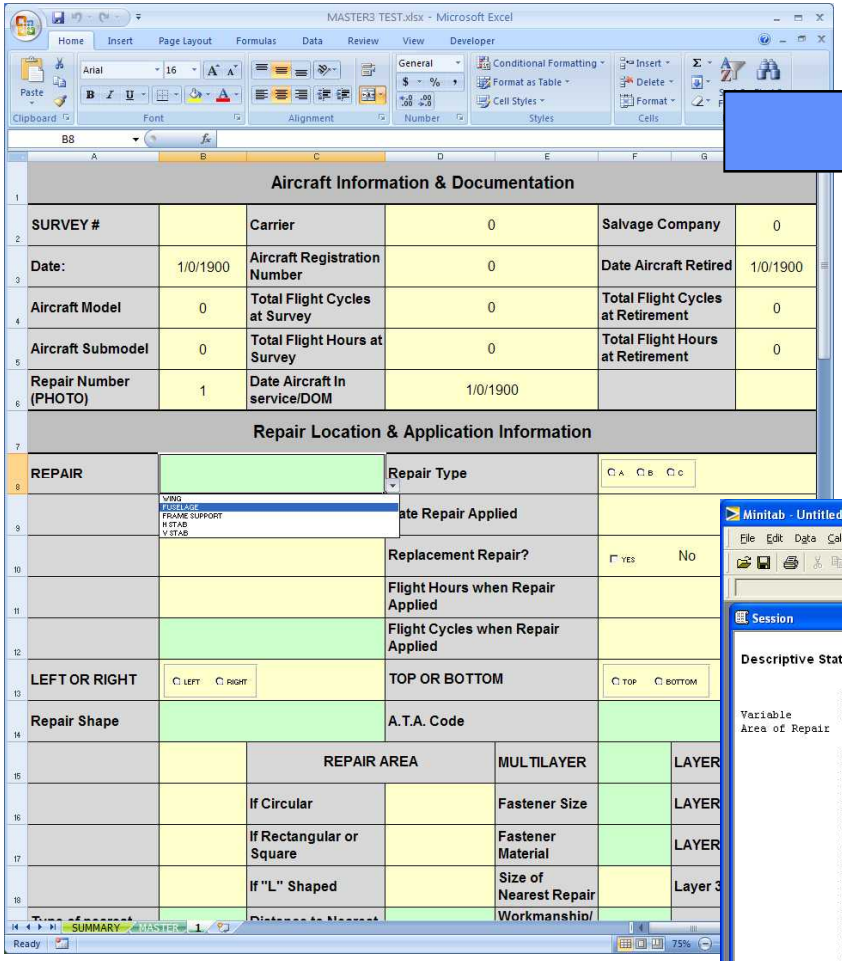
B737-200 fuselage sections – Lap Joint Modification

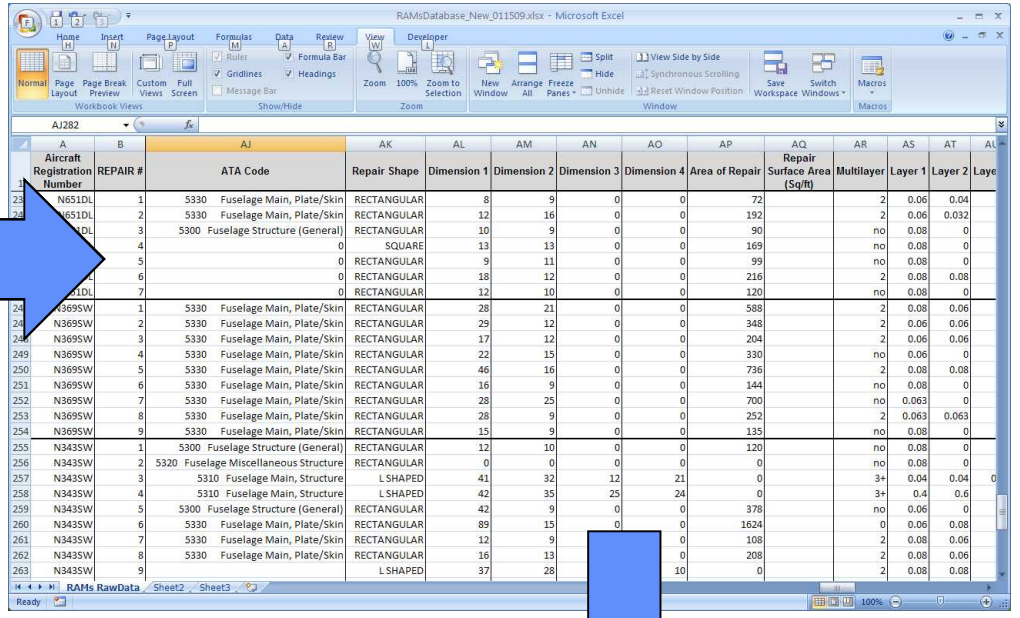
- Fastener removal of first large window belt lap splice alteration completed
- Bolt Hole Eddy Current NDI of fastener holes about half done. Other Eddy Current to follow
- Detailed Visual inspection of surrounding structure done
- Removal of layers and final NDI remains to be done
- Modified structure has 25452 cycles since installation and 76633 total cycles at retirement

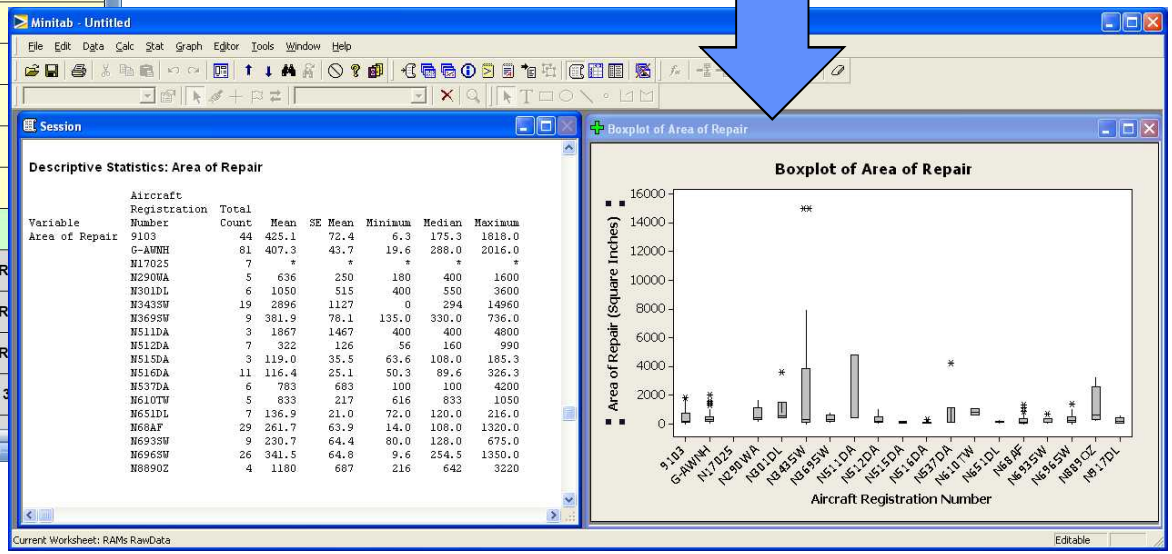
RAMs Field Survey and Teardown Database Deliverable

- Microsoft Excel with links to photo documentation & maintenance records
- Using digital technology to increase the speed and accuracy of field data acquisition
  - Tablet computer
  - Real-time image import and annotation of digital images
  - Direct download of annotated images
  - Easy importation of operator supplied repair assessment technical data (when available)
  - Automatic generation of status reports and running totals
  - Capturing information in up to 72 categories for each RAM

Automation of Data Entry, Manipulation, and Analysis

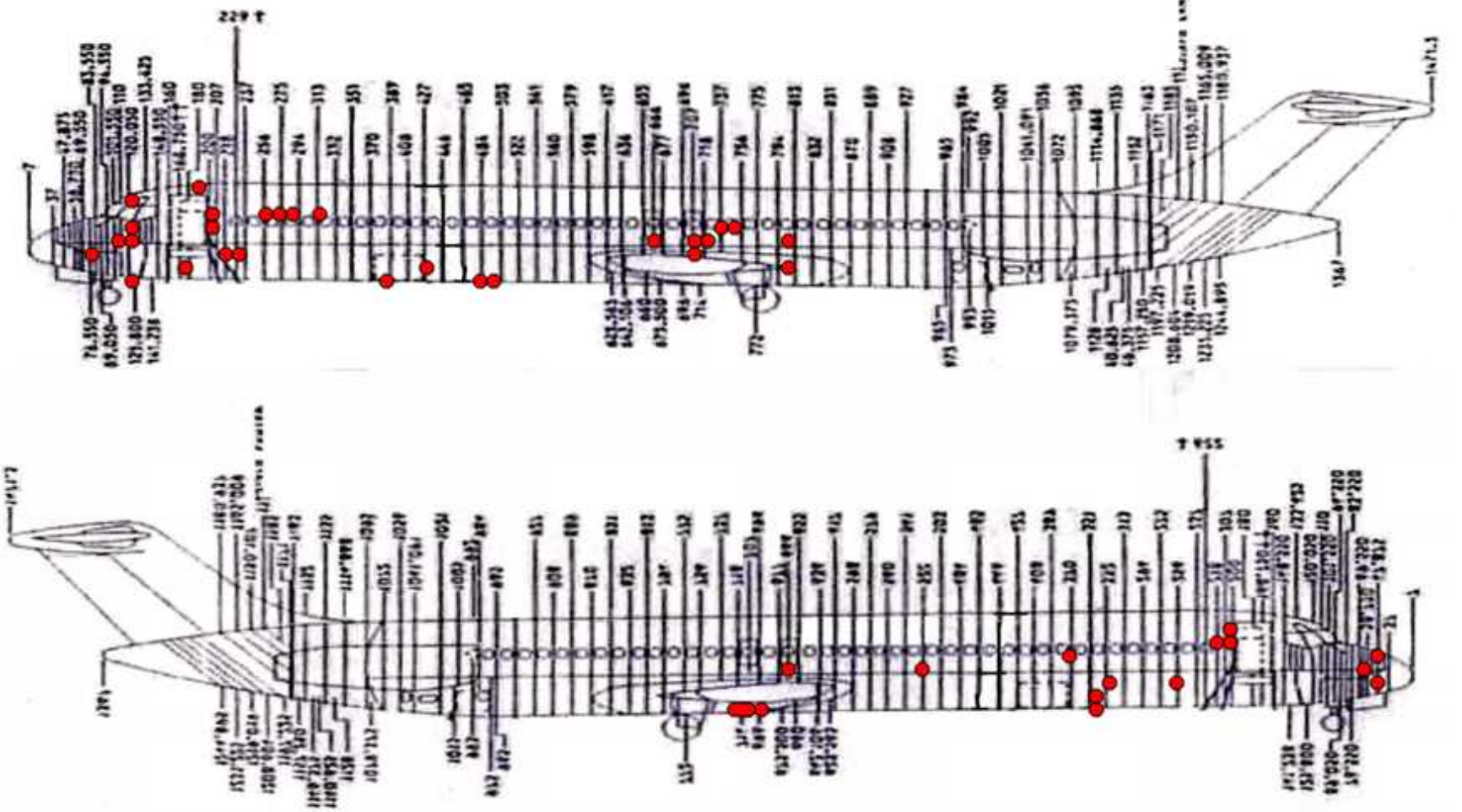






Example Airplane RAM Location Map

Repair Locations on AANC DC-9



RAMs Survey Statistics as of 27 April 2009

Aircraft Model	Number of Aircraft	Number Retired	Number In-Service	Number of RAMS	Number of RAMS In-Service	Number of Rams Retired	Number of Teardown Specimines
727	11	7	4	114	75	39	0
737	13	5	8	380	238	142	8
747	2	2	0	88	0	88	0
757	7	0	7	68	68	0	0
767	4	1	3	18	13	5	0
DC-9	3	1	2	105	61	44	0
MD-88	1	0	1	7	7	0	0
MD-10	2	0	2	58	58	0	0
A300 B4	1	0	1	15	15	0	0
A310	1	0	1	4	4	0	0
A320	3	0	3	8	8	0	0
Total	**48**	**16**	**32**	**865**	**547**	**318**	**8**

Goal	134	2165
% Goal	35.82%	39.95%

Rams with Documentation
183

Schedule

- AANC will complete field surveys on schedule by December 09
  - 134 Airplanes
  - Thousands of individual RAMs anticipated
- Teardown activities have been deferred until 2010
  - Number of specimens to be defined
  - Types of specimens are well defined

Summary

- Conducting survey and teardown of Repairs, Alterations and Modifications on Transport Airplanes in US Domestic Fleet
- Gathering data on incidence of fatigue cracking associated with RAMs
- Data to determine if additional rulemaking is necessary to address RAMs for WFD in transport airplanes

- QUESTIONS???