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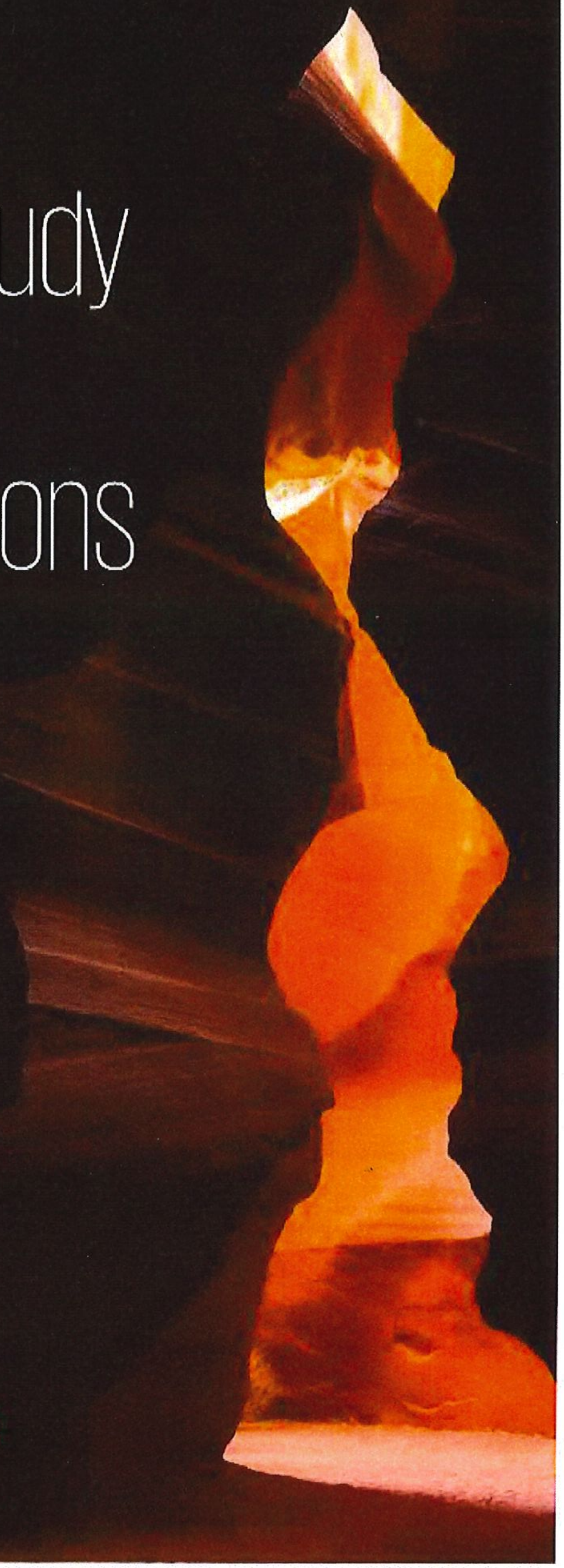
KPMG

F-35A Cost Study on Corrosion Mitigation Options



Costing Report

November 2017
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Contents

November 2017

Document Classification: KPMG Confidential

1 - Executive Summary

KPMG was engaged by Defence Science and Technology Group (DST Group) to complete a costing of a scenario analysis of intergranular corrosion[1] mitigation options for the Joint Strike Fighter F-35A fleet of 72 aircraft.

The fleet will be housed at Luke Base Air Force Base (Arizona, United States), RAAF Base Tindal (Northern Territory) and RAAF Base Williamtown Base (New South Wales). Williamtown is the only environment that DST Group has assumed will cause intergranular corrosion due to climatic conditions and the presence of salt. While up to 54 of the fleet of 72 aircraft can be housed at Williamtown at any one time, all aircraft will be rotated though Williamtown and are therefore susceptible to intergranular corrosion.

The intergranular corrosion mitigation scenarios considered comprised of the following:

A. Plug-in dehumidification of the aircraft both part time and full time utilising the following techniques:
   i. Centralised dehumidification infrastructure which is supplied to aircraft parking bays;
   ii. Mobile dehumidification infrastructure;
   iii. Utilisation of planned dehumidification infrastructure within aircraft hangars.

B. Dehumidified aircraft hangars utilised part time and full time;

C. Application of Corrosion Inhibiting Compounds (CICs)

D. Increased Corrosion Inspections

This report presents the cost and availability impact of the above scenarios, noting that Scenarios A (i), B and D were, after investigation, deemed impractical or less beneficial than the other options by DST Group and RAAF and were removed from scope.

Prior to KPMG being engaged, Defence and Defence Industry personnel took part in an Expert Elicitation s33(a)(ii), s47G [redacted]

s33(a)(ii), s47D [redacted]

Baseline Availability and Total Cost Impact FY2018 – FY2054

s33(a)(ii), s47D [redacted]

Table 1 - Availability and Total Cost Impact FY2018 - FY2054

[1] Refer to Appendix A for a definition of intergranular corrosion

[2] Refer to Appendix B for detail on this analysis.

Corrosion Mitigation Scenarios

Scenario A (iii) Use of planned infrastructure involves using the planned three dehumidifiers in the maintenance facilities full time. *Scenario A (i) Mobile dehumidification* examines using mobile dehumidification units that are either switched on full time or part time (30%).

Scenario A (i) Mobile dehumidification assumes that the three planned dehumidifiers in the maintenance hangars would also be used and therefore incorporates the cost and benefit of *Scenario A (iii) Use of planned infrastructure.*

Scenario C Use of CICs, involved applying a CIC to each aircraft, through a fogging of the internal at risk areas, once every two years. This option is independent of the others, however while there is an incremental benefit, Scenario benefits cannot be summed.

Probability Metrics

For *Scenario A (ii) Mobile Dehumidifiers* used part time and full time the Expert Elicitation concluded a new probability of corrosion occurring.

s33(a)(ii), s47G

[redacted]

Table 2 - Probability Metrics

Scenario Availability and Total Cost Impact FY2018 – FY2054

Each of the Corrosion Mitigation Scenarios involve increased labour for RAAF. The labour in the table below relates to towing the aircraft with the specific purpose of dehumidification (i.e. not business as usual towing), connecting and disconnecting the dehumidifiers and applying the CIC. Refer to *Figures 1-2, 5-6* on page 4 for a visual comparison of these factors.

s33(a)(ii), s47D

[redacted]

Table 3 - Scenario Availability and Average Annual Cost Impact FY2018 - FY2054

Benefit Metrics

The cost model calculated an estimate of the benefit of each Scenario relative to the baseline cost and availability impact. A risk reduction value was calculated by multiplying the Scenario percentage improvement on the baseline s33(a)(ii), s47D [redacted] It should be noted that the *Risk Reduction Benefit* in the table below is not a reduction in the budgeted cost of ownership, rather a method of expressing the relative risk as a dollar value.

s33(a)(ii), s47D [redacted]

Table 4 - Benefit Metrics

*The life of the fleet is from first arrival in FY18 to last arrival in FY24 plus 30 years and considered the build-up/ramp down of aircraft numbers

Findings

The following insights can be drawn from above analysis:

- **The largest net benefit would be derived from combining *Scenario A (ii) Mobile dehumidification (full time)* with *Scenario C Use of CICs*. This also assumes use of the three currently approved dehumidification systems in the planned maintenance hangars (capacity to dehumidify 17 aircraft simultaneously). The annual cost of these two options** s33(a)(ii), s47D [redacted]
- All options have a positive net benefit and a high Return on Investment.
- The corrosion mitigation option with the highest risk reduction and net benefit is *Scenario A (ii) Mobile dehumidification (full time)*.
- The option with the highest Return on Investment is *Scenario C Use of CICs*.
- The benefit from using *Scenario A (iii) Use of planned infrastructure* s47D [redacted] is the same as *Scenario A (ii) Mobile dehumidification (part time)*. However the cost of using the planned units is higher because there is additional towing to the maintenance bays that would not be required with the use of mobile dehumidifiers for the parking bays. Therefore the *Net Benefit* is higher for part time dehumidification.

2- Background

Defence Science and Technology Group (DST Group) s33(a)(ii), s47G s33(a)(ii), s47G s33(a)(ii), s47G [redacted] Intergranular corrosion is a selective attack in the vicinity of the grain boundaries of an alloy. Differences in metallurgical structure cause the grain boundaries of a metal, or areas adjacent to the grain boundaries to corrode in preference to the bulk material, producing a fine network of corrosion damage. These differences in structure are usually related to segregation of specific elements or the formation of grain boundary precipitates. Intergranular corrosion can compromise the aircraft's structural integrity. DST Group developed the following set of initial study questions in order to define the potential impact:

i. What is the risk (likelihood and consequence) posed to RAAF F-35A supportability from intergranular corrosion damage s47 [redacted]

ii. What are the potential local mitigation options to reduce the risk?

iii. What is the residual risk if a mitigation option is applied?

iv. What is the cost of each mitigation option in terms of Fundamental Inputs to Capability (FIC)?

s33(a)(ii), s47G [redacted]

DST Group took part in an Expert Elicitation, consisting of 21 corrosion personnel across ADF and Industry, to address questions i, ii, and iii above. The Expert Elicitation participants were briefed on and discussed the following:

- Historic instances of corrosion on ADF platforms
- Aluminium Alloys and intergranular corrosion
- F-35A structure
- Conditions required for corrosion
- Praseodymium corrosion inhibitors
- F-35 corrosion protection and performance in lab testing

Participants then answered a number of questions relating to the likelihood of intergranular corrosion occurring under various mitigation options, expressed as three point estimate: lowest, highest, and best guess. These options closely align to the Scenarios provided to KPMG and outlined below in the Scope section.

KPMG was subsequently engaged by Defence to undertake a study of corrosion management scenarios which could be applied to the Australian F-35A aircraft fleet and to attain Rough Order of Magnitude (ROM) costs of applying each scenario. This addresses question iv. above. This Study describes the corrosion mitigation Scenarios, outlines the enactment and sustainment assumptions, and lists the costing input requirements.

3 - Scope

This KPMG study comprises of the following two Phases:

Phase 1: Scenario Development Documentation

i. Develop initial set of data requirements for the corrosion mitigation options;

ii. Develop scenarios for how each mitigation option would be enacted and sustained; and

iii. Define how each element of each scenario will have costings applied.

Phase 2: Mitigation Costing Model

i. Provide initial set of ROM costings for each scenario for discussion with stakeholders;

ii. Provide final set of ROM costings which include stakeholder feedback; and

iii. Provide final report summarising study and detailing findings.

This document is the deliverable addressing the 2 phases of the study scope. The following three scenarios are considered:

A. Plug-in dehumidification of the aircraft both part time and full time utilising the following techniques:
   i. Centralised dehumidification infrastructure which is supplied to aircraft parking bays;
   ii. Mobile dehumidification infrastructure;
   iii. Utilisation of planned dehumidification infrastructure within aircraft hangars.

B. Dehumidified aircraft hangars utilised part time and full time;

C. Application of Corrosion Inhibiting Compounds (CICs)

Mapping of the Expert Elicitation intergranular corrosion mitigation options to those above is provided at Appendix B.

4 - Out of Scope

Of the above Scenarios a number were considered to be non-feasible based on information provided by potential suppliers. These were:

- Scenario A (i) *Centralised dehumidification*, as the central dehumidification units are made up of a number of mobile units in one casing. As the scenario would require a longer length of ducting than Scenario A (ii) mobile dehumidification units, the energy to maintain pressure would be higher and therefore costs would be higher.
- Scenario B *Dehumidified hangars*, as parking bays are already planned to be built. Enclosing the parking bays after they have been built was discussed, however an initial cost estimate from AIR 6000 facilities indicated that enclosure would be cost prohibitive. Drop down curtains and other mechanisms were discussed, however none were rated by DST Group as more effective than the other planned options.
- An option involving increasing corrosion inspections was investigated, but it was agreed that whilst the inspections may create cost savings, the potential damage or on-costs to the aircraft would most likely outweigh the benefits.

The following have been deemed out of scope for the purposes of consideration in this study and costing model:

- A technical or practical assessment of the mitigation options.
- s33(a)(ii), s47G [redacted]
- Any corrosive process that takes place that is not intergranular corrosion.
  s33(a)(ii), s47G [redacted]
- The planned exterior wash facility at Williamtown. The Expert Elicitation identified that only corrosion of internal surfaces was likely to result in significant unplanned structural refurbishment. There is relatively little metallic structure on the exterior of the aircraft.
- The regular exercises attended by the F-35 aircraft as outlined by the Statement of Operating Intent (2013). These exercises, for example Talisman Sabre, Red Flag and Pitch Black, are considered out of scope as it is not known how many aircraft will be sent and the duration that they will be away.
- The mission types carried out by the F-35 during training are not considered to have a material effect on intergranular corrosion. If a training mission is carried out over sea, however, the risk of corrosion increases. Exercises over sea are less likely to take place out of Tindal and Luke AFB.
- s33(a)(ii), s47G [redacted]

- The current repainting schedule s33(a)(ii) [redacted]
- s33(a)(ii) [redacted]
- s47D [redacted]

5 - Costing Methodology

The Methodology involved in costing the corrosion mitigation options is as follows:

Steps

1 s33(a)(ii), s47D, s47G [redacted]

2 A baseline was then created which took into account the life of type of the aircraft of 30 years and the year each aircraft is expected to arrive at Williamtown.

There will be 54 parking bays built at Williamtown to accommodate the aircraft. This is 75% of the in-scope fleet of 72 aircraft. While aircraft will rotate between Williamtown and Tindal bases, Williamtown will house 54 aircraft until the fleet begins to be decommissioned. The model also assumes that each aircraft spends 75% of its life at Williamtown, which is assumed to be the only location to cause intergranular corrosion. In practice, aircraft may experience salt build-up at Williamtown and carry it to Tindal where there will be no planned dehumidification; thus there would be a low residual risk.

3 Quotes were obtained from providers for dehumidifier capital, maintenance and running costs and quotes were obtained from CIC providers for the cost of purchasing the CICs. Of the two dehumidifier quotes obtained only one was used as the other was unreliable.

4 RAAF provided an estimate for each scenario of effort required for towing the aircraft to the maintenance hangar dehumidifiers (for *Scenario A (iii) Use of planned infrastructure*) and for connecting and disconnecting dehumidifiers. A *Leading Aircraft Man/Woman* is assumed to carry out the work and costs are based on per *FINMAN4 V1.2.*

5 The cost elements per Scenario are shown below:

s47D [redacted]

6 A profile of each applicable cost element in Steps 3 and 4 was then created based on each scenario and the years in which the aircraft are expected to arrive at Williamtown. It is assumed that s47D [redacted] s47D [redacted]

7 Availability was calculated by determining the amount of time an aircraft in Williamtown would be available to be dehumidified by removing time spent on sorties, taxiing and scheduled depot maintenance. s33(a)(ii), s47G [redacted] s33(a)(ii), s47G [redacted]
Following this, the reduction in availability was calculated for each scenario to account (where relevant) for towing, disconnecting and reconnecting dehumidifiers and curing time.

8 Costs and availability for each scenario were then compared to the baseline using the each scenario's improvement over the baseline in terms of intergranular corrosion risk reduction.

Key assumptions that apply to all Scenarios are shown below. Those that apply to individual Scenarios are shown in the individual Scenarios sections of the report.

1 Life of type for the aircraft is 30 years

2 Life of fleet is 37 years (first aircraft arrives FY18, last aircraft arrives FY24)

3 Each aircraft will spend 75% of total time at Williamtown

s33(a)(ii), s47G [redacted]

s47D [redacted] (source: FINMAN4 – refer to Costing Methodology section above)

6 - Baseline

6.1 Outline

s33(a)(ii) [redacted]

The baseline assumes no corrosion mitigation options will be implemented; however, instead of re-acquiring the capability it is assumed that the aircraft will be repaired when intergranular corrosion is found. Scenarios A – C consider several corrosion mitigation strategies for management consideration, each of which are estimated to reduce the likelihood of intergranular corrosion.

s33(a)(ii), s47G, s47D [redacted] s33(a)(ii), s47G, s47D [redacted] DST Group has indicated that if intergranular corrosion were to ground an aircraft this would most likely occur between years 6-15 of an aircraft's life. s47G [redacted]

s47G, s33(a)(ii) [redacted]

It is assumed that the inspection regime and the depot maintenance schedule would be able to be adjusted to accommodate the repairs in every aircraft.

The risk of intergranular corrosion is impacted by the following: the climate in which the aircraft is operated; the climate of the facilities in which the aircraft is stored; and the amount of time the aircraft spends in storage and in flight. These impacts are described below.

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s33(a)(ii) [redacted]

6.2 Climate

Australian F-35 aircraft will be based at RAAF Base Williamtown, RAAF Base Tindal and Luke AFB Arizona, United States (until FY2021). The Tindal and Luke AFB bases are inland and the climate is such that intergranular corrosion is unlikely to be caused by these environments. Williamtown's proximity to the coast, however, results in a high salt content in the air resulting in a greater risk of intergranular corrosion.

6.3 Facilities

The New Air Combat Capability (NACC) Facilities Project will see upgrades to RAAF base facilities in preparation for the Joint Strike Fighter's introduction in 2019. The baseline for this study assumes that the proposed site at RAAF Base Williamtown will include the following facilities which impact the overall assessment, in accordance with the *AIR 6000 Phase 2A/B New Air Combat Capability Parliamentary Standing Committee for Public Works Statement of Evidence*:

i. Off-Aircraft Maintenance Facility. Off-aircraft maintenance for all three squadrons at RAAF Base Williamtown is proposed to be conducted at a shared facility. Components or elements that can be removed from the aircraft for maintenance, such as engines, wheels, tyres, canopies and batteries will be maintained in this facility.

ii. Parking Apron. The proposed parking apron provides a secure area where aircraft are parked when not flying and minor maintenance tasks can be conducted. An aircraft wash facility with two bays will be shared between the three squadrons. One of the bays is proposed to include an engine wash facility.

iii. Depot Maintenance Facility. Depot maintenance is proposed to be conducted in a specialised, contractor-run, facility that will be delivered after 2020 through adaptive re-use of the existing Hornet Upgrade Hangar.

6.4 Ferry Planning

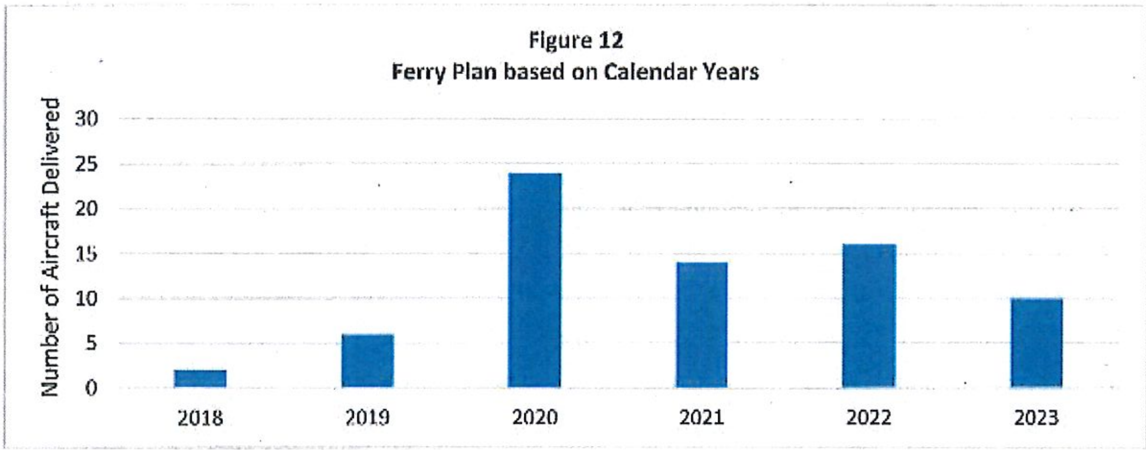
As noted above, intergranular corrosion is more likely to occur in the Williamtown environment. Therefore, the corrosion mitigation measures in this Study are primarily performed at Williamtown, as opposed to Tindal and Luke AFB.

For the purposes of this Study it is assumed that the 30 year life of each aircraft commences at the time it is delivered to a base (either in Australia or the U.S.), with Scenarios A – C coming into effect on arrival in Australia only.

The ferry plan for the 72 in-scope F-35 aircraft is outlined in the table on the next page, based on the dates the aircraft will arrive at the bases:

Calendar Year	Number of Aircraft
2018	2 x F-35 aircraft will be delivered
2019	6 x F-35 aircraft will be delivered
2020	24 x F-35 aircraft will be delivered
2021	14 x F-35 aircraft will be delivered
2022	16 x F-35 aircraft will be delivered
2023	10 x F-35 aircraft will be delivered

Table 5 – Ferry Plan



6.5 Maintenance and Inspections

The baseline scenario assumes that standard maintenance checks will be carried out on the aircraft, with no additional measures taken to prevent corrosion. The maintenance and inspection regime for the Australian F-35 aircraft is currently being developed, however the Analytical Conditioning Inspection Program will involve a select sample of aircraft being inspected in order to determine corrosion, with the scope and scheduling of this still to be determined. For each aircraft, Depot Maintenance is currently assumed to occur once every four years for a four month period.

s33(a)(ii)

[redacted]

6.7 Costing Assumptions and Inputs

The following assumptions and inputs were used in the Cost Model for the Baseline:

s33(a)(ii), s47G [redacted]

s33(a)(ii) [redacted]

s33(a)(ii), s47D, s47G [redacted]

s33(a)(ii), s47G [redacted]

6.7.5– All aircraft located at Williamtown will have a parking bay at any given point in time. The parking bay positions are unassigned, meaning that for the purposes of this Study it can be assumed that aircraft will be stored next to each other in order to fully utilise the dehumidification infrastructure.

6.7.6 – The depot maintenance schedule indicates that each aircraft will be in depot maintenance for four months every four years.

s33(a)(ii), s47G [redacted]

6.7.8 – The F-35 life-of-type is 30 years. Historically, for RAAF aircraft, service is often extended past the initial end-of-life date - this has not been accounted for in this study.

6.7.9 – De-skinning is not required. If de-skinning is required the aircraft would be sent back to Lockheed Martin and repair time/cost would be significantly increased.

s33(a)(ii), s47D, s47G [redacted]

s33(a)(ii), s47D, s47G [redacted]

s33(a)(ii), s47D [redacted]

7 - Scenario A: Plug-In Dehumidification

7.1 Outline

This scenario outlines plug-in and centralised dehumidification options and is broken into three sub-scenarios:

i. Centralised dehumidification supplied to parking bays – part time and full time

ii. Mobile dehumidification – part time and full time

iii. Utilisation of planned dehumidification infrastructure within aircraft hangars – full time only

7.2 Costing Assumptions and Inputs

The following assumptions and inputs were used in the Cost Model for Scenario A (for all sub-scenarios):

7.2.1 – The number of aircraft at Williamtown is equal to the total number of aircraft delivered, up to a maximum of 54

7.2.2 – DST Group has defined part time dehumidification as 30% of each aircraft's time in storage, and full time dehumidification as 100% of the time in storage (excluding depot maintenance).

7.2.3 – Part time dehumidification, may not, in practice be 30% of the time, but rather it will take place at the times where it will have the greatest effect. For example, aircraft are more susceptible to corrosion following a sortie after it has taken in humid air or flown in wet conditions.

7.2.4 – Percentage of total time the aircraft is available for dehumidification s33(a)(ii) [redacted]

7.2.5 – Aircraft humidity levels must reach 40% s33(a)(ii) [redacted] for dehumidification to effectively reduce the likelihood of corrosion.

7.2.6 – Time required for a connection and subsequent disconnection s33(a)(ii) [redacted]

7.2.7 – The dehumidification infrastructure in maintenance hangars can service up to 17 aircraft altogether

7.2.8 – Infrastructure is built per the current proposed construction plans, i.e. aircraft will be housed in non-enclosed parking bays.

7.2.9 – Aircraft will be housed in depot hangars during depot maintenance and will not be dehumidified.

7.2.10 – Defence will either maintain the dehumidification machines/infrastructure itself, or engage a third party contractor.

7.2.11 – The month of aircraft arrival does not factor into the calculations for running and labour costs, i.e., those costs assume the aircraft is there the entire year of arrival and no part of the year of retirement.

7.2.12 – [redacted] This would provide the capability to dehumidify the aircraft to the extent required (which may not be full time or 30% as per the model user inputs). The Scenario also assumes that the aircraft will receive the same dehumidification regardless of whether they are located in the maintenance hangars or in the parking bays.

7.2.16 – Each dehumidifier is capable of dehumidifying two aircraft simultaneously.

7.2.17 – For costing purposes, the part time aspect of Scenario A (ii) [redacted] interchangeably between aircraft. This also assumes that the planned units in the maintenance hangars [redacted] In practice, the aircraft may be dehumidified in either location. [redacted] units is accounted for, however the maintenance hangar unit [redacted] - [redacted]

i. Centralised dehumidification infrastructure which is supplied to aircraft parking bays

7.3 Outline

This sub-scenario would entail a central dehumidifying system with ducts running to multiple parking bays and dehumidifying the aircraft simultaneously. The main system/s would sit adjacent to the parking bay structure, with ducts running through the roof and dropping down to each aircraft.

This scenario was deemed out of scope by DST Group and RAAF as the central dehumidification units are made up of a number of mobile units in one casing. As the scenario would require a longer length of ducting than *Scenario A (ii) Mobile dehumidification* units, the energy to maintain pressure would be higher and therefore costs would be higher.

ii. Mobile dehumidification infrastructure

7.4 Outline

This sub-scenario involves connecting mobile dehumidifiers directly to the aircraft in parking bays under the above definitions of full time/part time. The dehumidifiers will be powered by compressed air units, [redacted]

7.5 Probability Metrics

s33(a)(ii), s47D, s47G

[redacted]

7.6 Availability and Total Cost Impact FY2018 – FY 2054

s33(a)(ii), s47D

[redacted]

7.7 Benefit Metrics

s33(a)(ii), s47D [redacted]

*The life of the fleet is from first arrival in FY18 to last arrival in FY24 plus 30 years and considered the build-up/ramp down of aircraft numbers

7.8 Costing Assumptions and Inputs

The following assumptions and inputs were used in the Cost Model for *Scenario A (ii) Mobile dehumidification*:

7.8.1 – For full time dehumidification, the number of connections/disconnections required is 168 connections/year

7.8.2 – For part time dehumidification, the number of connections/disconnections required is 52 connections/year

7.8.3 – The upfront drawing/planning s47D [redacted]

7.8.4 – Under the part time aspect of this sub-scenario, two mobile dehumidifiers are required per eight parking bay structure, as the 30% requirement allows for the dehumidifiers to be moved between the aircraft.

s47D [redacted]

7.8.8 – Mobile dehumidifiers will be kept at base and not taken on missions/exercises.

7.8.9 – For full time dehumidification the aircraft are dehumidified whether they are in a parking bay or a maintenance hangar.

7.8.10 – For part time dehumidification the aircraft are dehumidified in either a parking bay or maintenance hangar. However they are only dehumidified for 30% of their time in storage

iii. Utilisation of planned dehumidification infrastructure within aircraft hangars

7.9 Outline

This sub-scenario had a part time option, but after investigation it was determined by JSF that only the full time option should be considered. Full time use of the planned infrastructure equates to each aircraft being dehumidified approximately 30% of the time.

Three hangars will be built for maintenance of the F-35 fleet at Williamtown. The hangars have capacity to house 17 aircraft in total (seven at 2OCU, five at 3 Squadron and five at 77 Squadron). Each hangar contains an avionics dehumidification system which together are capable of dehumidifying the 17 aircraft. The aircraft will be rotated through on a schedule to be determined at a later date. The dehumidifiers are not mobile and are powered by base power. The baseline scenario assumes that these dehumidification systems will not be used. This sub-scenario involves utilising this equipment to mitigate intergranular corrosion.

7.10 Probability Metrics

s33(a)(ii), s47D, s47G

[redacted]

7.11 Availability and Total Cost Impact FY2018 – FY 2054

s33(a)(ii), s47D

[redacted]

7.12 Benefit Metrics

s33(a)(ii), s47D

[redacted]

*The life of the fleet is from first arrival in FY18 to last arrival in FY24 plus 30 years and considered the build-up/ramp down of aircraft numbers

7.13 Costing Assumptions and Inputs

The following assumptions and inputs were used in the Cost Model for *Scenario A (iii) Use of planned infrastructure*:

7.13.1 – It takes 4 personnel to tow an aircraft and takes 0.25 hours tow to the maintenance hangar and a further 0.25 hours to tow back to the parking bay. This is a total of two personnel hours.

7.13.2 – The amount of towings per year if assuming one every three weeks is 18 towings

7.13.3 – The capital cost of dehumidifier (i.e., cost to replace once Life of type is over) is s47D [redacted]

7.13.4 – The shelf-life of planned dehumidifier is 10 years. Shelf-life starts in year dehumidifier is first turned on.

7.13.5 – The dehumidification systems have the capacity to be utilised 24 hours a day (i.e. 17 aircraft will be dehumidified at all times).

7.13.6 – Available bays in the maintenance facilities will be occupied at all times.

8 - Scenario B: Dehumidified Aircraft Hangars

8.1 Outline

The study found that parking bays are already planned to be built. Enclosing the parking bays after they have been built was discussed between DST Group and RAAF, however an initial cost estimate from AIR 6000 facilities indicated to RAAF that enclosure would be cost prohibitive. Drop down curtains and other mechanisms were discussed, however none were considered by DST Group to be more feasible than the other planned options. Therefore, this Scenario was deemed to be out of scope for the study.

9 - Scenario C: Application of Corrosion Inhibiting Compounds (CICs)

9.1 Outline

This scenario involves applying a CIC to the aircraft to help mitigate potential corrosion. At this stage there is no specific CIC(s) intended for use on the F-35 aircraft.

Corrosion inhibiting compounds (CICs), also commonly known as corrosion prevention compounds (CPCs), have been used to provide temporary corrosion protection on metallic aircraft components for many years. CICs usually consist of oils, waxes or resins dissolved in a solvent that, when the solvent evaporates, leaves behind a barrier film on the metal that prevents moisture from reaching the metal surface.

In the absence of a CIC being selected at this point in time, DST Group have identified a CIC to be used for costing purposes. The CIC selected by DST Group is LPS 2, which has an application frequency of two years.

The CIC will be applied using the "fogging" method, which involves spraying a mist of CICs into the areas most at risk of intergranular corrosion. This is considered to be the most effective method of reaching otherwise inaccessible areas.

9.2 Probability Metrics

s33(a)(ii), s47D, s47G

[redacted]

9.3 Availability and Total Cost Impact FY2018 – FY 2054

s33(a)(ii), s47D [redacted]

9.4 Benefit Metrics

s33(a)(ii), s47D [redacted]

*The life of the fleet is from first arrival in FY18 to last arrival in FY24 plus 30 years and considered the build-up/ramp down of aircraft numbers

9.5 Costing Assumptions and Inputs

The following assumptions and inputs were used in the Cost Model for *Scenario C Use of CICS*:

9.5.1 – DST Group have advised that, as this scenario did not form part of the Expert Elicitation s33(a)(ii) [redacted] s33(a)(ii) [redacted]

9.5.2 – The frequency of coating s33(a)(ii) [redacted]

9.5.3 – The quantity required per coating application is two litres

9.5.4 – The effort required for to apply coat of CIC s33(a)(ii) [redacted]

9.5.5 – The additional time that an aircraft is unavailable following coating s33(a)(ii) [redacted]

9.5.6 – Any period of time required to disconnect the aircraft from the dehumidification infrastructure will not impact dehumidification process.

9.5.7 – Any CIC applications will be done in accordance with, and with approval of, JPO and Lockheed Martin (where required)

9.5.8 – The minimal amount of paint required is purchased each year and there is no leftover paint from prior year purchases

10 - Findings

This section provides findings and observations based on the data analysed.

10.1 Findings

- The largest net benefit would be derived from combining Scenario A (ii) Mobile dehumidification (full time) with Scenario C Use of CICs. This also assumes use of the three currently approved dehumidification systems in the planned maintenance hangars (capacity to dehumidify 17 aircraft simultaneously). The annual cost of these two options s33(a)(ii), s47D [redacted]
- All options have a positive net benefit and a high Return on Investment.
- The corrosion mitigation option with the highest risk reduction and net benefit is Scenario A (ii) Mobile dehumidification (full time).
- The option with the highest Return on Investment is Scenario C Use of CICs.
- The benefit from using Scenario A (iii) Use of planned infrastructure s47D [redacted] is the same as Scenario A (ii) Mobile dehumidification (part time). However the cost of using the planned units is higher because there is additional towing to the maintenance bays that would not be required with the use of mobile dehumidifiers for the parking bays. Therefore the Net Benefit is higher for part time dehumidification.

10.2 Sensitivity analysis

- A sensitivity analysis was run whereby the Expert Elicitation probability of corrosion occurring was adjusted s33(a)(ii) [redacted]
- The result did not materially affect the financial numbers and did not vary change the rank of any scenario in terms of the benefit profiles.

10.3 Graphs

The following two pages provide a visual representation of key results in the tables above.

- The Average Annual Cost of each scenario is shown at *Figure 1* on page 27.
- The Average Annual RAAF Labour cost per scenario is shown at *Figure 2* on page 27.
- A Net Benefit comparison is shown at *Figure 3* on page 27.
- The improvement on the Baseline probability of each Scenario is shown below and at *Figure 4* on page 27.
- The Average Reduction in Availability over 30 years is shown at *Figure 5* on page 27.
- A longer term life-of-fleet view is shown in *Figures 6-10* on pages 27 and 28.

s33(a)(ii), s47D, s47G

[redacted]

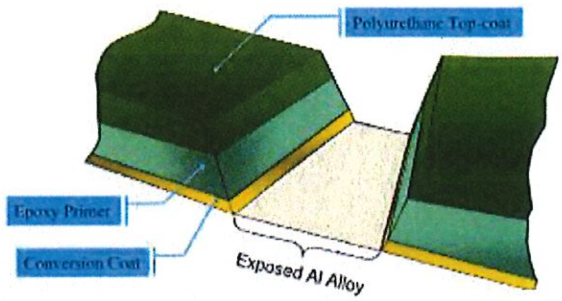
s33(a)(ii), s47D

[redacted]

Appendix A: Intergranular Corrosion

Corrosion Fundamentals (as detailed in the Expert Elicitation presentation)

- Corrosion occurs as a chemical reaction between metal and the environment (oxidant), depending on the type of metal and environmental conditions.



- Corrosion can degrade the material properties, cause stress cracking, and cause tensile stress which can impact adjacent components.

Problems Concerning the F-35 (as detailed in the Expert Elicitation presentation)

- The F-35 utilises the Aluminium Alloy 7085 in construction, and is the first time AA 7085 has been used in widespread production of a military aircraft. AA 7085 is reported to have increased susceptibility to intergranular corrosion.

s33(a)(ii), s47

[redacted]

Appendix B: Expert Elicitation and Scenario Mapping

Expert Elicitation

DST Group initiated an Expert Elicitation on the topic of corrosion where experts from Defence and Defence Industry considered a series of questions in relation to corrosion mitigation scenarios. These scenarios have been referred to in this document and used in the costing model.

In the Expert Elicitation there are two questions per scenario, one relating to mid-life (15 years) and the other relating to end of life (30+ years). For each question the group determined a three point estimate – the lowest probability, the highest probability, and the best guess probability. This study has taken the average of the three data points [redacted] so as to not omit the highest and lowest response. Note that the average of the best guess is [redacted] and the average of the lowest and highest responses is [redacted].

The results of the Expert Elicitation are detailed on the following page:

What is the probability of widespread corrosion requiring significant structural rework* across the entire fleet:			
	Realistically, what is the **lowest** probability of the problem occurring by mid-life under this scenario?	Realistically, what is the **highest** probability of the problem occurring by mid-life under this scenario?	Realistically, what is the **best guess** probability of the problem occurring by mid-life under this scenario?
Under anticipated maintenance practices at mid-life? (Q1)**	s33(a)(ii), s47D [redacted]	[redacted]	[redacted]
Under anticipated maintenance practices at end life? (Q2)**	[redacted]	[redacted]	[redacted]
With Australian-specific maintenance practices* at mid-life? (Q3)**	[redacted]	[redacted]	[redacted]
With Australian-specific maintenance practices* at end life? (Q4)**	[redacted]	[redacted]	[redacted]
With aircraft (plug-in) dehumidification for a defined period at mid-life? (Q5)	[redacted]	[redacted]	[redacted]
With aircraft (plug-in) dehumidification for a defined period at end life? (Q6)	[redacted]	[redacted]	[redacted]
With continual hangar dehumidification at mid-life? (Q7)	[redacted]	[redacted]	[redacted]
With continual hangar dehumidification at end life? (Q8)	[redacted]	[redacted]	[redacted]

Table 17 - Expert Elicitation Results

* Defined as maintenance actions requiring multiple months of downtime

** Defined as *intended* practices of mature JSF system, for instance a fully functioning Corrosion Prognostic Health Management System

*** May include additional aircraft washing, inspections, hangaring, basing or other activities

Subsequent to the Expert Elicitation, for the purposes of this study the following assumptions have been made by DST Group:

- The term "defined period" is the same as "part time", which is 30% of non-flying hours.
- The term "continual" is the same as "full time", which is 100% of non-flying hours.
- The term "hangar" has been agreed to be defined as an enclosed parking bay.

Scenario Mapping

Once the assumptions and interpretations surrounding the Expert Elicitation were agreed, the questions and results were then mapped to the mitigation scenarios as described in the *Scope* of this document, as shown below:

Expert Elicitation Questions	Scenarios for Corrosion Mitigation
Under anticipated maintenance practices at mid-life? (Q1)**	Baseline
With Australian-specific maintenance practices* at mid-life? (Q3)**	Cannot be mapped to any scenario
With aircraft (plug-in) dehumidification for a defined period at mid-life? (Q5)	As this is interpreted as part time it covers the part time aspect of Scenario A: Plug-In Dehumidification Part/Full Time ii) Mobile dehumidification infrastructure 13% Part Time
With continual hangar dehumidification at mid-life? (Q7)	As this is interpreted as full time it covers the full time aspect of Scenario A: Plug-In Dehumidification Part/Full Time ii) Mobile dehumidification infrastructure 8% Full Time iii) Utilisation of planned dehumidification infrastructure within aircraft hangars 8% Full Time

Table 18 - Expert Elicitation Mapping

The second round results for questions 3 – 8 as they were incomplete. Questions 1 and 2 from the second round were completed and will replace questions 1 and 2 from the first round.

Appendix C: Photos

Photos of Dehumidifiers

The dehumidifiers in the quote used for the cost model are shown below to give an indication of size. The dehumidifier example is shown in silver in front of the car. The four dehumidifiers per bay (one between two aircraft) are run by the electric compressor shown in green. s47D [redacted]

s47D [redacted]

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