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F-111 Adhesive Bonded Repair Assessment Program (FABRAP) - Phase I Testing, Preliminary Results

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ABSTRACT

Adhesive bonded repairs are being used for the through-life-support of secondary and tertiary aircraft structure. This technology has not been accepted for application to primary aircraft structure due largely to the lack of a non-destructive inspection technique for, and uncertainty regarding the environmental durability of, adhesive bonds. Over the last twenty five years a large number of adhesive bonded repairs have been applied to the Royal Australian Air Force F-111 and its retirement in December 2010 represented a unique opportunity to evaluate these bonded repairs. The F-111 Adhesive Bonded Repair Assessment Program (FABRAP) was created to generate statistically valid data regarding the efficacy of the tap-test as a non-destructive-inspection technique and the environmental durability of adhesive bonds. In FABRAP Phase I Testing, over 300 repairs were tap tested and 820 residual strength tests conducted using a pneumatic adhesion tensile testing instrument. This report details the FABRAP process and summarises the results from the Phase I testing.

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F-111 Adhesive Bonded Repair Assessment Program (FABRAP) - Phase I Testing, Preliminary Results

Executive Summary

Adhesive bonded repair technology (ABRT) has been used extensively by the Australian Defence Force (ADF) for the through-life-support of secondary and tertiary aircraft structures, where failure of the repair would not result in structural failure of the aircraft. This has resulted in significant cost savings and increased aircraft availability. Wider adoption of ABRT, particularly on primary aircraft structure that is critical to the safety of the aircraft, has the potential to compound these benefits.

A major impediment to the adoption of ABRT for primary aircraft structure is the difficulty in obtaining airworthiness certification. The two major reasons for this are (i) the lack of a non-destructive inspection (NDI) technique that can assess the in-service integrity of a bonded joint, and (ii) uncertainty regarding the environmental durability of adhesive bonds.

ABRT has been used to reinforce and repair parts on the Royal Australian Air Force (RAAF) F-111 for over twenty five years. It is estimated that over 5,000 ABRs have been applied, mainly to honeycomb sandwich panels. Retirement of the RAAF F-111 in December 2010 represented a unique opportunity to evaluate the integrity of a large number of airworthy ABRs.

The F-111 Adhesive Bonded Repair Assessment Program (FABRAP) was created to (i) generate statistically valid data on the efficacy of the “tap-test” NDI method and (ii) evaluate the environmental durability of the adhesives and processes used in these repairs. This report details the FABRAP program and a summary of the raw results from the first phase of testing (Phase I).

FABRAP – Phase I Testing occurred in November 2010. It consisted of a team of DSTO scientists travelling to RAAF Base Amberley and identifying the ABRs on eleven aircraft. Tap-test NDI was performed on over 300 ABRs followed by over 820 tensile tests on the ABRs using a pneumatic adhesion tensile test instrument (PATTI). FM300 adhesive was found on approximately 170 of these ABRs (500 PATTI tests), FM300-2K adhesive on 60 ABRs (190 PATTI tests) and other adhesives on the remaining ABRs. A search was made of the aircraft records in order to acquire the service history of the tested ABRs.

Additional phases of testing are planned. These will consist of (i) tap and PATTI testing additional ABRs, and (ii) stripping the ABR doublers off to ensure that the adhesive under the PATTI stub was representative of the condition over the entire ABR. When the testing phases have been completed the (i) NDI and mechanical test results will be correlated in order to evaluate the efficacy of the tap-test to detect failed bonds, and (ii) service history and mechanical test results correlated in order to quantify any environmental degradation of the adhesive bonds.

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1. Introduction

Adhesive bonded repair technology (ABRT) has been used extensively by the Australian Defence Force (ADF) for the through-life-support of secondary and tertiary aircraft structures, where failure of the repair would not result in structural failure of the aircraft. This has resulted in significant cost savings and increased aircraft availability. Wider adoption of ABRT, particularly on primary aircraft structure that is critical to the safety of the aircraft, has the potential to compound these benefits.

A major impediment to the adoption of ABRT for primary aircraft structure is the difficulty in obtaining airworthiness certification. The two major reasons for this are;

- the lack of a non-destructive inspection (NDI) technique that can assess the in-service integrity of a bonded joint, and
- uncertainty regarding the environmental durability of adhesive bonds.

It is estimated that over 5,000 ABRs have been applied to the Royal Australian Air Force (RAAF) F-111 aircraft over the last twenty five years, mainly to honeycomb sandwich panels. Retirement of the fleet in December 2010 represented a unique opportunity to evaluate the integrity of a large number of airworthy ABRs.

The F-111 Adhesive Bonded Repair Assessment Program (FABRAP) was created to:

- generate statistically valid data on the efficacy of the "tap-test" NDI method, and
- evaluate the environmental durability of the adhesives and processes used in these repairs.

This report details the FABRAP program and the raw results from the first phase of testing (Phase I). This testing was executed in accordance with the intent of the FABRAP Statement Of Work (SOW) shown in Appendix A. The deviations from Appendix A are shown in Table 1.

Table 1: Deviations from FABRAP SOW

Applicable section in the FABRAP SOW (Appendix A)		Actual implementation during testing
Section 2.1.6 Section 2.1.7	Test – NDI (RAAF Base Amberley) Test - Mechanical test (RAAF Base Amberley)	• FABRAP testing will be conducted in phases. • FABRAP Phase I testing was conducted from 25 October 2010 to 26 November 2010. • FABRAP test phases will be timed and coordinated to satisfy the availability of: o accessible aircraft and panels, o funding, and o personnel for bonding and testing.
Section 2.1.7	Test - Mechanical test (RAAF Base Amberley)	• In Phase I: o only Porta-pull testing was conducted using a pneumatic adhesion tensile testing instrument (PATTI), and o no Porta-shear tests were conducted.

2. Phase I Testing

2.1 Timeline

The DSTO Scientists identified in Table 2 travelled to RAAF Base Amberley and conducted the FABRAP - Phase I Testing.

Table 2: FABRAP Phase I Test team members

Date	Test Team Members						
	David Dellios	Ivan Stoyanovski	Paul Callus	Andrew Rider	Eudora Yeo	Kelvin Nicholson	Paul Chang
25-29 Oct 10	✓	✓	-	-	✓	-	-
01-05 Nov 10	-	✓	-	✓	✓	✓	-
08-12 Nov 10	✓	-	✓	✓	-	-	✓
15-19 Nov 10	✓	✓	✓	-	-	-	-
22-26 Nov 10	✓	✓	✓	✓	✓	-	-
20 Nov – 3 Dec 10	-	-	-	-	✓	-	-

2.2 Testing Procedure

All work was conducted in accordance with the Trial Safety Plan shown in Appendix B.

The aircraft present in the "F-111 Graveyard" at RAAF Base Amberley during FABRAP Phase I Testing were A8-[112, 114, 130, 131, 140, 143, 144, 145, 146, 259, 264, 265, 270, 271, 277, 278, 281, 282, 506, 512, 514].

These aircraft were examined by the Test Team and the testing detailed in Appendix C was conducted. In summary each ABR was subjected to:

- tap-testing of an approximately 25 mm wide strip around the periphery of the patch, then
- PATTI testing conducted along this strip at intervals of 100+ mm.

Most testing was conducted on-aircraft in the F-111 Graveyard site. Some removable panels were removed from the aircraft and relocated to the Boeing Bond Shop as a contingency in the event of bad weather. This removal was performed by members of the Boeing Bond Shop and Boeing Structures. Testing on these panels was performed in the same way as the on-aircraft testing, but conducted in the Boeing Bond Shop.

2.3 Repair Documentation and Service History

Prior to, during and following FABRAP Phase I Testing, a search was/is being conducted for repair documentation. The intent of this search was to acquire the service history (particularly adhesive type, surface preparation procedure, repair date and flight hours) and correlate this with adhesive performance, thereby quantifying environmental durability.

Initial discussions with the ADF – Strike Reconnaissance Systems Program Office (SRSPO) revealed that regular repair documentation was held for only the last seven years then destroyed. The only older documents that had been archived were Engineering Dispositions for non-standard maintenance, known as Requests for Disposition/Waiver (RFD/W). These files were located in SRSPO archives and the Boeing Engineering Office. Over 200 RFD/Ws between eight and eighteen years old were located and copied. They were useful because they provided information on the nominal repair method, however they did not always provide specific details of damage location or type of adhesive, and importantly did not give confirmation that the repair was conducted in accordance with the process that was specified. In addition, significant numbers of the panels and components referred to in these RFD/Ws had been removed for repair and replaced on other aircraft or retired as unserviceable.

All repair documentation since 2002 has been archived by Boeing, who released to DSTO in electronic format all non-conforming repair (NCR) documentation that they believed would be of use. The Boeing Maintenance Control Section (MCS) is responsible for archiving all maintenance documentation. Over 280 MCS archive boxes were held in archives, some of which contained repair documentation for bonded repairs. Roughly 260 pieces of repair documentation were obtained by searching these boxes. In the future these will be linked to the ABRs that were inspected and tested.

The Boeing Bond Shop had maintained a repair database since 1996. This database was accessed and used to identify those panels that contained internal ABRs and could be removed from the aircraft. This database was also used to identify the date of repairs and associated documentation.

Boeing provided service histories for all the C-model aircraft that were inspected. It was found that fuselage fixed structure and fuselage panels were generally not swapped across aircraft, so this information may be used to trace repair histories.

It was also possible to track the service histories of serial number-tracked components from at least 2004 onwards using the Computerised Asset Maintenance and Management system (CAMM2). At the time of writing this report it is believed that full service histories may be tracked for at least twenty repairs to components, and at least partial service histories can be tracked for many more.

Further details on repair documentation and service histories are given in Appendix D. It is estimated that by the end of the FABRAP testing, a service history will be found for approximately one third of the tested ABRs.

2.4 Test Results

A summary of the FABRAP Phase I Testing results, sorted in terms of aircraft tail number and adhesive type, is presented in Table 3. More detailed raw and analysed data will be published in the future.

Table 3: Summary of FABRAP Phase I Testing results sorted by aircraft tail number and adhesive type

Tail No.	Total			FM300			FM300-2k		
	Panels	Patches	Stubs	Patches	Stubs	Average burst pressure (psi)*	Patches	Stubs	Average burst pressure (psi)*
A8-112	19	33	88	21	57	32.2	7	21	22.6
A8-114	14	27	59	11	28	24.5	6	20	26.8
A8-130	19	39	92	15	39	26.2	9	27	25.4
A8-131	17	31	86	21	62	30.6	4	15	34.2
A8-140	20	25	64	7	24	35.7	8	15	35.0
A8-143	7	8	37	5	33	19.7	1	1	20.8
A8-144	12	24	54	17	44	29.7	3	6	24.1
A8-145	15	31	74	15	45	26.2	8	16	26.4
A8-271	9	23	95	12	36	26.5	10	58	23.0
A8-512	16	32	88	20	60	24.7	5	13	25.9
A8-514	13	31	90	24	77	26.6	-	-	-
TOT	**161**	**304**	**827**	**168**	**505**	**27.6**	**61**	**192**	**26.0**

* Raw Patti-Test failure pressure. This must be multiplied by the F-16 Piston Conversion Factor in order to calculate adhesive tensile strength.

2.5 Further Testing

A significant number of patches were not tested during FABRAP Phase I Testing. These included patches on:

- the aircraft in the graveyard that:
  were not identified,
  were not tested, or
  if PATTI tested the results were invalid because the adhesive for the PATTI test, and not the adhesive in the ABR, failed
- panels contained in at least four large boxes located in the Boeing Bond Shop. These boxes contain three horizontal stabilators and an assortment of smaller panels, and

- aircraft that have been reserved for other use such as museum displays.

Negotiations are underway to test some of these patches in the first half of 2011 under FABRAP – Phase II Testing.

The ABR doublers that were tap and PATTI tested in FABRAP will need to be removed in order to verify that the adhesive subjected to the PATTI test is representative of that in the entire ABR. This has not occurred on a significant number of the doublers from the ABRs evaluated in FABRAP Phase I Testing. Thus Phase II Testing will need to take into account the considerable time required to remove the doublers, photograph the adhesive faces, and cover the adhesive with dummy doublers (required as part of the asbestos management plan).

2.6 Analysis

At the completion of FABRAP testing the results will be:

- analysed to assess the efficacy of the tap-test NDI method, and
- coupled with the service histories to quantify the effects of critical variables such as repair age and location on adhesive strength, thereby quantifying repair durability.

The results of such analysis will be reported in the future.

3. Conclusions

The F-111 Adhesive Bonded Repair Assessment Program (FABRAP) has been created to (i) generate statistically valid data on the efficacy of the "tap-test" non-destructive inspection method for, and (ii) evaluate the environmental durability of, the adhesives and processes used in adhesive bonded repairs on retired Royal Australian Air Force F-111 aircraft.

FABRAP Phase I Testing was conducted in November and December 2010. Over 300 adhesive bonded repairs were subjected to tap-test non-destructive inspection then over 800 destructive tensile tests conducted with a pneumatic adhesion tensile test instrument on these repairs. Approximately half of these repairs contained FM300 adhesive, one fifth contained FM300-2K and the remainder a variety of other adhesives. The service history for approximately one third of these repairs either has, or will be, acquired.

In Phase II Testing, tap and residual strength testing will be conducted on other repairs. Finally, the doublers from all repairs will be stripped to ensure that the adhesive subjected to the residual strength test was representative of the adhesive across the entire repair.

FABRAP will, upon completion, have produced the largest pool of data regarding the performance of structural adhesives in airworthy adhesive bonded repairs. Analysis will be conducted to assess the (i) efficacy of the tap test as a non-destructive inspection method for identifying failed adhesive bonds and (ii) environmental durability of these adhesive bonds.

4. Acknowledgements

Substantial effort has been required to realise FABRAP. Without the assistance and efforts of the following people this valuable pool of data could not have been generated. Support and funding was provided by ASI-DGTA through the Task Desk Officer, Dr Madabhushi Janardhana. DSTO colleagues Steve Galea, Khan Sharp and Greg Bain reallocated resources to support FABRAP. WGCDR Dave Abraham, F-111 Disposal Project Manager, provided the permissions for DSTO to work at RAAF Base Amberley and Peter Cavanagh, Deputy Project Manager Disposals, provided direct assistance. Stephen Pendrey, Darryl Hooper, Wayne Hughes, Aled Roberts, Grant Wingfield, Jamie Jones, Justin Meehan, Paul Mokrzycki and Brad Wise of Boeing Defence Australia provided overall approval for the work and on-the-ground support. Personnel from 6 Squadron conducted additional non-destructive inspections on some suspect ABRs.

5. References

1. Department of Defence, “Planned withdrawal from service of F-111 Weapons Platform”, DEFGRAM No 466/2010, 28 July 2010
2. *Receipt, handling, storage and disposal of asbestos in all aircraft and equipment at Boeing Amberley*, WI-AMB-856, Issue no. 17, Date of Issue 20/9/2010, Boeing Defence Australia
3. *Asbestos Management in Defence*, Defence Safety Manual SAFETYMAN, Vol 1, Part 5, Chapter 2, First edition 2002, Department of Defence
4. Australian Air Publication AAP 7014.003-3B5, Aircraft Structural Repairs F-111 Aircraft, revised 27 April 1999, Royal Australian Air Force
5. *Management of heavy metals and spray painting within the aircraft maintenance environment*, WI-AMB-101, Issue no. 9, Date of Issue 02/01/2009, Boeing Defence Australia

Appendix A: Statement of Work – F-111 Adhesive Bonded Repair Assessment Program (FABRAP)

A.1. Introduction

Adhesive bonded repair technology (ABRT) has been used by the Australian Defence Force (ADF) for over thirty years for the through-life-support of secondary and tertiary aircraft structures, where failure of the repair would not result in structural failure of the aircraft. This has resulted in significant cost savings and increased aircraft availability. Wider adoption of ABRT, particularly for the through life support of primary aircraft structure, has the potential to compound these benefits.

Adhesive bonded repairs (ABRs) may be applied:

- before damage occurs in deficient or susceptible aircraft parts. This reduces or even obviates the need for subsequent repairs, and

- in damaged parts to restore the structural integrity of the aircraft part. This would obviate the need for more expensive or less efficient alternatives. In some cases this may mean the difference between retaining and scrapping parts.

A major impediment to the adoption of ABRT, both within the ADF and around the world, is the difficulty in obtaining airworthiness certification. This has largely prevented its application on primary aircraft structure where failure of the part would result in structural failure of the aircraft. The two major reasons that airworthiness authorities have not accepted ABRT for application to primary aircraft structure are:

- the lack of a non-destructive inspection (NDI) technique that can assess the integrity of a bonded joint, and

- uncertainty regarding the environmental durability of the adhesive bond.

It is intended that the F-111 Adhesive Bonded Repair Assessment Program (FABRAP), as detailed in this SOW, will generate statistically valid data to address these uncertainties, and thus progress the case for airworthiness acceptance of the ABRT.

ABRT has been used to reinforce and repair RAAF F-111 parts for over twenty five years. It is estimated that in the order of 5,000 ABRs have been applied, mainly to the honeycomb sandwich panels. A small number of ABRs have also been applied to primary aircraft structure (wing pivot fittings and some FAS281 lower wing skins) but these were special cases and have been managed very closely.

Retirement of the Royal Australian Air Force (RAAF) F-111 on 31 December 2010 [1] represents a unique opportunity to evaluate a large number of airworthy ABRs. Under the FABRAP, a team of DSTO scientists will travel to RAAF Base Amberley and evaluate, by

NDI followed by destructive mechanical testing, as many retired F-111 ABRs as practicable. Where possible these tests will be correlated with service history documentation. A selection of parts containing ABRs shall be transported to DSTO – Melbourne for more detailed NDI and mechanical testing. The results of this work will be analysed to assess the (i) efficacy of NDI and (ii) environmental degradation of adhesive bonds. Sufficient numbers of ABRs will be examined to allow statistically valid conclusions to be drawn.

A.2. Statement of Work

A.2.1 Project overview

The FABRAP will consist of the following approach and timelines:

• Plan	Jul-Aug 2010
• Identification and quarantine – Parts	Aug-Dec 2010
• Identification and quarantine – Documentation	Aug-Dec 2010
• Transport - selected parts to DSTO - Melbourne	Oct 2010 – Dec 2010
• Correlate service history documentation with parts	Sep 2010 – Feb 2011
• Test – NDI (RAAF Base Amberley)	Sep - Dec 2010
• Test - Mechanical test (RAAF Base Amberley)	Sep – Dec 2010
• Correlate - NDI and mechanical test	Nov 2010 – Mar 2011
• Correlate – Service history and mechanical test	Nov 2010 - Mar 2011
• Report	Jan - Jun 2011
• Test - NDI and mechanical test (DSTO – Melbourne)	Mar – Dec 2011
• Analyse results of DSTO-Melbourne testing	Jan – May 2012
• Report	Mar - Jun 2012

Each of these steps is detailed below.

A.2.1.1 Plan

A.2.1.1.1 Consultation

It is proposed that the majority of the NDI and mechanical testing be conducted at RAAF Base Amberley. The justification and costing for this approach is given in Section A.3.

In August 2010 the DSTO FABRAP Manager shall meet or liaise with the following key stakeholders in order to refine then obtain agreement on the plan:

- ASI3B ASI-DGTA
- Project Manager – COM04002 SOR QQAS
- SRSPO F-111 Aero-Mechanical & Structural Systems Manger
- Boeing Defence Australia (BDA) – Point of Contact
- Relevant DSTO personnel - NDI STL, Composites STL, Task AIR 07/053 Task Leader and Staff Officer Science (SOS) RAAF Combat Support Group (CSG)
- Joint Logistics Unit – Southern Queensland (JLU-SQ) – Wallangarra
- F-111 Disposal Team (Mr Peter Cavanagh)

A.2.1.1.2 Trial Plan

The DSTO FABRAP Manager shall write a Trial Plan that:

(i) details all aspects of the FABRAP that will be conducted at RAAF Base Amberley and other storage locations,

(ii) contains Standard Operating Procedures (SOPs) for all NDI and mechanical tests, and

(iii) satisfies the requirements for work conducted at these sites. Possible items include risk assessments, plans for using hazardous substances, emergency procedures, security plans, etc.

The issues that the plan must address include, but are not limited to:

Timing – The F-111 is scheduled to retire on 31 Dec 2010 with the final flight planned for 2 December 2010 [1] and is currently in draw-down mode. There is a risk that during this draw-down, relevant documentation and parts will be inadvertently disposed.

BDA acceptance – It is suspected that much of the service history documentation is held by BDA. It is vital that this be accessed, reviewed and relevant information archived. There is a risk that BDA will resist this. Reasons may include, but are not limited to, (i) this work is outside the scope of the BDA contract, (ii) the perception that the FABRAP will be used to 'rate' the performance of BDA, (iii) BDA has insufficient resources to support this work, or (iv) this information is commercially sensitive. Negotiations must be handled sensitively and appropriately – the aim of this program is to assess the performance of the ABRT, not BDA. Alternatives, such as photo-copying relevant pages rather than acquiring entire files, are acceptable if this gives DSTO access to those parts of the service history that support the intent of the FABRAP.

SRSPO acceptance – There is a risk that the priority of the FABRAP within SRSPO will be low. Sufficient effort must be directed at convincing the SRSPO stakeholders of the importance of this work to the ADF.

Access to aircraft and ground support equipment – The F-111 aircraft are stored in a secure area and access is strictly controlled. At present the custodian has mandated that all inspections must be supervised. In addition it is expected that the custodian will need to approve and supervise the use of the necessary ground support equipment, such as cherry pickers, gantries, harnesses, etc. It is expected that maintaining a 'guest' status for the 24+ days of the FABRAP would present an excessive administrative burden on the custodian. It is proposed that the FABRAP team be trained to comply with all the requirements to conduct the FABRAP. Potential requirements include access to RAAF Base Amberley, working-on-aircraft, access to F-111 aircraft, working on ground support equipment and others. The training requirements necessary to complete the FABRAP shall be negotiated between the FABRAP Manager and the relevant authorities at RAAF Base Amberley.

NDI and mechanical test techniques – The types of NDI and mechanical tests to be performed will need to be determined in consultation with the applicable DSTO Science

Team Leads (STLs) and take into account the, technical applicability of the technique, resource availability, number of ABRs to be evaluated, and amount of service history available for each ABR. The DSTO FABRAP Manager must obtain:

- stakeholder (ASI DGTA, AFRL, NATA) approval or input as appropriate to the NDI and mechanical test plan and method of demonstrating traceability/reliability
- calibration certificates for NDI and mechanical test equipment
- certification for NDI and mechanical test operators.

A SOP will need to be written for each NDI and mechanical test technique. The SOP will address technical and Occupational Health and Safety (OHS) aspects. Working in accordance with the SOP will assure the technical reliability of the inspection/test results, the health and safety of the operators, and the protection of the equipment and test specimen.

Sample size – A statistical analysis must be performed in order to determine an appropriate target sample size for the FABRAP. One aspect to consider will be to select the appropriate statistical distribution and statistical test. DSTO experts on adhesive bonding argue that the intuitive approach of judging the effectiveness of an ABR on the basis of its mechanical strength (in a porta-pull or porta-shear) is not correct. That is, representing adhesive bond effectiveness as a continuous distribution (such as normal or Weibull) and that bonds with a higher tensile or shear strength be considered "better" than bonds with a "lower" strength, is not appropriate. In contrast, they propose that almost all adhesive bonds that survive the bonding process and tap-test NDI are sufficient providing that bond fails cohesively within the adhesive. This suggests that a pass/fail binomial distribution would be more appropriate.

A.2.1.2 Identification and quarantine - Parts

The DSTO FABRAP Manager shall:

- organise for the identification and quarantining of surviving F-111 parts that contain ABRs,
- visit RAAF Base Amberley on a monthly basis, and other F-111 storage locations as required, in order to organise a method of quarantining that suits local conditions and ensure that the quarantining is occurring,
- organise for the safe storage of parts prior to NDI/mechanical testing or transportation to DSTO - Melbourne,
- organise for the DSTO team to conduct NDI and mechanical testing at RAAF Base Amberley,
- organise for the FABRAP Team to receive the required training,
- coordinate with the Project Manager – COM04002 SOR QQAS, and
- use DSTO SOSci CSG, staff from ASI BSTT and other personnel as available to maintain a continuous presence at SRSPO, BDA and other F-111 storage locations.

It is critical that this work be commenced in August 2010 and conducted continuously until December 2010, in order to minimise the inadvertent loss of items during the draw-down phase of F-111 operations.

A.2.1.3 Identification and quarantine - Documentation

The DSTO FABRAP Manager shall organise for the identification and quarantining of all documentation that relates to the service history of F-111 ABRs.

It is critical that this work be commenced in early August 2010 and conducted continuously until December 2010, in order to minimise the inadvertent loss of items during the draw-down phase of F-111 operations.

A.2.1.4 Transport – selected items

The DSTO FABRAP Manager shall:

- identify those parts and documentation for which the tests specified in A.2.1.6 and A.2.1.7 will be conducted in the field - RAAF Base Amberley, Joint Logistics Unit – Southern Queensland (JLU-SQ) Wallangarra and National Defence Storage and Distribution Centre – Moorebank, etc)., and
- organise to transport selected quarantined parts and documentation to DSTO-Melbourne for more detailed NDI, mechanical test and service history analysis.

A.2.1.5 Correlate service history documentation with parts

The DSTO FABRAP Manager shall organise for the service history documentation that has been obtained to be linked with the parts that are available.

Ideally the full service history of each ABR that has been acquired will be available. This will support evaluation of the environmental durability of repairs. It is expected that there will be very few cases where the full service history is available. In these cases other indicators (direct or indirect) may be used to provide a lesser, but still useful, measure of the age of the bond and therefore the environmental durability of the adhesive bond. For example it may be possible that chemical, spectroscopic, chromatographic or diffraction analysis techniques may be able to measure the age of an adhesive bond and the amount of degradation of that bond.

All ABRs shall be:

- photographed
    - Wide angle (panel on aircraft)
    - Detailed (field of view = patch + 50 mm)
- overlaid on blueprint drawings (or computer based drawing)
    - Highlight patch on drawing

Ideally this step should be performed prior to A.2.1.6 and A.2.1.7 so that the NDI and mechanical testing can be tailored to suit the history that is available. However it is more likely that the documentation acquisition will overlap with the NDI/testing and the correlation phase will occur subsequent to this. It is therefore important to ensure an accurate and comprehensive record (including tail number, part number, location on part) of the location of the ABRs that are tested.

A.2.1.6 Test – NDI (RAAF Base Amberley)

The DSTO FABRAP Manager shall:

- liaise with the appropriate DSTO Science Team Leads (STLs) to establish and agree on the NDI evaluations to be conducted,
- write/review and approve the SOP and include it in the Trial Plan,
- ensure the operators have the appropriate training,
- organise for the agreed NDI evaluation to be conducted,
- review the NDI and ensure the results are valid prior to commencement of mechanical testing, and
- ensure that certified NDI results are obtained.

The following steps are proposed:

Tap test
Inspect and mark-up disbond boundary
Complete certification requirements
Bondmaster
The bondmaster shall be applied only to those ABRs that the tap test indicates may be disbonded
Inspect and mark-up disbond boundary
Complete certification requirements
Photograph
Obtain photographic record of disbond boundary as determined by tap test and the Bondmaster
Review
Review NDI results and repeat inspection if initial results are invalid or inconclusive
Certify
Complete NDI result certification

The NDI will need to be conducted in a form that is accepted by airworthiness authorities. It is expected that this will require licensed operators performing work using certified equipment in accordance with recognised standards. It is possible that this may require NATA accredited testing.

A.2.1.7 Test - Mechanical tests (RAAF Base Amberley)

Conduct destructive mechanical tests on the repairs using the following mechanical testing techniques in accordance with the approved SOPs. The following mechanical tests are proposed:

Porta-pull (2 per patch)
Clean
Bond stub
Pull stub
Record strength

Complete certification requirements

Porta-shear (2 per patch)

Clean
Bond stub
Shear stub (use automated test fixture if possible)
Record strength
Complete certification requirements
Photograph

Peel

Strip patch off
Assess and record failure locus (cohesive in adhesive, adhesive)
Photograph

It is proposed that semi-automated test fixtures be designed, manufactured and used to pull and shear the stubs. These fixtures will ensure that load is applied to the stubs in the desired direction and with less variability than purely manual application. Both of these factors will enhance confidence in the validity of the mechanical test results. Such fixtures currently exist in prototype form but are suited to laboratory tests. It is expected that a modest effort and cost (approximately $5,000 each) will be required to re-design and manufacture fixtures that would be suited for on-aircraft use.

A.2.1.8 Correlate - NDI and mechanical test

Perform statistical analysis on the test results.

A.2.1.9 Correlate – service history and mechanical test

Correlate mechanical test results with the service history that is available for that repair. Perform statistical analysis on results pool.

A.2.1.10 Report

Report on the results of field-based NDI/mechanical testing and subsequent analysis in a form that is suitable to progress the case for airworthiness certification.

A.2.1.11 NDI/mechanical testing at DSTO - Melbourne

It is intended that the parts returned to DSTO – Melbourne be subjected to NDI and mechanical testing that is technically and/or logistically difficult to perform outside of the laboratory. Potential techniques include:

NDI
- *Flash thermography*
- *Sonic thermography*

Mechanical testing

Residual strength test - These would demonstrate that the residual strength of the repaired component was restored to above Design Ultimate Load (DUL).

A.2.1.12 Report

Report on the results of laboratory NDI/mechanical testing and subsequent analysis in a form that is suitable to progress the case for airworthiness certification.

A.2.2 Testing Rate

It is proposed that the FABRAP NDI/mechanical test phases be conducted on the flight-line at RAAF Base Amberley, and any other storage location (JLU-SQ - Wallangarra and NDSDC – Moorebank, etc) where suitable ABRs have been identified, by a 4 person DSTO team working at a rate of one aircraft (25+ patches) per day. This will require a total test period at RAAF Base Amberley of approximately 25 days for the fleet of 24 aircraft.

This target rate was derived on the basis of experience. One of the proposed members of the DSTO team has inspected 10 patches in one day in the DGTA - BSTT facility at RAAF Base Amberley. However this was an unsustainably long day, in a laboratory environment, without all of the NDI and mechanical tests planned under the FABRAP. NDI and mechanical tests on aircraft on the flight-line will be slower.

It was judged that a sustainable rate for one person in a flight-line environment would be approximately 5 patches per day. For a team of 4 people this should equate to 20 patches per day, however efficiencies of scale are expected to increase this to 25 patches per day. Much of the efficiency would arise because each team member could focus on conducting and optimising one or two elements of the work (documenting, preparing and conducting NDI, preparing and conducting the mechanical testing) rather than conducting all parts of the Test Plan for each ABR.

A.2.3 Timing

Timing is of critical importance.

The F-111 will be withdrawn from active ADF service on 31 December 2010. Operations are being drawn down. There is a risk that, unless documentation and parts are identified and quarantined, they will be disposed.

A.2.4 Key Personnel

A.2.4.1 Program Sponsor – ASI3B ASI-DGTA (Dr Madabhushi Janardhana)

Responsible for progressing the case for airworthiness certification of ABRT in the ADF. Responsible for:

- ensuring that the FABRAP plan addresses ASI-DGTA requirements, and
- providing sponsorship and support within the ADF.

A.2.4.2 FABRAP Manager – DSTO (Ms Eudora Yeo)

To coordinate and conduct the work program.

A.2.4.3 Project Manager – COM04002 SOR QQAS (Mr Chris Dooley)

To support the DSTO FABRAP Manager, within the limitations allowed by ASI3B ASI-DGTA, in coordinating and performing the FABRAP.

A.2.4.4 Staff Officer Science RAAF Combat Support Group (CSG) (Mr Jean-Pierre Gibard)

To provide day-to-day contact with BDA and SRSPO staff in order to identify and quarantine candidate parts.

A.2.4.5 SRSPO F-111 Aero-Mechanical & Structural Systems Manger (FLTLT Damon Stefani)

To provide SRSPO support for the FABRAP.

A.2.4.6 F-111 Disposal Team (Mr Peter Cavanagh)

To ensure that the selected items are not disposed prior to the conduct of NDI and mechanical testing.
To be kept informed of progress by FABRAP Manager.

A.3. Justification and costing for conducting NDI and mechanical testing at RAAF Base Amberley

A.3.1 Justification

There are two options for the conduct of the FABRAP NDI/mechanical test phases. The first option is for a team of DSTO scientists to travel to RAAF Base Amberley and conduct the testing on the flight-line. A selection of parts containing ABRs would be transported to DSTO – Melbourne for more detailed NDI and mechanical testing. The second option is to transport all panels containing ABRs to DSTO – Melbourne for testing in the laboratory. The advantages and risks associated with each option are described below.

It is recommended that Option 1 be implemented, primarily because of the advantages of this Option plus the risks associated with Option 2.

Option 1 – DSTO scientists to conduct tests at RAAF Base Amberley and a selection of panels to be tested at DSTO - Melbourne
Advantages

- Dedicated team will be able to focus exclusively on the testing and complete it before the fleet is retired and aircraft are disposed

- Reporting is expected to be completed by Jun 2011. Timely completion has greater potential to facilitate acceptance of adhesive bonded repairs under the ADF Safety-By-Inspection (SBI) regime
- F-111 aircraft will be left largely intact. There will be many 20 mm diameter holes in the outer skin rather than entire panels removed
- Reduced disruption for SRSPO/BDA relative to option 2
- Reduced requirement to transport panels to, and store at, DSTO – Melbourne
- No requirement for F-111 component disposal plan
- No requirement for asbestos management plan

Risks

- The accelerated test program conducted on the flight-line has the potential to be of lower quality. An incomplete array of tests may be conducted and/or the 'flight-line' tests may be inferior to 'laboratory' tests
- Difficulty in selecting and obtaining appropriate quality assurance (NATA?) for NDI and mechanical tests
- Significant funding is required to send 4 DSTO staff to RAAF Base Amberley for 25 days

Option 2 – Transport all panels to DSTO - Melbourne
Advantages

- Can conduct more comprehensive NDI and mechanical testing
- Can extend duration of program in order to accommodate funding and staff availability

Risks

- May not get permission to remove panels from aircraft
- May take significant resources to remove panels from aircraft
- Transport may be expensive
- Will need a panel disposal plan
- Will need an asbestos management plan
- Will delay publication of test results

A.3.2 Costing

Two options were considered, working at RAAF Base Amberley and relocating panels to DSTO-Melbourne. Option 1 was selected because it was judged to represent better value for money.

A.3.2.1 Option 1

Work at RAAF Base Amberley was expected to cost $40,000 as detailed in Table A.1. The option of accommodating the DSTO Team in the RAAF Base Amberley Officers Quarters was investigated however it was found not to be suitable for the purposes of the FABRAP work program.

Table A.1: Preliminary costing for DSTO team to conduct NDI and mechanical testing at RAAF Base Amberley

	Daily rate	1 x 1 week then 2 x 2 weeks		1 x 5 weeks	
		Number	Cost	Number	Cost
Per Person					
Flight	$550	3	$1,650	1	$550
Accommodation	$120	26	$3,120	32	$3,840
TA	$110	29	$3,200	33	$3,642
Sub total - Per Person	**$780**		**$7,970**		**$8,032**
Per Team					
Sub total - All People	**4**		**$31,881**		**$32,126**
One-off					
Miscellaneous	$1,000		$1,000		$1,000
Car hire	$70	29	$2,030	33	$2,310
Sub-total - Fixed Costs			**$3,030**		**$3,310**
TOTAL			**$34,911**		**$35,436**

A.3.2.2 Option 2

The second option was to transport all relevant panels to DSTO-Melbourne, conduct the testing there then dispose of the panels. The items that would need to be considered for this option were:

- Identify panels
- Documentation
    - Asbestos management plan
    - Disposal plan
- Unfasten panels
- Pack
- Transport
- NDI at DSTO-Melbourne
- Mechanical test at DSTO-Melbourne

The costs for this option were not detailed because:

- they were expected to be substantially greater than the costs associated with Option 1, and
- ABRs were applied to some very large fixed and removable panels. The feasibility of transporting these to DSTO-Melbourne was considered to be very low.

Appendix B: F-111 Adhesive Bonded Repair Assessment Program (FABRAP) Trials Safety Plan

B.1. Update to F-111 Adhesively Bonded Repair Assessment Program (FABRAP) Trials Safety Plan, 28 October 2010

The original document noted that repairs for which paperwork was not located may still be tested if FM300 adhesive, which does not contain asbestos, could be clearly identified. This was intended as an option in case insufficient repair paperwork was located in time for the commencement of the test program.

One full day of searches of the aircraft indicated that it was extremely difficult locating repairs for which paperwork was held, as panels may have been scrapped or swapped onto other aircraft. It was decided to take up the option to test repairs with no paperwork, in which case the Work Method must be revised. Step 1 on page 8 is updated to include step 1b.

1. Identify repairs to be tested
    a. Using available paperwork
    b. If paperwork cannot be matched to repairs, remove sealant from edge of repair, inspect colour of adhesive. Blue adhesive is FM300, grey is EA9321, bright yellow is FM73 and dark yellow is FM300-2k. All of these are safe to test. Straw coloured adhesives are likely to contain asbestos. If the repair contains a yellow-coloured adhesive, consult bonding technicians with experience in identification of adhesives containing asbestos. If there is any doubt, treat repairs as containing asbestos. The exposed adhesive must be resealed using aluminium tape or protective red enamel paint.

The Job Safety Analyses in Appendices A and B are also updated to include step 1b.

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls
1	Identify repairs to be tested a) using available paperwork b) by inspecting colour of adhesive in the fillet at the repair edge	b) Potential of exposure to asbestos if adhesive containing asbestos is disturbed	b) Wear minimum P2 face mask. If repair is suspected of containing asbestos, do not test, and	b) L = Rare C=Catastrophic **Risk = High**	Removal of sealant will not disturb asbestos if care is taken not to damage the adhesive. If there is any doubt as to whether the adhesive may contain asbestos, treat the repair as containing asbestos and do not test

			reseal edges of repair using aluminium tape or red enamel spray		

B.2. Introduction

Currently, adhesively bonded repairs are not certified for use on metallic primary aircraft structure. Certification of bonded repairs to primary aircraft structure has the potential to provide significant savings for the Australian Defence Force and other organisations, as aircraft structures can be repaired instead of being replaced.

There are two main hurdles in the route to certification. Firstly, there is no non-destructive inspection (NDI) technique which can assess the integrity of a bonded joint, other than simply detecting delaminations. The second issue is that there is little data on the strength of bonded repairs that have been in extended service, and there is uncertainty regarding the environmental durability of the adhesive bond.

The goal of the F-111 Adhesively Bonded Repair Assessment Program (FABRAP) is to collect enough data to address these issues, and progress the case for the certification of bonded repairs. The Defence Science and Technology Organisation (DSTO) and Aircraft Structural Integrity – Director General Technical Airworthiness (ASI-DGTA) are collaborating with the US Air Force Research Laboratories to test adhesively bonded repairs that have seen aircraft service. DSTO aims to obtain 200+ repairs to F-111 for NDI and residual strength testing, along with their corresponding paperwork. This will enable correlation of the results of NDI and residual strength testing with repair design, application techniques, and service history.

This report is the Trials Safety Plan for activities undertaken at RAAF Base Amberley as part of FABRAP under Task Air 07/053. The anticipated trial period is 25/10/2010 to 03/12/2010.

B.3. Overview of Activities

B.3.1 Testing in the F-111 Graveyard

DSTO proposes assessing repairs in-situ in the F-111 Graveyard at RAAF Base Amberley. DSTO aims to begin testing in late October through to early December. Depending on the progress, this work may recommence in February 2011 and continue until the aircraft are destroyed.

B.3.2 Testing in Bond Shop Facilities

In addition to the assessment of repairs in the graveyard, DSTO would also like the opportunity to retrieve panels held in storage. It is proposed that these panels would be sent to RAAF Base Amberley for testing in Bonded Structures Technology Team (BSTT) and/or Boeing bond shops. Smaller panels could be sent back to DSTO Melbourne to permit research to be undertaken using a wider range of NDI techniques.

B.4. Overview of Asbestos Hazards

Adhesives used in the manufacture of F-111 bonded panels are known to have contained asbestos as a high temperature reinforcing filler. Asbestos was also used as a filler in the liquid shim (cures hard) which was used during assembly to improve the fit between certain panels. In these cases, the asbestos is encapsulated within the adhesive or shim material.

For the purposes of the FABRAP, three groups of operations are considered to pose an asbestos hazard:

1. High speed cutting or grinding operations through adhesive or shim that contain asbestos will create dust and can liberate formerly encapsulated asbestos fibres. All bonded panels are to be treated as containing asbestos in the original adhesive layers. Any operations that require cutting through the original panel are considered to create an asbestos hazard.

2. Damaged panels with exposed adhesive potentially pose a risk of exposed asbestos. Although DSTO considers that asbestos remains encapsulated within the adhesive and that the risk of asbestos exposure is extremely low, DSTO will treat any bonded panels with through-skin damage as a potential asbestos hazard.

3. Removal of panels which were assembled using liquid shim exposes the shim material, and may also potentially expose asbestos. Although DSTO considers that asbestos remains encapsulated within the shim and that the risk of asbestos exposure is extremely low, DSTO will treat panels which used liquid shim during assembly as a potential asbestos hazard on removal from the aircraft. These panels are not considered a hazard when installed.

Any activities which may expose workers to asbestos are to be undertaken in an appropriate environment such as the BSTT and Boeing "dirty room" facilities, and work must be undertaken in a safe manner. DSTO proposes working in accordance with Boeing's Work Instructions for handling, storage and disposal of asbestos, WI-AMB-856 [2]. Additionally, Defence guidelines on asbestos management can be found in SAFETYMAN [vol 1, part 5, chapter 2] [3].

B.5. Full Description of Activities

B.5.1 Testing in the F-111 Graveyard

The types of repairs DSTO intends to test are doubler repairs. There are two main types:

- Potted doubler repairs
- Full or partial core repairs

B.5.1.1 Potted doubler repairs

Typically, damage is a dent to the skin showing no evidence of disbonding, or may be a repair to a monolithic metallic component, e.g. corrosion grind out repair. The metal is smoothed and any holes or indentations filled with a potting compound. An aluminium doubler is bonded over the potted area for stiffness reinforcement.

B.5.1.2 Full or partial core repair

Figure B.1 is adapted from AAP 7014.003-3B5 [4]. The only changes made to the original diagram are colours used to highlight the different types of adhesive used in this type of repair.

- Yellow adhesive denotes the original adhesive used in manufacture, e.g. AF-131 which contains asbestos.
- Grey adhesive denotes foaming adhesive used in core repairs, e.g. FM 404 NA
- Blue adhesive denotes adhesive (normally a structural film adhesive) used to bond on the doubler or repair plate, e.g. FM300

The installation of the repair would have involved cutting through the original panel, disturbing the asbestos-containing adhesive, and potentially exposing operators to loose asbestos fibres. However once the repair was in place, the original panel and any adhesive containing asbestos would have been re-encapsulated by the adhesives used in the repair. Since at least the early-1990s, adhesives used in Australian bonded repairs have not contained asbestos.

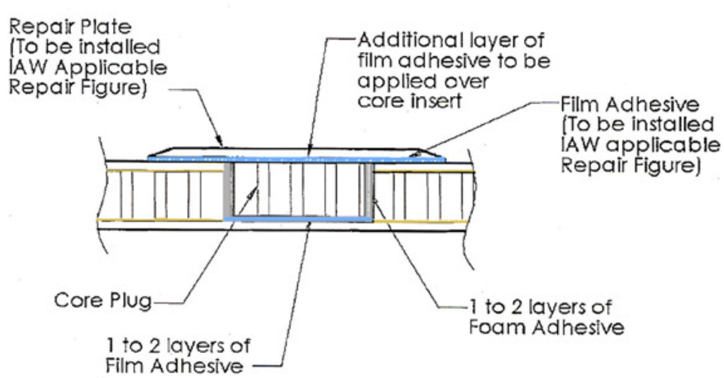


Figure B.1. Full core repair to bonded sandwich panel

DSTO intends to assess the repairs only, and not the original panel. The assessment includes destructive testing of the doubler/repair plate. The test involves bonding on test stubs, in order to test the residual strength of the bond which holds the doubler in place. Test stubs, half-inch in diameter, are bonded onto the doubler. A hole cutter is used to carefully cut through the doubler to the repair adhesive around this test stub to interrogate the condition of the doubler to panel skin bond only, without compromising the integrity of the original panel. Figure B.2 illustrates the test configuration.

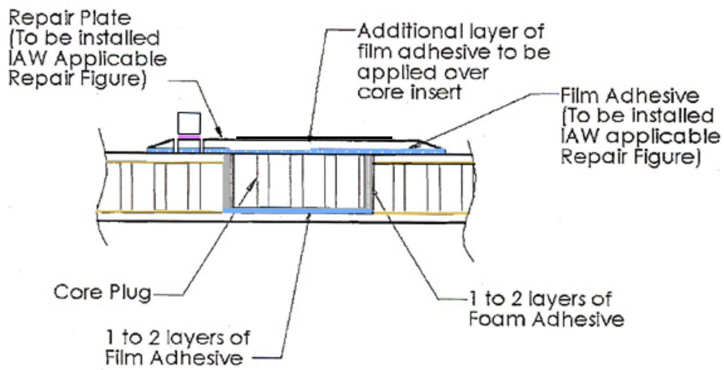


Figure B.2. Test stubs are bonded on for residual strength testing

When residual strength testing is complete, the doubler will be removed to enable visual assessment of the bond quality.

Figure B.3 shows the panel at the end of testing. Although the repaired core has been exposed, the original panel has not been breached in any way. The repaired section of core is isolated from the original panel by one or two layers of adhesive, therefore there is no exposure to the original adhesive used in construction. However, visible sections of open core may cause concern to casual onlookers, and DSTO is able to seal up any opened core sections using an aluminium doubler and sealant. This would also provide additional protection against impact damage during disposal activities.

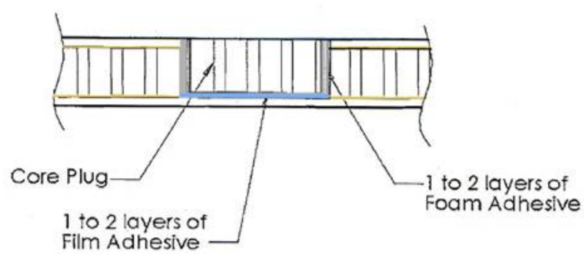


Figure B.3. At the end of testing, the doubler is peeled off for visual assessment of the adhesive bond

There is a small possibility that the original panel may have deteriorated in strength to the point that a pull-off test on the doubler area above the skin may cause a delamination of the original skin. Operators will undertake post-test NDI to determine if the original skin to honeycomb bond has been damaged. As the pull-off load is low, any skin delamination would be in a small area directly underneath the test stub. If there are any signs of skin delamination, the doubler will not be removed. This will ensure that there is no possible exposure to the original adhesive which may contain asbestos.

DSTO will test repairs for which paperwork is held or if the FM300 adhesive can be clearly identified at the doubler perimeter. The identification of FM300 is straight forward as it is the only repair adhesive used that has a light blue colour and it is known this adhesive began being used when the current RAAF repair processes were adopted. The paperwork should detail the repair procedure, including which adhesives were used. Repairs which used adhesives containing asbestos will not be tested.

B.5.1.3 Work Process Steps

1. Identify repairs to be tested – using available paperwork

2. NDI of repairs
    - Tap testing
    - Bondmaster – on selected repairs which provide an indication from the tap test
    - SAIC ultrasonic C-scan – on selected repairs
    - Thermography – on selected repairs

3. Photograph repairs, showing any areas which have been identified by NDI as having a suspect bond

4. Determine the areas on each repair which will be destructively tested

5. Clean the areas to be tested – doubler and also test stub
    - Scotchbrite/orbital sander or paint stripper removal of surface paint only in the location where the half inch stub is to be located– paint may contain chromates, strictly adhere to procedures outlined in risk assessment
    - Remove surface contaminants such as residual paint, oils or greases using a solvent. MEK or acetone are normally recommended for their superior solvent properties, but pose additional hazards when used outside of a fume cupboard/booth. Citrasafe is a non-toxic low volatile plant extract solvent which has been shown to be as efficient as MEK without the associated exposure hazards. It is planned to use Citrasafe for the current work.
    - Following solvent cleaning, surfaces are to be wiped down using distilled or deionised water to remove solvent residues

6. Roughen bonding surface
    - Use scotchbrite or alumina sanding paper rather than grit blasting
    - Clean surface again, using distilled water

7. Dry bonding surfaces using a hot air gun

8. Bond on test stubs
   - Prepare adhesive (EA 9309.3NA). Weigh out parts A and B in a mixing cup. Mix thoroughly until completely combined
   - Apply a thin layer of adhesive to both bonding surfaces
   - Press test stub onto doubler surface, push down to squeeze out excess adhesive
   - Tape down test stub to hold firmly in place until bonded
   - Allow to cure for 7 days at room temperature
   - It may be desireable to post-cure for 2 hours using a hot air gun

9. Route out doubler test area (the area under the stub)
   - Attach hole cutter into hand drill
   - Cut through doubler until reaching the blue of the FM300 adhesive, being sure to proceed very slowly once initial adhesive is identified.

10. Perform PATTI® or PASTI testing
    - PATTI® – Pneumatic Adhesion Tensile Testing Instrument, performs a pull-off tension test, measures flatwise tension strength of the bond
    - The piston is screwed on to the test stub. As the piston is pressurised using compressed air, the piston applies a tensile load on the test stub, normal to the surface. The PATTI® unit measures the air pressure applied, and records the maximum pressure.
    - PASTI – Pneumatic Adhesion Shear Testing Instrument, applies a torsional shear load to the test stub
    - Compressed air powers a torsional drive fixture. Only a small torsional movement is required to break off the test stub. The PATTI® unit is used to measure the maximum applied air pressure prior to failure.

11. Photograph failure surfaces and place the stubs in sealed, labelled bags

12. Tap test around PATTI® test sites to determine if there has been any damage to the underlying structure. If any skin-core delaminations are detected, no further work is to be undertaken on this repair.

13. Repeat application and testing of stubs if necessary (e.g. test locations too close together to allow multiple stubs to be applied simultaneously)

14. Remove doubler
    - Pry off the repair, using a plastic wedge and multigrips

15. Photograph failure surfaces and place the peeled doubler surface in a sealed, labelled plastic bag.

16. Cover up any holes left on airframe using an aluminium doubler and sealant, to provide protection to the panel surface in the event of unforeseen panel impacts during disposal operations.

B.5.2 Testing in Amberley Bond Shop Facilities

As with testing undertaken in the graveyard, the testing planned to be undertaken in bond shop facilities are on doubler repairs. The work will be undertaken within the BSTT Bond Shop or Boeing Bond Shop, depending on availability of the facilities.

The work process steps are identical to those for working in the graveyard, however some of the hazards are different. The hazards associated with working outdoors will not apply, but the bond shop environments have "dirty room" facilities which enable work to be undertaken on panels which have exposed asbestos.

B.6. Identification and Risk Assessment of Anticipated Hazards

Risk assessments have been written for the range of work to be performed as part of FABRAP, as described below. These risk assessments were written using the DSTO WorkingSAFER application and are documented in assessment number 1756.

B.6.1 Testing in the F-111 Graveyard

A full risk assessment for testing in the F-111 Graveyard can be found in Section B.16 and is documented in WorkingSAFER assessment number 1756. Five hazards were assessed as having a moderate risk, requiring further consideration on whether the risks are acceptable or require additional controls.

B.6.1.1 Exposure to chromates during removal of paint from repairs

Zinc chromate paint primer was commonly used on RAAF aircraft. Removal of paint could potentially expose personnel to hexavalent chromium, which is highly toxic. There are two acceptable methods of removing aircraft paint – by sanding, or using paint strippers.

Sanding may create a toxic dust hazard. Containment measures include using a 5 m exclusion zone, use of vacuum extraction to gather dusts, not working on high wind days, and wearing PPE such as disposable coveralls and a P3 filtered respirator.

Use of paint strippers removes the dust hazard, however paint stripper (TURCO 5351) is also toxic, containing dichloromethane and phenol, and the removed paint still contains a risk of exposure to chromate. Safety measures include holding the MSDS with the paint stripper, wearing a carbon filtered respirator, safety glasses, long sleeved protective clothing and gloves, and bagging up hazardous waste materials for specialist disposal.

It should be noted that as the area of paint removal is relatively small, only half inch to one inch diameter areas are need to be cleaned for each stub and only one or two stubs are applied for each repair. The total amount of material that would be removed for the whole exercise would be an area not likely to exceed more than 25 cm by 25 cm. The small amount of material, the limited exposure time and the use of safe working practices makes the health risks associated with this activity minimal.

In addition to the low exposure quantities, the control measures reduce the likelihood of exposure to rare. However, even very low exposure to chromates may cause health problems. The risk of the activity is therefore high.

The safety management procedures follow industry best practice, and when all measures have been followed, the likelihood of exposure is extremely rare. The risk is considered acceptable.

B.6.1.2 Uncontrollable exothermic reaction

The curing process is a normal exothermic reaction. Uncontrollable exothermic reactions can occur when larger quantities of resin are mixed and stored. To minimise the risk of an exotherm, mix only the amount of resin expected to be used within the pot life. Do not allow more than 5 mm depth of resin to sit unused at the bottom of mixing containers, as the build-up of heat may cause an uncontrolled exotherm. Instead, spread larger quantities of unused resin across a larger area, or immerse mixing containers in a quenching medium such as a large bucket of cold water.

The adhesive in use, EA 9309.3NA is fairly stable and not normally known to cause uncontrolled exotherms. The likelihood of a dangerous exotherm was assessed as rare. The consequence, however, is moderate, as it could generate hazardous smoke and heat causing burns, requiring medical treatment. The risk is therefore moderate.

On review of this hazard, it was decided to make it mandatory to have an exotherm quench bucket prepared and on hand at all times, for ready access at the first sign of any problems. An uncontrolled exotherm that is halted in the early stages poses little danger.

B.6.1.3 Mechanical – Gas cylinders supplied under high pressure.

Damage to the fittings at the top of the cylinder may cause air to be expelled extremely rapidly, causing propulsion of the cylinder. Cylinders are required to be restrained at all times to prevent a falling hazard and minimise the risk of accidental damage. Cylinders must only be transported using appropriate trolleys or other suitable transport.

The likelihood of cylinder damage is extremely rare, however gas under pressure has a large amount of energy, and the potential consequence of damage to a cylinder is moderate. The risk is therefore moderate.

Under normal controls, gas cylinders must always be restrained, whether in storage, in use, or during transport. Existing controls are considered adequate.

B.6.1.4 Work at heights

Above 2 metres holds an increased risk of injury due to falls.

Work at heights holds an increased risk of injury in the case of a fall. Any work undertaken above two metres will require the use of gantries or a cherry picker. Both these devices have side rails that provide a barrier, minimising the risk of falling from heights.

The likelihood of a fall would be extremely rare, however a fall could result in broken bones or concussion, which is a moderate consequence. The risk is therefore moderate.

On review of this hazard, it was determined that a safety harness must be worn by any personnel working above 2 metres height. The harness must be attached to a suitable anchor point. This will prevent falling if activities are performed according to the prescribed methods.

B.6.1.5 Insect and animal stings/bites

While most insect bites or stings are minor, in rare cases there could be serious reactions to insect or snake bites or stings. Two scenarios were considered, venomous spider or snake bites, and severe allergic reactions to bites or stings.

Insect repellent will be made available for staff use. Staff will be required to wear sturdy, steel capped boots as part of their normal work clothing, which will protect the feet and ankle area, which are common locations for snake and spider bites. First aid procedures will be made available in the first aid kit, e.g. symptoms to watch for, pressure immobilisation of known or suspect bite areas using broad bandages, calling for medical assistance.

Despite measures that will be in place, serious bites or stings are still a moderate risk, as although the likelihood of a serious bite or sting is rare, the consequence is moderate as hospitalisation may be required.

A review of the risks noted a few areas where early first aid intervention can minimise health consequences. Staff with known severe allergies will be required to supply medication for treatment, e.g. EpiPen. Instructions on dealing with anaphylaxis and venomous bites will be given as part of the Graveyard site induction. Written instructions will also be made available with the first aid kit.

B.6.1.6 Risk of electric shock

Only equipment which has been tested for electrical safety in the past 12 months can be used. Staff are to check electrical safety tagging of equipment before use. Work is not to be undertaken during rain showers, and equipment is to be dried before being reconnected to power sources and used.

Although the likelihood of electrocution is rare, the consequence is catastrophic, as it could result in death. Therefore the risk is high.

The control measures in place minimise the chance of electrocution, and the use of powerboards with built-in safety switches will virtually eliminate this possibility. The risk is considered acceptable.

B.6.2 Testing in BSTT and Boeing Bond Shop Facilities

A full risk assessment for testing in Amberley Bond Shop Facilities can be found in Section B.17. Three hazards were assessed as having a moderate risk, requiring further consideration on whether the risks are acceptable or require additional controls.

B.6.2.1 Asbestos

Damaged bonded panels are to be considered an asbestos hazard. Panels which used liquid shim during assembly are to be considered an asbestos hazard on removal from the aircraft. Any work on panels assessed to be an asbestos hazard will be undertaken in accordance with Boeing Work Instructions WI-AMB-856, annexe B [2]. Control measures include working in a “dirty room”, wearing appropriate PPE (including full face respirator with P3 filter), and double bagging of all contaminated waste, including contaminated PPE. For full details, refer to WI-AMB-856.

When all precautions have been taken, the likelihood of a dangerous exposure is rare, however the consequence is catastrophic as there is no treatment for many asbestos-related diseases. The risk is high.

FABRAP testing intends not to damage any adhesive or shim which may contain asbestos. In those cases where suspect adhesive or shim is exposed, Instant Airframe tape can be used to cover the exposed areas. Staff working with potential asbestos hazards must undergo an induction on safe work procedures, and any work will strictly adhere to the procedures detailed in WI-AM-856 [2]. When appropriate PPE is used while working in the dirty room environment, the possibility of exposure is far less than experienced in normal asbestos removal operations which are considered acceptable in this country. The risk is therefore considered acceptable.

B.6.2.2 Exposure to chromates during removal of paint from repairs

Zinc chromate paint primer was commonly used on RAAF aircraft. Removal of paint could potentially expose personnel to hexavalent chromium, which is highly toxic. There are two acceptable methods of removing aircraft paint – by sanding, or using paint strippers.

Sanding may create a toxic dust hazard. Containment measures include working in a dirty room or using a 5 m exclusion zone, use of vacuum extraction to gather dusts, and wearing PPE such as disposable coveralls and a P3 filtered respirator.

Use of paint strippers removes the dust hazard, however paint stripper chemicals are hazardous, and the removed paint still contains a risk of exposure to chromate. Safety measures include holding the MSDS with the paint stripper, working in an extraction booth, wearing a carbon filtered respirator, safety glasses, long sleeved protective clothing and gloves, and bagging up hazardous waste materials for specialist disposal.

Although control measures reduce the likelihood of exposure to rare, even low exposure to chromates can cause health problems with major consequences. The risk is therefore high.

The safety management procedures follow industry best practice, and when all measures have been followed, the likelihood of exposure is extremely rare. The risk is considered acceptable.

B.6.2.3 Mechanical – Gas cylinders supplied under high pressure.

Damage to the fittings at the top of the cylinder may cause air to be expelled extremely rapidly, causing propulsion of the cylinder. Cylinders are required to be restrained at all times to prevent a falling hazard and minimise the risk of accidental damage. Cylinders must only be transported using appropriate trolleys or other suitable transport.

The likelihood of cylinder damage is extremely rare, however gas under pressure has a large amount of energy, and the potential consequence of damage to a cylinder is moderate. The risk is therefore moderate.

Under normal controls, gas cylinders must always be restrained, whether in storage, in use, or during transport. Existing controls are considered adequate.

B.6.2.4 Risk of electric shock

Only equipment which has been tested for electrical safety in the past 12 months can be used. Staff are to check electrical safety tagging of equipment before use.

Although the likelihood of electrocution is rare, the consequence is catastrophic, as it could result in death. Therefore the risk is high.

If safety switches are not installed in the facilities, use powerboards with built-in safety switches, to virtually eliminate the possibility of electrocution. The risk is considered acceptable.

B.7. Authorities and responsibilities

Trials Director – Greg Bain, AVD, 03 9626 8574
Trials Officer – Eudora Yeo, AVD, 03 9626 7172
Trials Safety Officers – Ivan Stoyanovski, AVD, 03 9626 7524
– David Dellios, AVD, 03 9626 8095

Trials Personnel will be rotated from a pool of 6-8 participants plus two RAAF personnel

1. NDI Officer, will be RAAF personnel from 6 Squadron
2. Senior Technical Officer – Ivan Stoyanovski / David Dellios
3. Technical Officer – to be determined
4. Documentation/Photography – other personnel, to be determined
5. NDTSL additional staff as available for thermography and ultrasonic c-scan (optional)

Trials personnel will be required to sign a document indicating that they have read, understood and agreed to comply with the Trials Safety Plan (see Section B.18)

B.8. Staffing and training related to safety on the trial

Staff will require an induction into the F-111 Graveyard Site. DSTO will provide an induction based on the above risk assessment. An additional site induction will be given by Boeing on behalf of SRSPO, including information on evacuation and emergency muster points. As the F-111 Graveyard Site will be supervised by Boeing, work cannot be conducted without the approval of Boeing staff. Staff performing the roles of Trials Technical Officers must have prior induction to the DSTO Integrated Composites Facilities (ICF), or other relevant experience as approved by the Senior Technical Officer. Any staff who do not have ICF competency can only perform bonding and test operations if approved by the Senior Technical Officer, and may require additional induction, training or supervision.

Any work to be undertaken in BSTT or Boeing facilities will require the approval of the respective Facility Managers. There will be separate inductions for any work undertaken in BSTT and Boeing facilities.

Certain specialised equipment cannot be operated without a licence, e.g. forklift, crane, elevated work platform. Staff must not operate these pieces of equipment unless licensed. Approved contractors will be hired to assist where needed.

B.9. Medical clearances required for trials personnel

Medical clearances are not necessarily required, but health surveillance is required because of the risk of exposure to chromates.

An emergency information form is required for each participant, providing health, medication and next of kin details for use in an emergency. A sample form is included in Section B.19. This form will be destroyed at the conclusion of the trials.

B.10. Safety equipment required

- Steel capped safety boots with anti-static soles
- Lab coats or other long sleeved protective clothing
- Latex rubber gloves
- UV-protective and tinted safety glasses
- Wide-brimmed hats

- Sunscreen
- Insect repellent
- Respirator with carbon and P3 filters
- Earplugs
- Harnesses for working at heights
- Eye wash solution – at least 2 x 1L bottles
- Chemical spill kit
- Fire extinguisher(s)

For work in "dirty room" facilities:
- Respirator with P3 filter
- Tyvek coverall suits
- Latex rubber gloves
- Steel capped safety boots
- Boot covers
- Earplugs

B.11. Routine or Special Safety Procedures

Routine safety procedures will be followed as outlined in the Job Safety Analysis.

When working in the F-111 Graveyard, adhere to any safety procedures as directed by SRSPO, including emergency procedures.

When working in BSTT or Boeing work areas, adhere to safety procedures as directed by their Facility Managers, including emergency procedures.

B.12. First aid requirements

All staff working within the F-111 Graveyard will have basic instruction on how to respond to identified hazards. There is no need for trials personnel to have formal first aid training as there is a medical centre on site, and serious injuries will be referred to Ipswich Hospital. If the on-site emergency number is unavailable due to an aircraft emergency, dial 000 for assistance.

Emergency numbers			
Medical	07 5361 2444	or	*7444
Fire	07 5361 2333	or	*7333
Service Police	07 5361 2555	or	*7555
Front Gate Security	07 5361 2614		
After Hours	000		
Ipswich Hospital	07 3810 1111		

A first aid kit will be held on site whilst working in the F-111 Graveyard. The first aid kit contents will include:
- Disposable gloves (various sizes)

- Space blanket
- Band aids
- Elastic adhesive plaster tape
- Non-adherent dressings
- Wound dressings
- Gauze swabs
- Antiseptic swabs
- Safety pins
- Scissors
- Dressing tray
- Cotton crepe bandages
- Broad crepe bandages (for snake bites)
- Triangular bandage
- Cold/hot pack
- Biohazard waste bags and ties
- Resus O Mask
- CPR & Infections diseases module
- Antihistamine ointment
- Sprain ointment
- Note pad and pencil
- Emergency first aid instructions for identified hazards

B.13. Reporting requirements

All incidents and dangerous occurrences shall be reported to the Trials Safety Officer and addressed in the post-trial OH&S report, template in Section B.20. Copies of AC563 Defence OHS Incident Report to be held by the Trials Safety Officer.

Any fatalities are to be reported by telephone to OHSC and Comcare within 2 hours of personnel becoming aware of the fatality.

Serious injuries and dangerous occurrences are to be notified to OHSC and Comcare by fax using Part 1 form AC563 within 24 hours of the commander or manager becoming aware of the incident.

OHSC telephone: 1800 019 955, fax: 1800 563 563, <ac563@defence.gov.au >
Comcare telephone: 1300 366 979, fax: 1300 305 916

Traumatic Incident and Crisis Counselling is available through the Employee Assistance Program on 1800 451 138.

B.14. Communication Requirements

A list of mobile telephone numbers for trials personnel will be made available to the SRSPO host and DSTO managers. There is good mobile phone coverage outdoors at RAAF Base

Amberley, and mobile phones will be used for most communications. Fixed line telephones are also available across the site.

B.15. Environmental Requirements

Hazardous waste, whether solid or liquid, must be sealed in appropriate containers, clearly labelled, and MSDS provided. Disposal will be through private contractors equipped to handle hazardous waste.

B.16. Job Safety Analysis - Testing in the F-111 Graveyard

Task Title: FABRAP Repair assessment in the F-111 Graveyard
Location: F-111 Graveyard, RAAF Base Amberley

Ste p	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
1	Identify repairs to be tested – using available paperwork				
2	NDI of repairs a) Tap testing b) Bondmaster c) SAIC ultrasonic C-scan d) Flash thermography	d) Flash thermography uses a bright light to heat the test article. Looking directly at the light source may cause temporary flash blindness	d) Use screens or blankets to prevent people from looking directly at the light source	d) L = Rare C = Minor **Risk = Low**	
3	Photograph repairs, showing any areas which have been identified by NDI as having a suspect bond				
4	Determine the areas on each repair which will be destructively tested by PATTI or PASTI				
5	Clean the areas to be tested – doubler and also test stub a) Scotchbrite/orbital sander OR paint stripper removal of surface paint	a) Sanding operations may create a chromate dust hazard, chromates are highly toxic. Sanding operations may liberate small flying particles.	a) Wear disposable coveralls, disposable gloves, safety glasses and face mask with P3 filter. Maintain a 5m exclusion zone of the area using barriers and signage. Use a portable pneumatic explosion proof vacuum extraction system, with	a) L = Rare C = Major **Risk = High**	Paint removal using paint stripper would be the preferred option, as the chromate hazard is much easier to contain. Use of containment

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
		TURCO 5351 paint stripper is a toxic chemical, and waste product may contain toxic chromates.	Hepa filtration and 18 cmps flow rate, to gather dust from sanding operations. If paint stripper is used, supply MSDS for chemicals, wear carbon filtered respirator, safety glasses, long sleeved protective clothing, and gloves as recommended in MSDS.		measures and PPE is sufficient to control the risk
	b) Remove surface contaminants such as residual paint, oils or greases using a solvent. c) Following solvent cleaning, surfaces are to be wiped down using distilled or deionised water to remove solvent residues	b) MEK is commonly used for this work but is an irritant, harmful on skin contact, and liberates hazardous fumes. MEK is flammable, so care must be taken to prevent sparks or flames in the work area. Consider using other solvents.	b) Store MSDS with chemicals. Wear carbon filtered respirator, safety glasses, long sleeved protective clothing, and two pairs of Gammex latex gloves, replacing gloves every five minutes. Wear anti-static shoes. Consider using a dibasic ester solvent which is safer (but may not be as good at cleaning). Store solvent-soaked cleaning tissues for at least four hours in a well ventilated, covered wire bin. Label bin as “Flammable” and list solvents. When solvent has completely evaporated, the tissues can be disposed of as regular waste. No smoking in the Graveyard work area.	b) L = Unlikely C = Minor **Risk = Low**	Citrasafe will be the preferred solvent as it will remove need for respiratory protection. Hand and eye protection are still required, and Citrasafe is also flammable.

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
6	Roughen bonding surface a) Use scotchbrite or alumina sanding paper rather than grit blasting b) Clean surface again with distilled water	a) Sanding operations will create dust and may liberate small flying particles	a) Wear safety glasses and a dust mask	a) L = Rare C = Minor **Risk = Low**	
7	Dry bonding surfaces using a hot air gun	Hot air guns can reach very high temperatures.	Do not direct hot air guns at people. Wear thermally insulating gloves during use and when handling heated panels. Take care not to touch affected panels until they have cooled to below 50˚C. If hot panels are left unattended, post a sign alerting other staff of the heat hazard.	L = Unlikely C = Minor **Risk = Low**	
8	Bond on test stubs a) Prepare adhesive (EA 9309.3NA). Weigh out parts A and B in a mixing cup. Mix thoroughly until completely combined	a) This adhesive is a sensitising agent, corrosive agent, irritant, and has hazardous vapours. The curing process is a normal exothermic reaction. Uncontrollable exothermic reactions can occur when larger quantities of resin are mixed and stored.	a) Store MSDS with chemicals. Wear safety glasses, carbon filtered respirator, long sleeved protective clothing, and Gammex latex gloves. To minimise the risk of an exotherm, mix only the amount of resin expected to be used within the pot life (35 minutes). Do not allow more than 5 mm depth of resin to sit unused at the bottom of mixing containers, as the build-up of heat may cause an uncontrolled exotherm. Instead, spread larger quantities of unused resin across a larger area, or immerse mixing	a) Chemical L = Unlikely C = Minor **Risk = Low** Exotherm L = Rare C = Moderate **Risk=Moderate**	Have an exotherm quench bucket prepared and on hand at all times. This gives ready access at the first sign of any problems. Consider whether the purchase of a part A and Part B dual syringe auto mixer will be advantageous.

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
	b) Using a spatula, apply a thin layer of adhesive to both bonding surfaces c) Press test stub onto doubler surface, push down to squeeze out excess adhesive, wipe off excess d) Tape down test stub to hold firmly in place until bonded. e) Allow to cure for at least 7 days f) It may still be desireable to post-cure for 2 hours using a hot air gun	f) Hot air guns can reach very high temperatures.	containers in a quenching medium such as a large bucket of cold water. b) Waste materials in contact with adhesive are to be bagged and labelled, and stored until the adhesive is cured. They can then be disposed of as regular waste. f) Do not direct hot air guns at people. Wear thermally insulating gloves during use and when handling heated panels. Take care not to touch affected panels until they have cooled to below 50˚C. If hot panels are left unattended, post a sign alerting other staff of the heat hazard.	b) L = Unlikely C = Minor **Risk = Low** f) L = Unlikely C = Minor **Risk = Low**	
9	Route out doubler test area (the area under the stub) a) Using a hand drill with hole cutter attachment, cut through doubler to adhesive, through to the panel skin only	a) Hole cutting operations may release high velocity particles.	a) Operators and other staff working nearby are required to wear safety glasses, long-sleeved clothing and steel cap boots.	a) L = Unlikely C = Minor **Risk = Low**	

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
10	a) Perform PATTI® testing. The piston is screwed on to the test stub. As the piston is pressurised using compressed air, the piston applies a flatwise tensile load on the test stub, normal to the surface.	a) There is a small risk that the piston will eject away from the aircraft on failure of the test piece. The speed of ejection is typically quite low, as some energy is absorbed by the weight of the piston, and the piston can be easily caught by a watchful operator.	a) PATTI operators are to ensure that other staff are aware of test operations and keep clear of the area. The test must supervised closely during load application. Steel cap boots are to be worn by staff at all times.	a) L = Unlikely C = Minor **Risk = Low**	
	b) Perform PASTI testing. The torsional drive fixture is attached to the test stub, and powered by compressed air. The PATTI® unit is used to measure the applied air pressure	b) The PASTI fixture remains attached to the aircraft for the entire duration of testing.			
	c) PATTI® and PASTI tests use compressed nitrogen gas to apply test loads	c) Gas cylinders are supplied under high pressure. Damage to the fittings at the top of the cylinder may cause air to be expelled extremely rapidly, causing propulsion of the cylinder. Falling cylinders can cause injury due to their weight.	c) Cylinders are required to be restrained at all times to prevent a falling hazard, and minimise the risk of accidental damage. Cylinders must only be transported using appropriate trolleys or other suitable transport.	c) L = Rare C = Moderate **Risk=Moderate**	Existing controls are adequate.

Ste p	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
11	Photograph failure surfaces				
12	Tap test around PATTI® test sites to determine if there has been any damage to the underlying structure. If any skin-core delaminations are detected, no further work is to be undertaken on this repair				
13	If necessary, repeat steps 5 to 10 above. May be required if test locations are too close to allow multiple stubs to be applied simultaneously.				
14	Remove doubler a) Pry off the doubler, using a plastic wedge and multi-grips	a) The motion of tools used to pry off doublers may cause injury if hands or other parts of the body are in the way, e.g. tool slip	a) Operators are to ensure that other staff are well clear of the doubler area before removal and use protective gloves to avoid cuts from sharp or peeled edges	a) L = Unlikely C = Minor **Risk = Low**	
15	Photograph failure surfaces				
16	Seal up any holes left on panels using an aluminium doubler and sealant.				
			General hazards		
	Ergonomics Work on aircraft may require operators to work under non-ideal conditions, e.g. working on undersides of panels, reaching away from the body	Working in unergonomic positions, particularly repetitive work for prolonged periods, may cause strain injuries	Site induction will include advice on taking regular stretching breaks and minimising non-ergonomic positions by use of equipment such as steps, gantries or cherry pickers where	L = Unlikely C = Minor **Risk = Low**	

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
	due to limited access, leaning, etc		possible.		
	Manual handling This part of the work does not use individual items which are heavy. However equipment may be packed in larger and heavier boxes for transport.	Lifting heavy loads may cause injury	Staff are not to lift objects heavier than 20 kg unless they have undergone training in safe manual handling procedures. Staff are not to lift objects heavier than 30 kg without the assistance of lifting aids. Steel capped shoes must be worn. Lifting aids such as pallet trucks, forklifts or cranes are to be used for moving or lifting heavy objects	L = Unlikely C = Minor **Risk = Low**	
	Fatigue Staff will be performing manual duties throughout the day, and are likely be working in warm and humid conditions, which increases fatigue.	Fatigue increases the likelihood of making errors, which could cause unsafe conditions. Extended fatigue can cause ill health.	Staff will be provided with ample supplies of drinking water, and will be instructed to take breaks of at least 30 minutes every two hours. If the work environment temperature exceeds 30 degrees, rest breaks must be more frequent. The conditions that cause heat stress cannot be defined by a simple formula, so workers will be advised to take breaks as needed, including stopping work entirely if the temperature and humidity causes great discomfort. It may be possible to arrange for alternative work on hot days, which can be performed indoors in BSTT or Boeing airconditioned facilities.	L = Unlikely C = Minor **Risk = Low**	

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
			Outdoor work will not be performed in the rain, except for very light showers. There may be a need to set up a shelter close the work area.		
	Slip/trip/fall The F-111 Graveyard is at the edge of the tarmac, and some aircraft components overhang the grassed area. Staff may be required to work on the grassed area which is slightly uneven.	There is an increased chance of tripping on uneven surfaces. Equipment such as steps may be unstable on uneven surfaces.	Staff will be instructed to take extra care when working close to tarmac edges or on grassed areas, and steps can only be used in these areas if they are stable.	L = Unlikely C = Minor **Risk = Low**	
	Confined space Work in the Graveyard may require staff to work in confined spaces, for example, aircraft are located in close proximity of each other, and accessing some repairs will require squatting, kneeling, or working underneath aircraft components.	Working in close conditions increases the risk of head bump injury, or even of stepping backwards into unguarded components.	The work site will be assessed for sharp bump hazards, which will be padded as required. Helmets will be provided for use.	L = Unlikely C = Minor **Risk = Low**	
	Working at heights Some repairs are on elevated components. As it is desirable to test as many repairs as possible, there may be a need to access these repairs.	Work above 2 metres holds an increased risk of injury due to falls	Any work undertaken above two metres will require the use of gantries or a cherry picker. These devices have side rails that provide a barrier, minimising the risk of falling from heights. Operators working at heights will be required to wear a helmet. Do not work at	L = Rare C = Moderate **Risk=Moderate**	Additionally, wear a safety harness that is secured to an appropriate attachment point.

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
			heights on high wind days as there is an increased risk of falling. High winds may also cause chemical containers to topple over, which may lead to a hazardous spill.		
	Noise There are many sources of intermittent noise. These may include aircraft in neighbouring hangars, use of powered tools, and failure of test piece under high load.	High dB and sustained, mid-level dB sounds can cause hearing loss.	Disposable earplugs will be made available for use. Staff will be required to wear earplugs when performing work which creates a known noise hazard, e.g. certain cutting operations. Staff will be advised to wear earplugs when the noise level is lower but is constant.	L = Unlikely C = Minor **Risk = Low**	
	Ultraviolet exposure Outdoor work, even on cloudy days, will expose staff to UV radiation.	Exposure to UV radiation can cause sunburn, contributing to heat stroke.	Sunscreen, wide brim hats, and tinted, UV-protective safety glasses will be provided for use. Long sleeve clothing is already required for some tasks, but long sleeve, loose clothing is recommended to be worn between 11am-3pm. Staff may be able to make working arrangements to minimise sun exposure, e.g. work on shaded side of aircraft, or on under-side components during the middle of the day.	L = Unlikely C = Minor **Risk = Low**	
	Animal/insect bites and stings a) Work during warmer months will expose staff to increased insect attack from mosquitoes, bees,	a) Insect bites and stings may cause pain and/or itching with varying severity, and	a) Insect repellent to be made available for staff use. A first aid kit containing tweezers, antihistamine ointments,	Minor bites/stings L = Unlikely C = Minor **Risk = Low**	Staff with known severe allergies are required to supply medication for

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
	ants, flies, spiders, etc. b) There are many areas on site with long grass, including fields immediately surrounding the Graveyard. This poses a risk of snakes.	anaphylactic reaction in those with allergies. Spider and some insect bites may be venomous. b) If disturbed, snakes may bite. Even non-venomous bites can cause wounding and infection.	bandages, etc. to be carried when working in the Graveyard. Staff will be instructed on local base procedures for calling for medical assistance if necessary. b) Staff will be required to wear sturdy, steel capped boots as part of their normal work clothing, to protect the feet and ankle area which is the most common location for snake bites. Detailed first aid procedures will be made available in the first aid kit, e.g. symptoms to watch for, pressure immobilisation of known or suspect bite areas using bandages, call for medical assistance.	Serious bites/stings L = Rare C = Moderate **Risk=Moderate**	treatment, e.g. EpiPen. Instructions on dealing with anaphylaxis and venomous bites will be given as part of the Graveyard site induction. Written instructions will also be made available with the first aid kit.
	Energised electrical equipment	Risk of electric shock	Only equipment which has been tested for electrical safety can be used. Staff are to check electrical safety tagging before use. Work is not to be undertaken during rain showers. Equipment is to be dried before being reconnected and used.	L = Rare C= Catastrophic **Risk = High**	Use powerboards with built-in safety switch to prevent electrocution.
	Biological allergens The F-111 Graveyard is located near large expanses of grass and trees.	Outdoor work during hayfever seasons may expose workers to pollen allergens.	Staff with known allergies will be advised to prepare by using antihistamine medication where necessary. Staff with severe allergies may not be able to participate during peak hayfever periods.	L = Unlikely C = Minor **Risk = Low**	

B.17. Job Safety Analysis – Testing in a Bond Shop Environment

Task Title: FABRAP repair assessment in a bond shop environment
Location: BSTT or Boeing Bond Shops, RAAF Base Amberley

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
1	Identify repairs to be tested using available paperwork	Lifting heavy or unwieldy panels may cause injury	Staff are not to lift objects heavier than 20 kg unless they have undergone training in safe manual handling procedures. Staff are not to lift objects heavier than 30 kg without the assistance of lifting aids. Steel capped shoes must be worn. Lifting aids such as pallet trucks, forklifts or cranes are to be used for moving or lifting heavy objects	L = Unlikely C = Minor **Risk = Low**	
2	Identify whether panels pose an asbestos hazard	Damaged bonded panels and removed panels which used liquid shim during assembly are to be considered an asbestos hazard	Work will be undertaken in accordance with Boeing Work Instructions WI-AMB-856, annexe B [3]. Control measures include working in a "dirt room", wearing appropriate PPE (including full face respirator with P3 filter), and double bagging of all contaminated waste, including contaminated PPE. For full details, refer to WI-AMB-856.	L = Rare C= Catastrophic **Risk = High**	Strictly adhere to procedures detailed in WI-AM-856 [2]. Staff working with potential asbestos hazards must undergo an induction on safe work procedures.
3	NDI of repairs a) Tap testing b) Bondmaster c) SAIC ultrasonic C-scan d) Flash thermography	d) Flash thermography uses a bright light to heat the test article. Looking directly at the light source may cause temporary flash	d) Use screens or blankets to prevent people from looking directly at the light source	d) L = Rare C = Minor **Risk = Low**	

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
		blindness			
4	Photograph repairs, showing any areas which have been identified by NDI as having a suspect bond				
5	Determine the areas on each repair which will be destructively tested by PATTI or PASTI				
6	Clean the areas to be tested – doubler and also test stub a) Scotchbrite/orbital sander OR paint stripper removal of surface paint b) Remove surface contaminants such as residual paint, oils or greases using a solvent.	a) Sanding operations may create a chromate dust hazard, chromates are highly toxic. Sanding operations may liberate small flying particles. Paint stripper is a hazardous chemical, and waste product may contain toxic chromates. b) MEK or acetone are commonly used for this work as they are very strong solvents. These solvents are irritants, harmful on	a) Sanding/grinding work will be undertaken in accordance with Boeing Work Instructions WI-AMB-101, annexe D. Control measures including wearing full body protection and use of a vacuum extraction system with Hepa filtration to gather dust from sanding operations. If paint stripper is used, supply MSDS for chemicals, wear carbon filtered respirator, safety glasses, long sleeved protective clothing, and gloves as recommended in MSDS. b) Store MSDS with chemicals. Work only in a ventilated area, e.g. fume hood. Wear safety glasses, long sleeved protective clothing, and two pairs of Gammex latex gloves, replacing gloves every five	a) L = Unlikely C = Minor **Risk = High** b) L = Unlikely C = Minor **Risk = Low**	Paint removal using paint stripper would be the preferred option, as the chromate hazard is much easier to contain. Use of containment measures and PPE is sufficient to control the risk

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
	c) Following solvent cleaning, surfaces are to be wiped down using distilled or deionised water to remove solvent residues	skin contact, and liberate hazardous fumes. They are also flammable, so care must be taken to prevent sparks or flames in the work area.	minutes. Store solvent-soaked cleaning tissues for at least four hours in a well ventilated, covered wire bin. Label bin. When solvent has completely evaporated, the tissues can be disposed of as regular waste.		
7	Roughen bonding surface a) Grit blast surfaces b) Clean surface again with distilled water	a) Grit blasting operations will create dust and small flying particles	a) Wear safety glasses and a dust mask	a) L = Rare C = Minor **Risk = Low**	
8	Dry bonding surfaces using a hot air gun or oven	Hot air guns can reach very high temperatures. Ovens typically set at 110˚C	Do not direct hot air guns at people. Wear thermally insulating gloves during use and when handling heated panels. Take care not to touch affected panels until they have cooled to below 50˚C. If hot panels are left unattended, post a sign alerting other staff of the heat hazard.	L = Unlikely C = Minor **Risk = Low**	
9	Bond on test stubs a) Prepare adhesive (EA 9309.3NA). Weigh out parts A and B in a mixing cup. Mix thoroughly until completely combined	a) This adhesive is a sensitising agent, corrosive agent, irritant, and has hazardous vapours. The curing process is a normal exothermic reaction. Uncontrollable exothermic reactions can occur when larger	a) Store MSDS with chemicals. Wear safety glasses, long sleeved protective clothing, and Gammex latex gloves. Work in a ventilated booth. To minimise the risk of an exotherm, mix only the amount of resin expected to be used within the pot life (35 minutes). Do not allow more than 5 mm depth of resin to sit unused at the bottom of	a) Chemical L = Unlikely C = Minor **Risk = Low** Exotherm L = Rare C = Minor **Risk = Low**	

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
	b) Using a spatula, apply a thin layer of adhesive to both bonding surfaces c) Press test stub onto doubler surface, push down to squeeze out excess adhesive, wipe off excess d) Tape down test stub to hold firmly in place until bonded. e) Allow to cure for at least 24 hours f) It may be desireable to post-cure for 2 hours using an oven or hot air gun	quantities of resin are mixed and stored. f) Hot air guns can reach very high temperatures.	mixing containers, as the build-up of heat may cause an uncontrolled exotherm. Instead, spread larger quantities of unused resin across a larger area, or immerse mixing containers in a quenching medium such as a large bucket of cold water. b) Waste materials in contact with adhesive are to be bagged and labelled, and stored safely until the adhesive is cured. They can then be disposed of as regular waste. f) Do not direct hot air guns at people. Wear thermally insulating gloves during use and when handling heated panels. Take care not to touch affected panels until they have cooled to below 50˚C. If hot panels are left unattended, post a sign alerting other staff of the heat hazard.	b) L = Unlikely C = Minor **Risk = Low** f) L = Unlikely C = Minor **Risk = Low**	
10	Route out doubler test area a) Using a hand drill with hole cutter attachment,	a) Hole cutting operations may	a) Operators and other staff working nearby are required to wear safety	a) L = Unlikely C = Minor	

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
	cut through doubler and adhesive, through to the panel skin (or the repaired core, depending on location of stub)	release high velocity particles.	glasses, long-sleeved clothing and steel cap boots.	**Risk = Low**	
11	a) Perform PATTI® testing. The piston is screwed on to the test stub. As the piston is pressurised using compressed air, the piston applies a flatwise tensile load on the test stub, normal to the surface. b) Perform PASTI testing. The torsional drive fixture is attached to the test stub, and powered by compressed air. The PATTI® unit is used to measure the applied air pressure. c) PATTI® and PASTI tests use compressed nitrogen gas to apply test loads	a) The risk of the piston ejecting away from the test panels is much smaller than with on-aircraft testing, as removed panels can be positioned more safely. The speed of ejection would be very low. c) Gas cylinders are supplied under high pressure. Damage to the fittings at the top of the cylinder may cause air to be expelled extremely rapidly, causing propulsion of the cylinder. Falling	a) PATTI operators are to ensure that other staff are aware of test operations and keep clear of the area. The test must supervised closely during load application. Steel cap boots are to be worn by staff at all times. c) Cylinders are required to be restrained at all times to prevent a falling hazard, and minimise the risk of accidental damage. Cylinders must only be transported using appropriate trolleys or other suitable transport.	a) L = Unlikely C = Minor **Risk = Low** c) L = Rare C = Moderate **Risk=Moderate**	c) Existing controls are adequate.

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
		cylinders can cause injury due to their weight.			
12	Photograph failure surfaces				
13	Tap test around PATTI® test sites to determine if there has been any damage to the underlying structure. If any skin-core delaminations are detected, assess whether work should be halted or continued in a dirty room – see step 2 above.				
14	If necessary, repeat steps 5 to 10 above. May be required if test locations are too close to allow multiple stubs to be applied simultaneously.				
15	Remove doubler a) Heat the repair using a heater gun to soften the adhesive (optional) b) Pry off the doubler, e.g. using a wedge	a) Hot air guns can reach very high temperatures. b) The motion of tools used to pry off doublers may cause injury if hands or other	a) Do not direct hot air guns at people. Wear thermally insulating gloves. Take care not to touch affected panels until they have cooled to below 50˚C. If hot panels are left unattended, post a sign alerting other staff of the heat hazard b) Operators are to ensure that other staff are well clear of the doubler area before removal	a) L = Unlikely C = Minor **Risk = Low** b) L = Unlikely C = Minor **Risk = Low**	

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
		parts of the body are in the way, e.g. tool slip			
16	Photograph failure surfaces				
17	Seal up any holes left on panels using an aluminium doubler and Instant Aircraft tape.				
General hazards					
	Ergonomics Work on larger panels may require operators to work in non-ideal positions, e.g. leaning or reaching	Working in unergonomic positions, particularly repetitive work for prolonged periods, may cause strain injuries	Site induction will include advice on taking regular stretching breaks and minimising non-ergonomic positions by use of equipment such as steps where practical.	L = Unlikely C = Minor **Risk = Low**	
	Fatigue Staff may feel the need to work long days in order to maximise the testing opportunities.	Fatigue increases the likelihood of making errors, which could cause unsafe conditions. Extended fatigue can cause ill health.	Staff will be instructed to take breaks of at least 30 minutes every two hours. Staff performing physically demanding tasks will be discouraged from working more than 8.5 hours a day.	L = Unlikely C = Minor **Risk = Low**	
	Noise There are many sources of intermittent noise in the bond shop environment. These may include metal forming operations, use of powered tools, and failure of test piece under high load.	High dB and sustained, mid-level dB sounds can cause hearing loss.	Disposable earplugs will be made available for use. Staff will be required to wear earplugs when working in areas with noise hazards.		

Step	Description of job and/or task step	Hazard	Controls	Risk Rating (Likelihood & Consequence)	Further controls (For risks that are Moderate or higher)
	Energised electrical equipment	Risk of electric shock	Only equipment which has been tested for electrical safety can be used. Staff are to check electrical safety tagging before use.	L = Rare C= Catastrophic **Risk = High**	If safety switches are not installed in the facilities, use powerboards with built-in safety switches.

B.18. Trials Consent Form

I, ……………………………………………………………………………………………………… ,

have read, understood and agreed to comply with the F-111 Adhesively Bonded Repair Assessment Program (FABRAP) Trials Safety Plan, as documented in DSTO-CR-2010-0388, for the duration of my time working on FABRAP activities at RAAF Base Amberley.

Signed: ……………………………………………………. Dated: ……………………………….

B.19. Emergency Information Form

*NAME:*____*Employeee ID*__________

*NEXT OF KIN:*____________________________________*PH* ________________

1. Do you suffer from any medical conditions?

{ } NO
{ } YES
(Please indicate condition (s)______________________________________

____

2. Are you receiving any medical treatment by a doctor, physiotherapist or chiropractor?

{ } NO
{ } YES If yes, name and number of treating practitioner____________________

3. List any allergies {including food}

{ } NO
{ } YES
(Please indicate)____

4. Are you taking any medication prescribed or otherwise?

{ } NO
{ } YES
(Please list)____

____

5. If taking medication and bringing it on trial, do you have sufficient to last the duration of the trial?

{ } NO
{ } YES
(Please give details)____

6. Is there any information contained in the above of a confidential nature, which if disclosed, could affect you adversely?

{ } NO
{ } YES

Please hand competed form to Trials Safety Officer

THIS FORM WILL BE DESTROYED ON COMPLETION OF THE TRIAL

B.20. Post Trials Safety Report:

TRIALS DATE: .... to ....

SPNSR/Task No: ..../.........

The **Trials Safety Officer** shall provide a post trials safety report to the AVD Occupational Health and Safety Committee Secretary ref *AVD OHS Committee Contacts* on conclusion of trials for consideration by the AVD OHSC.

B.20.1 Breach of Procedures:

<Insert text>

B.20.2 Minor Injuries:

<Insert text>

B.20.3 Serious Personal Injuries:

<Insert text>

B.20.4 Dangerous Occurrences:

<Insert text>

B.20.5 Lessons Learnt:

<Insert text>

B.20.6 Other Comments:

<Insert text>

B.20.6.1 Post Trials Safety Report Sign-off:

Trials Safety Officer		
Signature:................................	Name:	Date:............

Appendix C: FABRAP Phase I Test Procedure

Stub identification, non-destructive inspection, surface preparation and bonding was performed in batches of 50.

All of the testing described in this Appendix was conducted in accordance with the Trials Safety Plan shown as Appendix B. Appendix C includes most, but not all, of the measures used to ensure occupational health and safety. A comprehensive description of these is given in Appendix B.

C.1. Identification

C.1.1 Locate patch

Locate all adhesive bonded repair patches on each aircraft. This may be done by identifying the bead of sealant that surrounds each patch, as shown in Fig. C.1. It is particularly useful to identify patches that contain “RFD/W” or “STK” numbers as these may be used to identify the age of the repair.

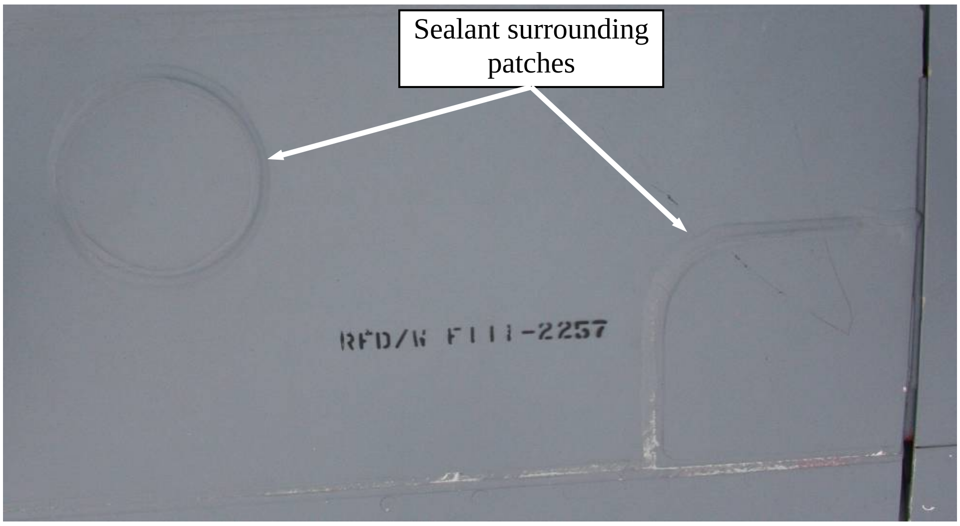


Figure C.1: Photograph of the sealant around two bonded repairs and their RFD/W identification number

C.1.2 Identify adhesive

Remove a 1 to 5 cm long section of sealant from the periphery of each patch as shown in Fig. C.2 then identify the adhesive using its colour and Table C.1.

Figure C.2: Photograph of a patch with sufficient sealant removed to identify the blue FM300 adhesive (arrowed)

AF130 and AF131 adhesives are brown and contain asbestos. If the adhesive colour is in the yellow to brown range, consult bonding technicians with experience in identification of adhesives containing asbestos. Patches bonded with these adhesives are to be marked with Rust Away red enamel paint as shown in Fig. C.3 and not handled under FABRAP. Any exposed AF130 or AF131 adhesive is to be sealed with a continuous film of Rust Away red enamel spray paint. Where there was any doubt, adhesives were treated as potentially containing asbestos.

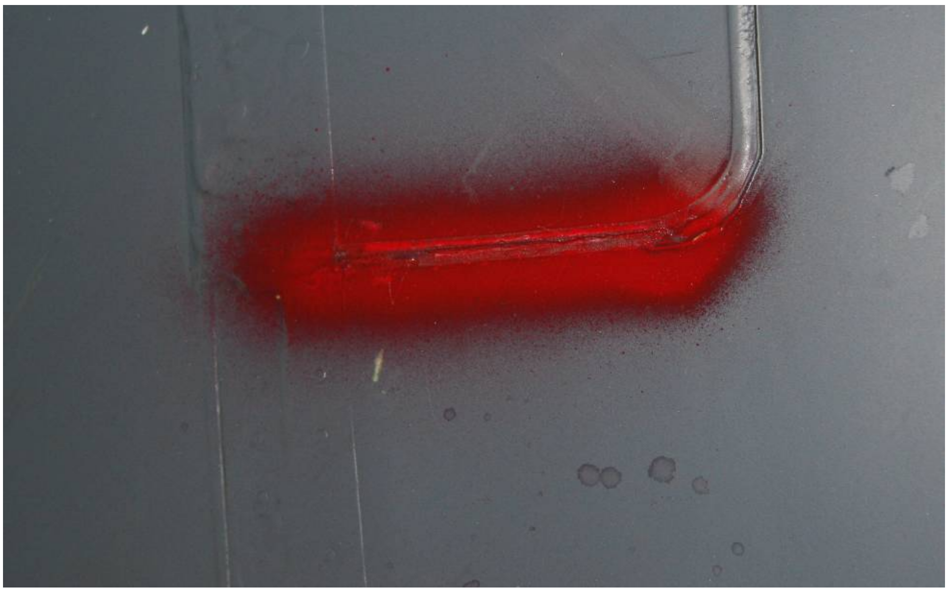


Figure C.3: Photograph of a patch containing AF131 adhesive marked with red enamel paint

Table C.1: Adhesive colours and FABRAP treatment for each adhesive type

Adhesive	Adhesive colour	Treatment under FABRAP
FM300	Blue	Test
FM300-2K	Dark yellow	Test
FM73	Yellow	Test
EA9321	Light grey	Test
EA9394	Dark grey	Test
AF130	Straw or cream	Do not test – contains asbestos
AF130-2	Straw	Do not test - different surface treatment
AF131	Straw	Do not test – contains asbestos
AF131-2	Straw	Do not test - different surface treatment

C.2. Non-Destructive Inspection

C.2.1 Initial Tap Test

The FABRAP Test Team member conducted a tap test, using a tap hammer, on a 25 mm wide strip around periphery of each patch. This is the zone where it overlapped and was adhesive bonded to the parent skin.

If there was no change in resonance caused by the tap hammer then it was assumed that the bond was intact. “Tap OK” was written in permanent marker adjacent to the patch.

C.2.2 Detailed Tap Test

If a change in resonance caused by the tap hammer was heard then this may indicate a disbond. The FABRAP Test Team member must then organise for the Boeing staff, either Aled Roberts or Grant Wingfield, to conduct a confirmatory tap test.

The periphery of any potential disbond was marked with permanent marker.

C.2.3 6 Squadron Inspection

If a suspected disbond was confirmed by Boeing Bond Shop personnel then the FABRAP Test Team member organised for 6 Squadron to conduct a tap test and Bondmaster inspection. The 6 Squadron personnel marked the edge of inspection zones and disbonds with red chinagraph pencil as shown in Fig. C.4.

Ideally no further testing was conducted until the Bondmaster inspection was completed however the testing tempo was so high that this was sometimes not achieved. In these cases the Bondmaster inspection was conducted around the stub location.

C.3. Stub Bonding

C.3.1 Paint Removal – Prior to 15 November 2010

Boeing Paint Shop personnel attended the F-111 Graveyard on a daily basis prior to 15 November 2010 and used a chemical paint stripper to remove the paint from any of the patches that had been identified for testing.

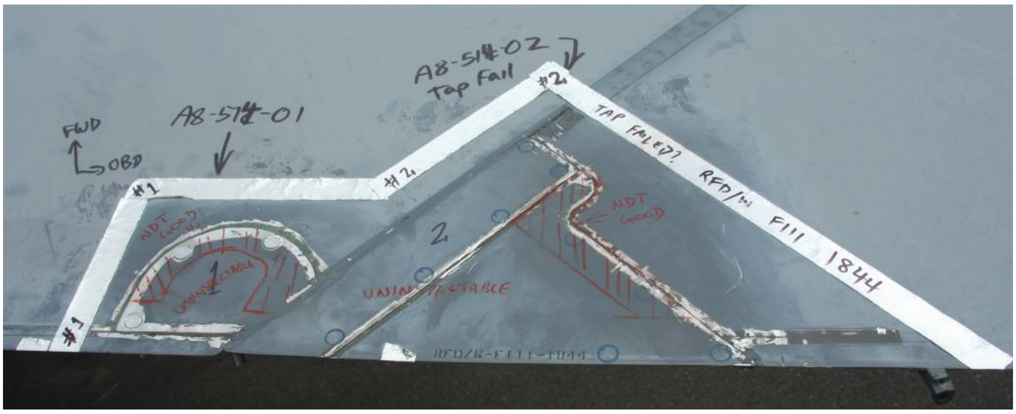


Figure C.4: Photograph of two patches that had been inspected and marked up by 6 Squadron

These patches may be identified in photographs because all paint has been removed from them, as shown in Fig. C.5.

C.3.2 Mark stub locations

The Hole Saw Template is a 127 mm diameter x 3 mm thick aluminium circle with a central 17 mm diameter hole. The central hole was used to guide the hole saw that was used to cut grooves in the patches in preparation for bonding Patti stubs. The outer diameter of the Template is the same as that of the Patti Piston and was used to ensure adequate separation between stubs. The procedure for marking-up the stub locations is described in the remainder of Section C.3.2.

For each patch the Hole Saw Template was placed so that (as shown in Fig. C.6 (a)):

- the outer edge of the central hole was approximately 3 mm from the edge of the patch. This ensured the stub would be on the adhesively bonded overlap between the patch and the parent skin.
- when the Stub Hole Saw Template rested on the aircraft skin it was approximately parallel to the skin exposed by the hole. This ensured the sub would be perpendicular to the Patti Piston. It was acceptable for there to be some bridging of the skin or the Template to be on a saddle providing the Piston would be perpendicular to the stub.

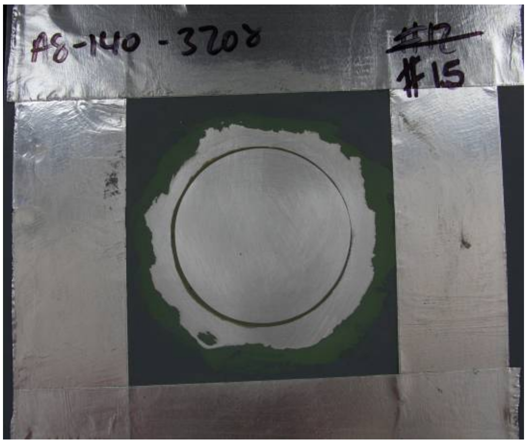
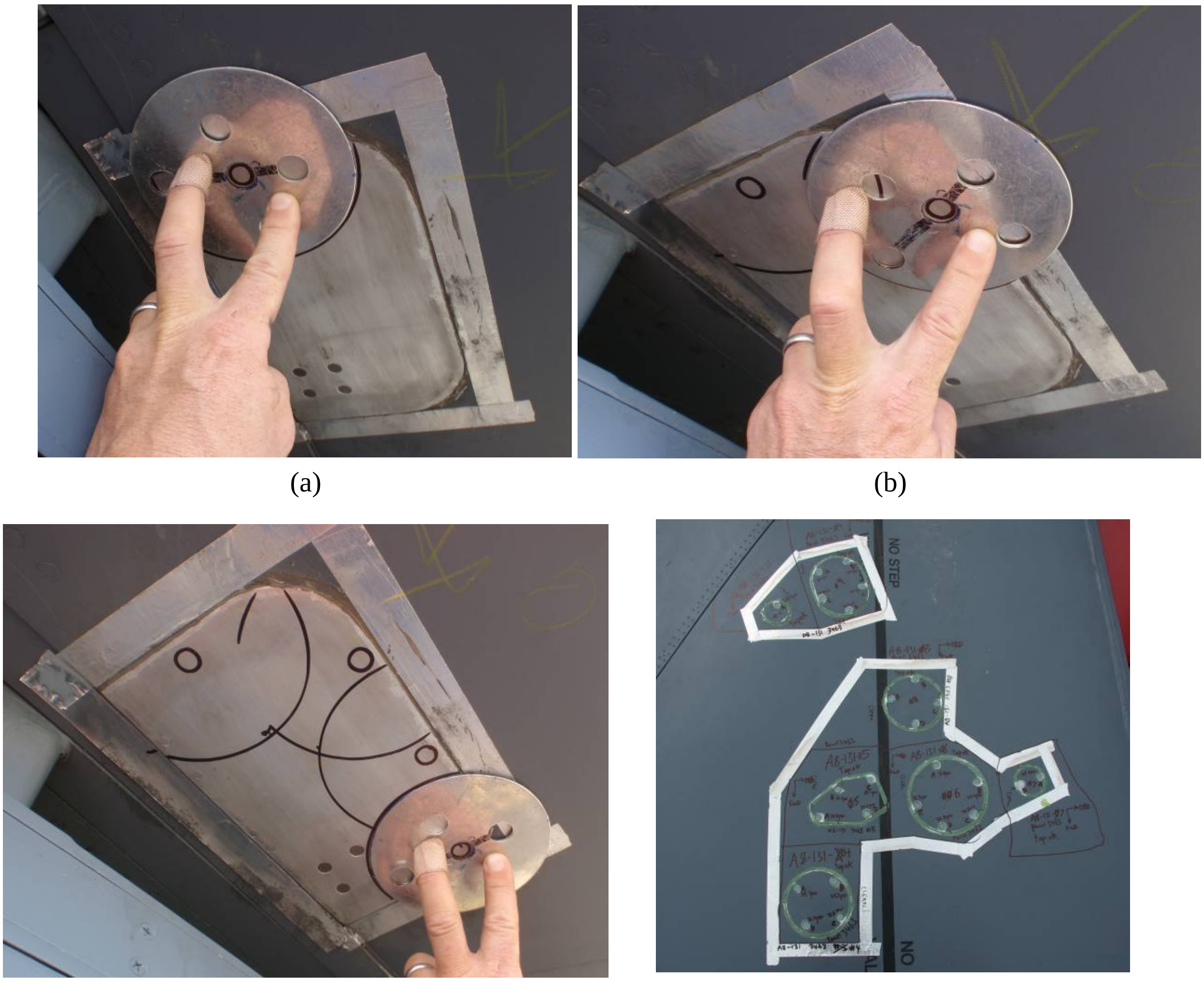


Figure C.5: Photograph of a paint-stripped patch



(a) (b)

(c) (d)

Figure C.6: Photographs of a patch showing (a) the Hole Saw Template on the patch and first stub mark-up, (b) the second mark-up, and (c) mark-up for four stubs. (d) Photograph showing the range of typical patch sizes and stub locations

The patch was marked with a permanent marker, as shown in Fig. C.6 (a), at the:

- central hole, and
- intersection between the outer edge of the Hole Saw Template and the edge of the patch.

The Hole Saw Template was moved to the next position around the patch, as shown in Fig. C.6 (b). This was where the edge of the central hole remained near the edge of the patch but was 5-15 mm outside the outer edge of the Hole Saw Template from the previous stub. The central hole and outer edge of the Hole Saw Template were marked-up as shown in Fig. C.6 (b).

The Hole Saw Template was moved and marked-up until the periphery of the patch had been covered, as shown in Fig. C.6 (c). The aim was to mark at least two stubs per patch. Most patches could accommodate between two and seven stubs as shown by the typical range of patches in Fig. C.6 (d).

Continue up until at least 50 stub locations had been identified and marked-up.

C.3.3 Cut groove through patch

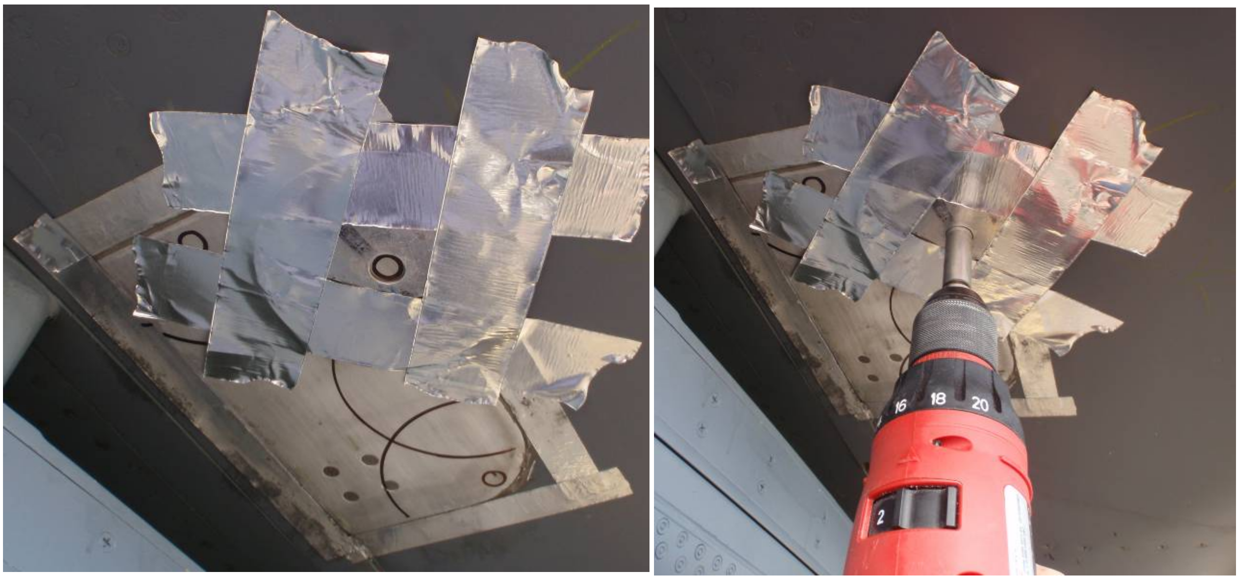
The Stub Hole Saw Template was positioned over the patch so the central hole was over a marked-up stub position then the Template fastened using four strips of 50 mm wide aluminium tape. Taping had to be sufficiently well bonded to prevent the Hole Saw from drifting before the groove was initiated. A sample setup is shown in Fig. C.7 (a).

A Hole Saw (12.7 mm inner diameter x 16.0 mm outer diameter), driven by a cordless drill, was passed through the central hole in the Template and into the patch as shown in Fig. C.7 (b). A groove was cut into the patch until the Hole Saw had cut wholly through the patch only.

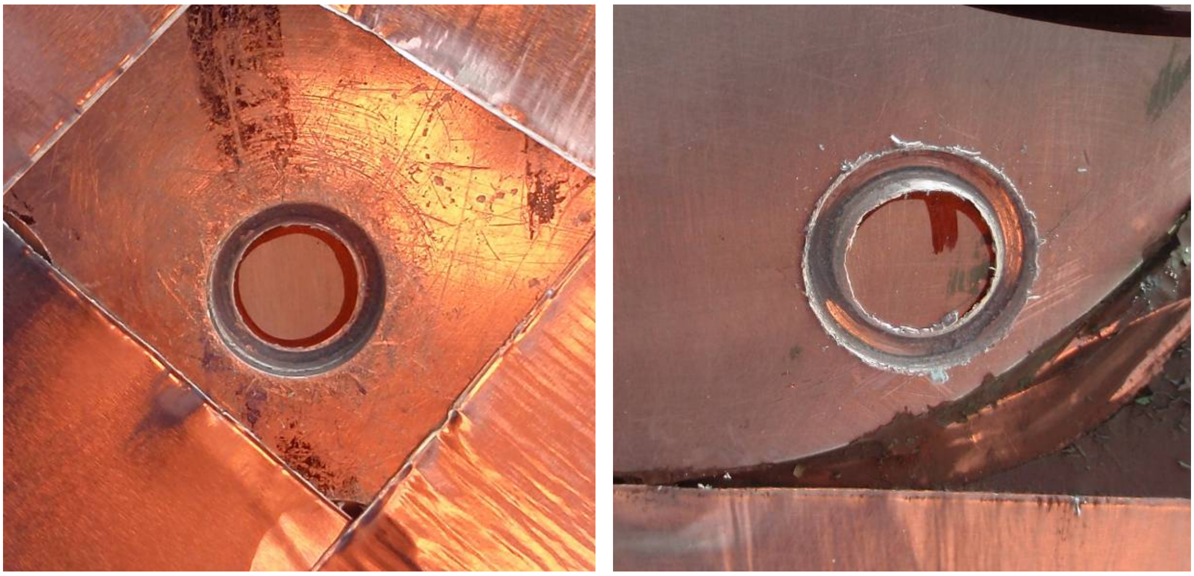
Some patches and skins were very thin (less than 0.5 mm) and easily penetrated. Cutting was performed slowly and progress checked regularly, in some cases with every revolution of the Hole Saw. On each check the location where the adhesive was exposed was noted then the angle of the Hole Saw/drill changed so that the opposing side of the groove root was cut. In this way a groove was gradually cut through the patch without extending into the parent skin. Ideally at the completion of cutting only adhesive was exposed at the root of the groove, as shown in Fig. C.7 (c). It took considerable skill and care to achieve this and it was more common for the Hole Saw to cut into the parent skin as shown in Fig. C.7 (d). This was acceptable provided the parent skin was not breached.

Every effort was made to prevent the Hole Saw from penetrating through the outer skin and into the core. Doing this had the potential to release asbestos from the adhesive used to bond the honeycomb core to the parent skin in the original manufacture of the panel. If the parent skin is penetrated then, immediately,:

- the penetration was sealed with red enamel paint and aluminium tape,



(a) (b)



(c) (d)

Figure C.7: Photographs showing (a) the Hole Saw Template fastened to the aircraft skin with aluminium tape, (b) a groove being hole sawed, (c) an ideal groove with adhesive only at the root of the groove, (d) an acceptable groove showing a shallow penetration into the parent skin

- any items trapped in the Hole Saw, such as plugs of core or discs of skin, were double bagged and disposed
- all residues were washed off the Hole Saw using water
- the operator washed their hands with soap and water.

C.3.4 Paint Removal – After 15 November 2010

The primers used under some F-111 paint contain hexavalent chromium (Cr^{6+}), a known carcinogen. In the work the mechanism of exposure would be by inhaling contaminated dust liberated during abrading. Every effort was made to avoid (i) releasing contaminated dust into the environment, and (ii) exposing operators and any other person to contaminated dust.

Two FABRAP Test Team operators donned full face masks with an in-life P-3 filter, disposable tyvek overalls and a pair of disposable nitrile gloves. One operator abraded the paint off the patch within the periphery of the groove using a scotchbrite pad driven in a cordless drill. The second operator trapped the dust generated by this process using a high efficiency vacuum cleaner with hepa filter.

During abrading the operators ensured that they were up-wind to the patch and that no other personnel approached closer than 5 m to the abrading operation.

Any paint dust or contaminated water droplets were wiped off the panel using Berkshire Wipes soaked in water.

Abrading was continued until the scotchbrite pad had become worn and lost its effectiveness in removing paint. It, and the contaminated Berkshire Wipes, was double zip-lok bagged and disposed of as hazardous waste.

Abrading was continued with a new scotchbrite pad and Berkshire Wipe until the batch of 50 stub bonding locations had been stripped.

C.4. Cleaning

Batches of 50 stubs were cleaned at a time. The efficiency of the cleaning process could be improved by masking the region around the stub prior to the commencement of cleaning. This ensured that only the bond face, and not the surrounding panel which may contain aircraft fluids and degraded paint, had to be cleaned. The following masking procedure was performed on some of the patches:

- a 100-200 mm long strip of 50 mm wide green flash-break tape was centred over the stub bonding location and pressed down onto the panel
- the tape was cut using a disposable knife along the outer periphery of the groove
- the tape over the stub bonding location was removed

The cleaning operation, regardless of whether the stub bonding location had been marked, was the:

- operator donned disposable nitrile gloves,
- stub bonding surface and groove was wiped with a Berkshire Wipe soaked with Citra Safe.
    - Wiping was conducted in a back-and-forth circular motion until all gross contaminants were removed,

    - A wipe was then conducted with clean sections of Berkshire Wipe (soaked with Citra Safe) in a single pass and firm pressure across the entire bonding surface.
    - Approximately 5-10 single-pass wipes with fresh Berkshipe Wipe soaked in Citra Safe were conducted.
- stub bonding surface and groove was wiped with a Berkshire Wipe soaked with deionised water. Approximately 5-10 single-pass wipes with fresh Berkshipe Wipe soaked in deionised water were conducted
- surface was allowed to dry. A hot air drier was used to accelerate drying on some stubs prepared in the Boeing Bond Shop.
- The nitrile gloves and soiled Berkshire Wipes were bagged and disposed.

C.5. Grit Blasting

Grit blasting was conducted in batches of 40 or 50. Two members of the Boeing Bond Shop donned full face masks each with an in-life P-3 filter, disposable tyvek overalls and a pair of disposable nitrile gloves. One operator grit blasted the freshly cleaned stub bonding locations on the patches and stubs with fresh alumina grit driven by bottled dry nitrogen. The operator also trapped the dust generated by this process using a high efficiency vacuum cleaner fitted with a hepa filter. The second operator turned the grit-blaster on and off.

Within 30 minutes of grit blasting, the stubs were prepared for bonding by sliding a Teflon ferrule (that had been slit longitudinally) over the head so that the end of the ferrule was coplanar with the bond face. Photographs of the grit blasting operation and the completed stubs, ready for bonding, are shown in Fig. C.8.

(a) (b)

Figure C.8: Photographs showing (a) grit blasting and (b) of a batch of 40 stubs with Teflon ferrules

C.6. Bond Stub

The Operators are to don disposable nitrile gloves.

Prepare the EA9309.3 adhesive by measuring out 25.0 g of Part A and 7.5 g of Part B then mixing both thoroughly using a tongue depressor.

Wipe a thin continuous layer of uncured adhesive onto the bond site on the stub and patch.

Bring the stub into contact with the patch then:

- Twist the stub back and forth approximately ±10 ° two or three times to ensure good contact between the stub and patch.
- Slide the Teflon ferrule into the groove in order to located accurately the stub over the patch and prevent slipping of the stub relative to the patch.
- For stubs on lower or vertical surfaces:
    - allow the paste to thicken before bonding,
    - place an approximately 30 cm strip of 25 mm wide aluminium tape over the channel alignment guide as shown in Fig. C.9,
    - while still holding the stub, position the channel so that the hole locates on the stub,
    - tape the channel to the aircraft skin while ensuring that the:
        - stub remains in full contact and perpendicular with the patch
        - stub remains in the required position, and
        - channel presses lightly against the back of the stub
- Allow the adhesive to cure for at least 72 hours on aircraft or overnight then 2 hours for panels in the Boeing Bond Shop hot room (80 °C)

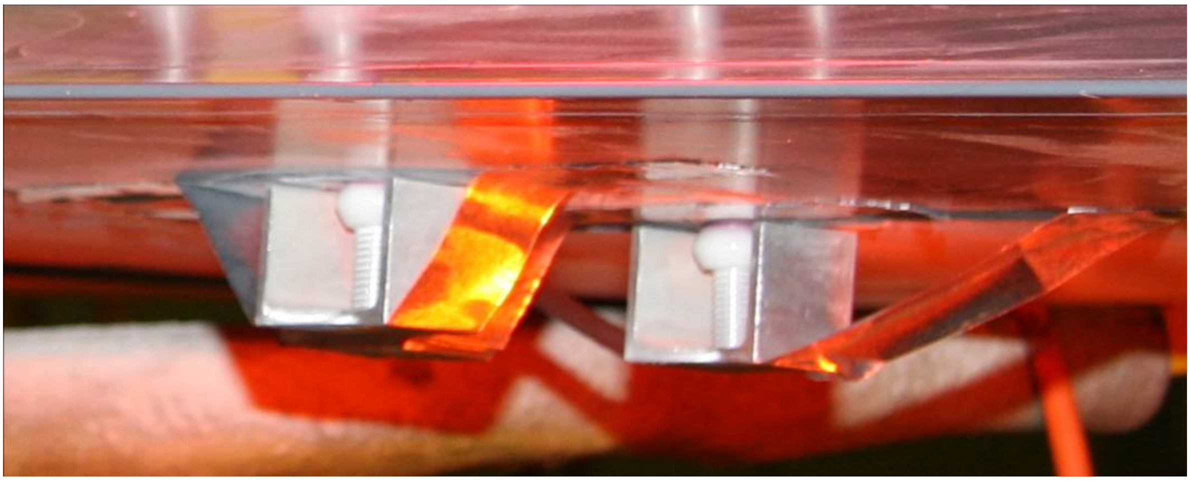


Figure C.9: Photograph of stubs bonded to the underside of a surface held in position with channels and aluminium tape

C.7. Patti-Testing

Testing

Remove Teflon ferrule and flash break tape from bonded stub.

Setup the Elcometer 110 P.A.T.T.I.® Pneumatic Adhesion Tester as shown in Fig. C.10. Connect the back of the Control Module to a gas bottle of dry nitrogen and set the regulator to approximately 100 psi.

Slide the F-16 Piston Housing over the stub.

Screw the Reaction Plate onto the stub and gently tighten. If the Piston Housing was on an uneven or highly curved surface then the interface between the panel and Housing was shimmed. Sufficient support was provided for the Housing to load the stub perpendicular to the surface of the patch.

The "Reset" button was pressed to zero the display.

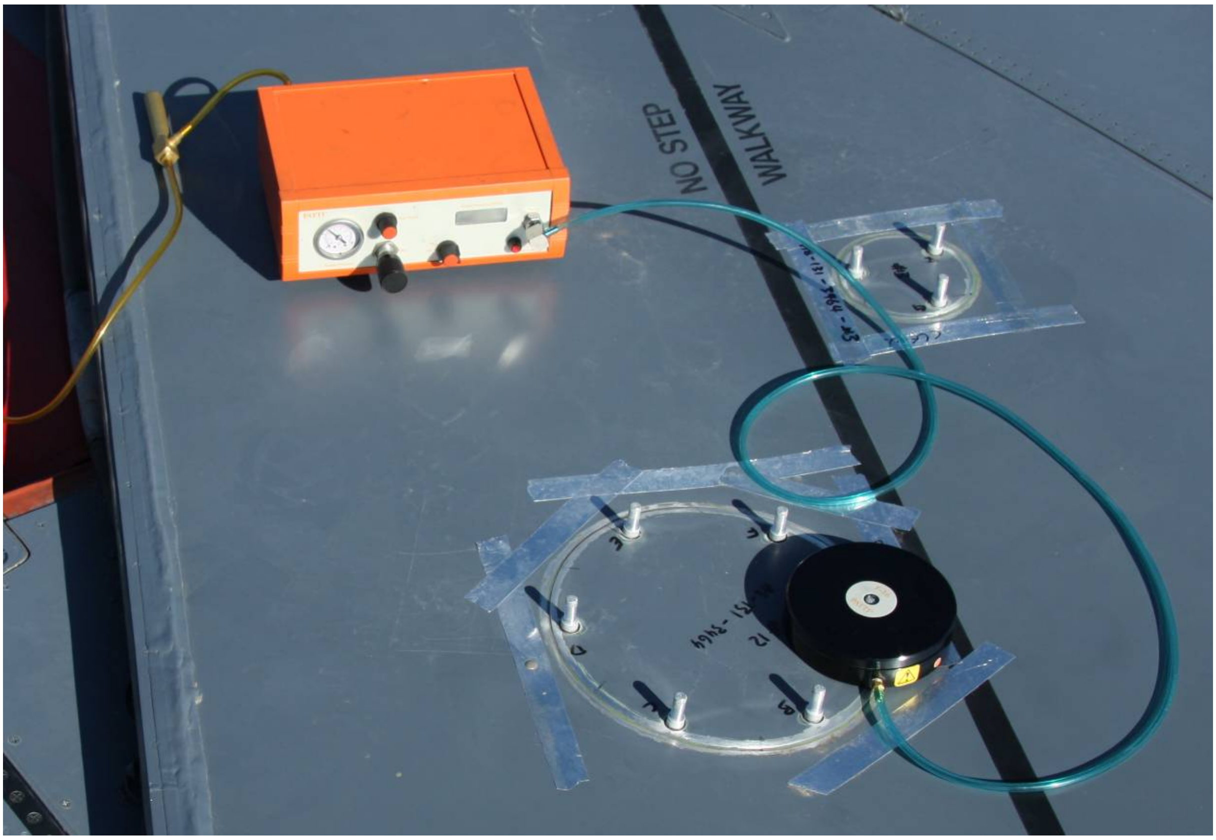


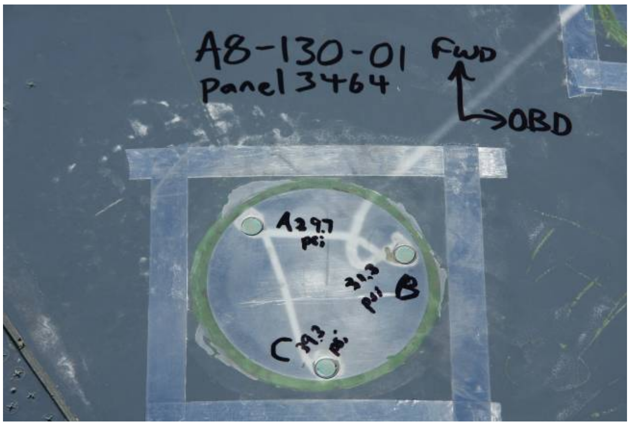
Figure C.10: Photograph showing the setup of the Patti-Tester

The "Run (Push)" button was pushed to begin loading the stub. The "Rate" valve was rotated to give a pressurisation rate in the order of 1 psi per 2 seconds. The "Run (Push)" button was held until the adhesive bond failed. The operator placed a hand loosely over the Piston and absorbed the recoil shock when the stub failed.

Photography

Each panel, patch and stub was photographed after testing using the Canon EOS 40D camera. Figure C.11 shows a typical example. These images are 3 MB jpg files and can tolerate substantial expansion. This will allow for more detailed analysis of the failure surface in the future.

(a)



(b)

(c)

(d)

Figure C.11 A typical set of post-test photographs showing the (a) panel, (b) patch, and (c) and (d) two of the stubs

Data Recording

The results of the test were recorded in the FABRAP PATTI Test Results spreadsheet. The first 10 records of the spreadsheet are shown in Fig. C.12 and the format of the data entry is described in Table C.3.

Test Number	Date of Pull (dd-Mmm-YY)	Time of Pull (hh:mm)	Tail Number	Stub ID (Patch No. Stub Letter)	Tap test (Ok/Fail)	Burst Pressure (psig)	Cohesive Area Fraction (%)	Adhesive on failure surface	Valid test (Yes/No)	Photographs			Porta-Pull Piston	Panel Number or Part Description	Panel/Part Serial Number	Patch RFD or STK Number	Comment
										Panel	Patch	Stub					
1	3-Nov-10	8:43	A8-145	12A		9.1	100	FM300	Yes	3613	3752	3753	F-16			RFD/W-F111-2117	
2	3-Nov-10	9:01	A8-145	23A		6.0	0	EA9309.3	No	3755	3754	3754	F-16	HSTAB LH L			
3	3-Nov-10	9:05	A8-145	23B		17.4	0	EA9309.3	No	3755	3754	3754	F-16	HSTAB LH L			
4	3-Nov-10	9:09	A8-145	23C		23.6	100	FM300	Yes	3755	3754	3754	F-16	HSTAB LH L			
5	3-Nov-10	9:22	A8-145	16A		18.8	85	FM300	Yes	3617	3758	3758	F-16	HSTAB LH U			
6	3-Nov-10	9:26	A8-145	16B		16.7	95	FM300	Yes	3617	3759	3759	F-16	HSTAB LH U			
7	3-Nov-10	9:58	A8-145	28A		33.3	100	FM300	Yes		3760		F-16	No1 Aft Slat LH		RFD/W 1903A	
8	3-Nov-10	10:01	A8-145	28B		30.1	0	EA9309.3	No		3761		F-16	No1 Aft Slat LH		RFD/W 1903A	
9	3-Nov-10	10:04	A8-145	28C		43.8	100	FM300	Yes		3762		F-16	No1 Aft Slat LH		RFD/W 1903A	
10	3-Nov-10	10:08	A8-145	27A		46.3	100	FM300	Yes		3763		F-16	No1 Aft Slat LH		RFD/W 1903A	

Figure C.12 A screen capture of the first ten records in the FABRAPPATTI Test Results Table

Stub Archiving

On a 25 mm wide x 30-50 mm long piece of masking tape write the:

Aircraft tail number
Stub ID
Panel number or panel description
Burst pressure

Fasten this tape to the failed stub.

Store the stubs for each patch in a zip-loc bag labelled with the aircraft tail number and panel number or panel description

C.8. Removal of Doublers

Between 29 November and 16 December, 2010, some of the ABR doublers that were tap and PATTI tested were removed, the adhesive bond photographed, and the doubler replaced with a dummy. The team performing this work consisted of Eudora Yeo (30 November – 2 December, 2010), Aled Roberts and Grant Wingfield.

The edge of each doubler was pried off by tapping with a wedge and hammer. The remainder of the doubler was removed by a combination of peeling using multigrips and further tapping with a wedge and hammer.

The surfaces of the repaired area and the removed doubler were photographed. The doublers were labelled with repair identification details, and bagged and sent back to DSTO for further analysis. A dummy aluminium doubler was bonded on using silicone bathroom sealant.

At 16 December 2010, work on the C-model aircraft was almost complete, but not many doublers from the G-model aircraft had been removed and replaced. Inclement weather and staff shortages hampered efforts.

Table C.3 The data entry format for the FABRAP PATTI Test Results table

Field	Data format
Test Number	This number is pre-filled. It is the next number in the sequence.
Date of Pull (dd-Mmm-YY)	Use format dd-Mmm-YY where: dd Day Mmm Month, e.g. Nov YY Last 2 digits of the year, e.g. 10 for 2010
Time of Pull (hh:mm)	Use format hh:mm where: hh the hour of the test using a 24 hour clock, mm the minutes past the hour
Tail Number	Tail number of the aircraft under test
Stub ID	Use format NNL where: NN Patch Number. NN commences at 01 for each tail number and indexes by 1 for each subsequent patch. L Stub Letter for each patch. L commences at "A" for each Patch and indexes by 1 letter (B, C, D, E, etc) for each subsequent stub.
Tap Test	"Ok" if tap hammer test indicated a sound bond at the stub location "Fail" if tap hammer test indicated a disbond at the stub location
Burst pressure (psi)	The pressure shown on the PATTI Control Module at the instant of stub failure
Cohesive Area Fraction (%)	The area fraction of purely cohesive failure within the adhesive
Adhesive on failure surface	The type of adhesive that failed.
Valid test (Yes/No)	Input "Yes" for all tests except those where the EA9309.3 adhesive failed
Photographs	Input the image number for the Panel, Patch and Stub.
Porta-Pull Piston	Input "F-16". The F-16 PATTI Piston was used for FABRAP Testing Phase I
Panel Number or Part Description	Input panel number or part description. Ensure consistency with nomenclature.
Panel/Part Serial Number	Input the serial number of the panel or part if this can be identified
Comment	Input any relevant information

Appendix D: Search for Repair Paperwork and Repair Service Histories

1.B. Repair Documentation and Service History

Prior to and during Phase I testing, a search was conducted for repair documentation. The intent was to be able to identify the inspected repairs, including adhesive and surface preparation procedure used, to date them, and track their service history.

Initial discussions with SRSPO revealed that documentation was only held for seven years. It was suggested that there would be no repair documentation available earlier than 2003.

Questioning and searches uncovered the existence of the so-called "RFD/W" paperwork, that is, Request for Deviation/Request for Waiver. RFD/Ws were engineering dispositions that allowed non-standard maintenance to be undertaken on aircraft. This included non-standard bonded repairs. SRSPO was in possession of electronic copies of almost all the RFD/Ws, which although useful, usually contained minimal engineering information or details of adhesives and damage location. Files from 501 Wing, which was formerly in charge of deeper level maintenance, had been kept for reference, and these contained all the engineering information. These files only give information on how a repair was supposed to be undertaken, but do not give confirmation that the repair was actually carried out as planned. Detailed information on damage location and adhesives is not always given. A large number of archive boxes containing RFD/Ws and associated engineering paperwork were located in the SRSPO temporary archive hangar, and relevant files were photocopied.

It was found that F-111 RFD/W files had been loaned to Boeing to assist with maintenance, and some were still held in the Boeing design offices. Relevant files were scanned electronically. Over 200 RFD/Ws were copied.

Discussions with Boeing revealed that all repair documentation from their tenure as deeper level maintenance providers (2002 onwards) was stored. However, it was noted that early documentation was not very comprehensive. It was also noted that the documentation would be difficult to search, although non-conforming repair (NCR) documentation was available electronically. Boeing NCRs are equivalent to RAAF RFD/Ws. Mr Justin Meehan from Boeing assisted by making this documentation available.

The Boeing Maintenance Control Section (MCS) is responsible for archiving all maintenance documentation. Discussions with MCS staff revealed that there were hundreds of boxes of documentation held in archives, some of which contained Work Orders for bonded repairs. MCS staff were able to supply information on which boxes contained known Work Orders, which were used by Boeing to record repairs. MCS were also able to identify which boxes contained repair documentation for R4 and R5 servicings for the retired aircraft. In this way, over 260 pieces of repair documentation were obtained, although it was not clear how many of these would be of use.

As the inspection program commenced, it became clear that it would be very difficult to match up repairs with individual pieces of documentation. Aled Roberts (Boeing Bond Shop) suggested that it was possible to identify repairs using a repair database held by Boeing which had been maintained since 1996. This database could be used to date repairs and identify any associated documentation. Incidentally, this database was also used to identify which panels contained internal repairs that could be removed from the aircraft to facilitate testing.

Mr Paul Mokrzycki and Mr Brad Wise of Boeing provided flight hours for all the C-model aircraft by tail number. Using the Computerised Asset Maintenance and Management system (CAMM2), it was possible to track the serial numbers of many components attached to airframes, as it is usually difficult to view the serial numbers as they are close to the attachment point. CAMM2 was also used to obtain service histories. Prior to CAMM2 there was the original CAMM system.

CAMM was developed in the early days of computers, when hard disk storage was at a premium. Only a limited number of lines of data were stored, before the system cleared all stored data by printing out logs. It is unclear whether these logs are still kept, and if they are, it was decided that the time and expense required to acquire old CAMM logs would not justify the benefit.

In 2004, CAMM was converted to a new CAMM2 system, and any information that existed in CAMM was transferred across. DSTO has been fortunate in that many requested searches have pulled up service histories pre-CAMM2, and some date as far back as 1996. At this stage it is unclear how many repairs to airframes or components can be matched with a full service history.

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19. ABSTRACT (U)

Adhesive bonded repairs are being used for the through-life-support of secondary and tertiary aircraft structure. This technology has not been accepted for application to primary aircraft structure due largely to the lack of a non-destructive inspection technique for, and uncertainty regarding the environmental durability of, adhesive bonds. Over the last twenty five years a large number of adhesive bonded repairs have been applied to the Royal Australian Air Force F-111 and its retirement in December 2010 represented a unique opportunity to evaluate the bonded repairs. The F-111 Adhesive Bonded Repair Assessment Program (FABRAP) was created to generate statistically valid data regarding the efficacy of the tap-test as a non-destructive-inspection technique and the environmental durability of adhesive bonds. In FABRAP Phase I Testing, over 300 repairs were tap tested and 820 residual strength tests conducted using a pneumatic adhesion tensile testing instrument. This report details the FABRAP process and summarises the results from the Phase I testing.

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