Ageing Aircraft Programme Working Group (AAPWG) Paper 012

Understanding the Corrosion Threat to Ageing Aircraft

Dennis Taylor

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DISTRIBUTION

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EXECUTIVE SUMMARY

With many military aircraft platforms being required to operate past their original out of service date, there is increasing concern that structures and systems may be experiencing an increased airworthiness risks from corrosion. This Paper has been commissioned to capture the full extent of corrosion issues in the long-term Ministry Of Defence air fleets. It is suggested that the information presented in this Paper should be used to assist in focusing the MOD's Research and Development Corrosion Programme onto key remedial requirements.

All current in-service platform PTs were contacted to arrange meetings to discuss their current Environmental Damage Prevention and Control (EDPC) problems and how they applied the requirements of RA 4507. Prior to these meetings the PTs were requested to provide current EDPC or Structural and/or Systems Integrity Working Group (SIWG/SyIWG) meeting minutes so an appreciation of current corrosion issues (if any) could be gained. PTs were also requested to provide any policy documents that supported EDPC management of the platform such as the Support Policy Statement from the Platform Topic 2(N/A/R)1 and the Structural Integrity Strategy Document.

To enable generic issues that affected a particular type of operation or aircraft platform category the air platforms were divided into three groups:

Heavy Aircraft and Communications (HA&C)

Fast Jet and Training Aircraft (FJ&T)

Rotary Wing (RW)

Examples of some of the significant issues identified are as follows:

The poor availability and serviceability of aircraft washing equipment and base washing facilities and an increase in reports of corrosion damage occurring to armament equipment

Widespread cadmium corrosion on electrical wiring connectors

The effect of runway de-icer fluid on landing gear and carbon brake packs on both FJ&T and HA&C aircraft

A lack of preparation for the impact that the Regulation, Evaluation and Authorisation of CHemicals) (REACH) will have on the supply of materials for EDPC protection on both FJ&T and HA&C aircraft fleets

It was found that there was a generally poor adherence by the PTs to the acceptable means of compliance for EDPC management contained in RA 4507. Three particular issues were identified:

- A lack of Environmental Damage Control Plans
- The meaning and intent “of the recovery procedure following an “exposure incident””
- A lack of clarity as to the PT’s responsibility with regard to training requirements

There is also an underlying problem with RA 4507 and potentially many other Regulatory Articles, bought about by the introduction of the Continuing Airworthiness Management Organisation (CAMO) role. There are many extant acceptable means of compliances where the responsibility is stated as being the PTs that are now likely to be in conflict with those of the CAMO.

32 recommendations have been made; some of the more significant are given below:

> The problems with aircraft washing equipment and facilities should be investigated
>
> The current concerns of the possible damage caused to undercarriages and associated equipment, particularly carbon brake packs, by Clearway 3™ runway de-icing fluid is formally addressed by each platform PT.
>
> It is recommended that a method to address the REACH regulations be carried out by cross-platform discussion to ensure a consistent cost effective solution

There were several examples of “beneficial practice” observed, such as:

- A specific post identified within the Typhoon PT responsible for EDPC
- The Chinook PT Environmental Damage Control Plan
- The Tornado PT 2(R)1 Leaflet for the handling of cadmium corrosion on electrical connectors

These have been identified as methods and procedures that other PTs might consider adopting to address similar issues or requirements on their particular platform.

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ABBREVIATION

AAA	Ageing Aircraft Audit
AAPL	Ageing Aircraft Programme Laboratory
ACI	Analytical Condition Inspection
AD	Accidental Damage
AD	Airworthiness Directive
ADM	Anti-Deterioration Maintenance
ADS	Aircraft Document Set
AESO	Aircraft Engineering Standing Orders
AMC	Acceptable Means of Compliance
AMM	Aircraft Maintenance Manual
AP	Air Publication
BBA	Bombardier Business Aircraft
CAA	Civil Aviation Authority
CAMO	Continuing Airworthiness Management Organisation
CPC	Corrosion Preventative Compounds
CS	Condition Survey
DAP	Digital Air Publication
DCAE	Defence College of Aeronautical Engineering
DH	Duty Holder
DO	Design Organisation
Dstl	Defence Science & Technology Laboratory
DTAL	Dennis Taylor Associates Limited
EASA	European Aviation Safety Agency
ED	Environmental Damage
EDPC	Environmental Damage Prevention and Control
ESVRE	Establish Sustain Validate Recover Exploit
EWIS	Electrical Wiring Interconnect System
FJ&T	Fast Jet & Training
FLC	Front Line Command
FOD	Foreign Object Damage
HA&C	Heavy Aircraft & Communications
HMS	Her Majesty Ship
LRU	Line Replaceable Unit
MAA	Military Aviation Authority
MAP-01	Manual of Maintenance and Airworthiness Processes
MAP-02	Manual of Maintenance and Airworthiness Processes and Supplement
MFRI	Mandatory Fault Reporting Instruction
MIG	Material Integrity Group
MLG	Main Landing Gear
MOD	Ministry Of Defence
MSG	Maintenance Steering Group
NAS	Naval Air Squadron
NDT	Non-Destructive Test
OEM	Original Equipment Manufacturer
OSD	Out of Service Date
PDM	Planned Depot Maintenance
PIWG	Propulsion Integrity Woking Group
PTs	Project Teams
PTL	Project Team Leader
RA	Regulatory Article
RAF	Royal Air Force
RAP	Repair Assessment Programme
RCM	Reliability Centred Maintenance
R&D	Research & Development

REACH	Registration, Evaluation, Authorisation and restriction of Chemicals
RJ	Rivet Joint
RNAS	Royal Naval Air Station
RTI	Routine Technical Instruction
RW	Rotary Wing
SAAE	School of Army Aeronautical Engineering
SAAG	Systems Airworthiness Advisory Group
SB	Service Bulletin
SEP	Structural Examination Programme
SI	Servicing Instruction
SI	Structural Integrity
SI(T)	Special Instruction (Technical)
SIWG	Structural Integrity Working Group
SPS	Support Policy Statement
SRM	Structural Repair Manual
SSI	Structurally Significant Item
STI	Special Technical Instruction
SyI	Systems Integrity
SyIWG	Systems Integrity Working Group
TLMP	Through Life Management Plan
TO	Technical Order
UK	United Kingdom
USAF	United States Air Force
UTI	Urgent Technical Instruction

1 INTRODUCTION

1.1 With many military aircraft platforms being required to operate past their original out of service date (OSD), there is increasing concern that structures and systems may be experiencing an increased airworthiness risks from corrosion. This Paper has been commissioned to capture the full extent of corrosion issues in the long-term Ministry Of Defence (MOD) air fleets. It is suggested that the information presented in this Paper should be used to assist in focusing the MOD's Research and Development Corrosion Programme onto key remedial requirements.

1.2 Aircraft materials have the potential to corrode immediately following manufacture and various procedures are used to avoid this through the application of rigorous design, quality assurance and manufacturing standards. The majority of materials used in aircraft applications are designed to provide specific mechanical properties whilst remaining as light as possible. They are also selected for their intrinsic corrosion resistance through the manufacturing alloying processes and heat treatments. These can be further enhanced using various techniques such as chemical conversion (anodising on aluminium alloys for example), cladding with the pure base element and various barrier materials such as primers and paints.

1.3 The conservation, repair and re-protection of the aircraft from the effects of corrosion are essential maintenance functions. However, barrier materials become degraded and many may reach the end of their expected life before the aircraft is retired from service. The Ministry of Defence (MOD) is therefore faced with an increasing and costly maintenance burden if the preservation of corrosion protection systems is not maintained adequately after the aircraft or equipment's introduction into service. This may be further exacerbated if the aircraft is operated in an environment that was not originally specified, such as operating the Apache at sea, for example.

1.4 The prevention of corrosion is therefore a fundamental concern and its timely detection and correct treatment, key to avoiding loss of airworthiness, availability and the associated increase in operating cost. Recent aviation history, both military and civilian, has many examples of aircraft types that suffered either catastrophic failures or very expensive repairs when corrosion damage was identified. The Boeing 737 Aloha Airlines, Flight 243 accident, was caused through lap joint corrosion that produced fatigue cracking of the riveted connections. Closer to home, the Jaguar suffered for much of its last 10 years of operational life with expensive and time consuming inspections to Fuselage Frame 25 caused through the effects of stress corrosion cracking. These two examples demonstrate the importance of corrosion protection to materials in the Aloha accident and of material design and selection in the Jaguar problem.

1.5 The key principles in avoiding corrosion are the correct selection of material at the design stage, early identification and rectification of any in-service degradation and the commitment to maintain corrosion protection systems to a high standard throughout the items service life. In order to evaluate the current methods employed by the Project Teams (PTs) to meet these requirements, information has been gathered from the majority of the in-service platform PTs in a series of meetings that covered the current corrosion problems that they were dealing with. This paper also addresses the processes and procedures used by the PTs to satisfy the requirements of the current Regulatory Article (RA) 4507 [1] the management of Environmental Damage Prevention and Control (EDPC). The acceptable means of compliance (AMC) for RA4507 is given in the Manual of Maintenance and Airworthiness Processes (MAP-01), Chapter 11.6. [2]. The outcome of meetings regarding the application of RA4507 is detailed in Section 7, Table 2 and Table 3. In addition to RA4507, a further ten RAs have been identified as having relevance to EDPC policy and these are identified and reviewed in detail in Appendix E:. To enable generic issues affecting a particular role, operation or aircraft type, the platforms were divided into three “Platform Groups” as listed below.

- Heavy Aircraft & Communications (HA&C)
- Fast Jet & Training (FJ&T)
- Rotary Wing (RW)

1.6 The platforms that participated in the work for this Paper are shown below in Table 1

Heavy Aircraft and Communications (HA&C)		
A400M Airseeker BAe 125 BAe 146	C17A Globemaster C130-J Hercules Islander/Defender Sentinel	Sentry Voyager
Fast Jets and Training Aircraft (FJ&T)		
Tornado Tucano Typhoon	Vigilant Viking	
Rotary Wing (RW)		
Apache Chinook Gazelle	Lynx Merlin Puma	Sea King Wild Cat

Table 1 Generic grouping of aircraft platforms

1.7 The following platforms were not included due to their close proximity to their out of service date (OSD):

- Hercules Mk C1/C3
- Tristar
- VC10

The F35 was not included due to its distant introduction into service. Remotely Piloted Air Systems and Historic Aircraft Flights[1] are also not included.

[1] Historic Aircraft Flights are defined as, Battle of Britain Memorial Flight (BBMF), Royal Navy Historic Flight (RNHF) and Army Historic Aircraft Flight (AHAF)

2 INFORMATION GATHERING

2.1 Although it was the intention to visit all of the in-service platforms, other than those specifically excluded and identified in Section 1, meetings were not possible to arrange with the PTs listed below.

1. Shadow/King Air (HA&C)
2. Hawk TI and T2 (FJ&T)
3. Augusta 109 (RW)
4. Bell 212 (RW)
5. Griffin (RW)
6. Squirrel (RW)

2.2 Of those platforms not visited, the Hawk is perhaps one that would have provided particularly useful information as the T1 version of the aircraft has been in service for over 30 years and operated for much of that time from airfields situated in a marine environment, presently at RAF Valley and RNAS Culdrose and previously at RAF Brawdy and RAF Chivenor. Of the other platforms unable to support a meeting, the rotary wing types are all operated to civilian maintenance schedules, as is the Shadow/King Air aircraft. These schedules are adjusted for the military operations and the number of corrosion arisings that they report would have made a useful comparison with those in the civilian fleet.

2.3 Review meetings took place at the PT offices in Abbey Wood or at the main operating base for the candidate platform. Prior to the meeting the PT were requested to provide their policy for EDPC management and as much relevant documentation as possible supporting specific corrosion issues. A caveat was added that if any of the documents were restricted (or above) then the PT was requested to forward them to Dstl. The documentation specifically requested is listed below.

1. Environmental Damage Prevention and Control (EDPC) Meeting Minutes
2. Structural Integrity Working Group (SIWG) Minutes
3. Systems Integrity Working Group Meeting (SysIWG) Minutes
4. Relevant leaflets from the Topic 2(N/A/R)1
    - Support Policy Statement
    - EDPC

- Surface Finish Policy,
- Dehumidification Procedure
- Spillage of Body Fluids
- Electrical wiring and interconnect system

5. Structural Integrity Strategy Document
6. Systems Integrity Strategy Document

2.4 Although the majority of PTs responded positively to the request a small number were unable to supply any documents prior to the meeting taking place. The meetings took place between September 2012 and June 2013 (as shown in Appendix A:) and were conducted to an Agenda (Appendix B:) based around the requirements of the MAP-01 Chapter 11.6 [2] EDPC process. Following the meeting a draft of the "Notes of Meeting" were circulated to attendees for comment and approval. The detail of the data gathered at these meetings is covered in the individual platform reports in Section 4, Heavy Aircraft and Communication (HA&C), Section 5, Fast Jets and Training (FJ&T) and Section 6, Rotary Wing (RW). The points of contact made during this Paper are listed in Appendix C: and the documentation provided is listed in Appendix D:.

2.5 A breakdown of the individual PTs response to their application of the EDPC policy - as stated in MAP-01 Chapter 11.6. - is given in Section 7 and summarised in Table 2 and Table 3. There was almost unanimous agreement on certain aspects of the regulation that PTs felt either did not fall under their jurisdiction or that they were unable to enforce. These aspects are discussed further in Section 7. To keep the findings in context it should be remembered that at the time that the meetings were being held the Continuing Airworthiness Management Organisations (CAMO) were still being established. This may have had some bearing on the findings of lack of policy or implementation as PT/CAMO responsibilities still had to be agreed.

2.6 Meetings were held with the three services training schools in order to understand the scope of the training provided to maintenance personnel. Details of the meetings held with the training schools are discussed in Section 8.5.

3 THE NATURE OF CORROSION

3.1 INTRODUCTION

3.1.1 Corrosion is defined in most textbooks and aircraft publications as the *“tendency of a metal to revert to a more stable natural state”* [3]. Corrosion damage to aircraft structures and equipment is one of the most recurrent faults found and can significantly compromise structural and systems integrity if left untreated. The resulting damage, depending on the degree of corrosion that has occurred before its detection, can also prove costly in both man-hours for its rectification and the loss of aircraft availability. The prompt detection and identification of corrosion is therefore of the utmost importance as is the correct application of procedures to remove it and re-protect the area from further attack. Corrosion left untreated can have serious consequences that include:

- A reduction in static strength
- The conditions to promote stress corrosion cracking
- A reduction in the fatigue life
- Seizure or failure to operate of mechanical, electrical, hydraulic and gaseous systems

3.1.2 Undetected or unrepaired corrosion can have an adverse affect on flight safety, airworthiness and costs.

3.1.3 The first line of defence is the processes, treatments and construction techniques employed in the design and build of the aircraft and its equipment. A major consideration in the selection of a material for aerospace use is its corrosion resistance qualities. However, compromises sometimes have to be made in the choice of materials and in these cases, other means of providing satisfactory corrosion resistance must be used, such as electroplating (anodic treatment). There are also platforms still in use that were manufactured using materials that although considered suitable at the time of their design, have over time been found susceptible to corrosion damage. For instance the 7000 series of aluminium alloys that contain copper and zinc are particularly susceptible to intergranular corrosion because of the high galvanic couples between the grain bodies and boundaries produced during heat treatment.

3.1.4 The corrosion prevention techniques and protective systems employed by the manufacturer are only as good as the organisation responsible for its upkeep. Any failings in the application of anti-corrosion maintenance will increase the risk of corrosion damage becoming an issue. Anti-corrosion maintenance begins with the application of good aircraft husbandry standards[2]. These include keeping the aircraft clean through washing at regular intervals, keeping it dry (particularly the interior) through the use of dehumidification equipment, the upkeep of protective coatings and the application of appropriate paints and corrosion preventative compounds (CPCs).

3.1.5 When corrosion is found it is important that it is reported, its impact on structural integrity assessed and the necessary rectification carried out as soon as possible. If immediate repair is not possible or considered necessary it is vital that the site of the damage is accurately recorded and its rectification properly managed so that the time to removal of the damage is minimised.

3.2 IDENTIFICATION OF CORROSION

3.2.1 There are a number of forms of corrosion that can affect the aircraft structure and its equipment. Some types of attack are more prevalent on certain materials than others but in all cases the damage should be rectified as soon as possible after the initial finding. The various forms of corrosion and the recognition of it are described below.

3.3 SURFACE CORROSION

3.3.1 This is the simplest and most common form of corrosion found on aircraft and components. It exhibits a uniform attack over any unprotected surface and is caused through the metal being converted into corrosion salts by direct chemical interaction with contaminants in the atmosphere. The corrosion appears as grey or white powdery product on light alloys while on ferrous materials it forms a reddish-brown rust and covers copper in a greenish powder.

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[2] Husbandry – *"the continuous task of maintaining an aircraft and its equipment in a high state of preservation throughout its life"*

The effects of surface corrosion should not be underestimated as serious pitting can occur if left untreated.

3.4 PITTING CORROSION

3,4,1 Pitting corrosion can affect both ferrous and non-ferrous components and occurs where surface protection has been lost, where no anti-corrosion protection is applied or where the material surface has been altered through heat treatment and/or mechanical working. Pitting may also be caused through poor quality production leading to impurity and flaws in the material. The severity of this form of damage depends on the materials susceptibility and will also be exacerbated by the local environment, especially salt laden atmospheres. In the presence of significant load reversals, corrosion pits will often act as the nucleation sites for fatigue cracks that can lead to component failure. Corrosion pits are recognised through the local disruption on the surface of the material with evidence of corrosion product in the sides and bottom of the pit. In mild attacks, removal can be through scouring and chemical treatment, but deeper pits may require the removal of material by blending to remove all of the corrosion damage followed by re-protection with the prescribed surface coatings. Corrosion pits can be microscopically small and still lead to complete failure of the component.

3.5 INTERGRANULAR CORROSION

3.5.1 This type of attack may occur due to pitting corrosion or along the grain boundaries of the material. Steel and aluminium alloy materials are both susceptible when subject to fluctuating loads that encourage separation of the grain boundaries. The significance of this type of corrosion is that it is extremely difficult to detect visually until the cracking has reached the surface. In this case it may already have caused extensive damage to the material and furthermore, the surface cracking allows moisture penetration to accelerate the condition. Intergranular corrosion cracking cannot be repaired or treated and affected components will either require extensive removal of the affected area, (if possible and permissible), or complete replacement.

3.6 EXFOLIATION CORROSION

3.6.1 This corrosion, again occurring in both steel and aluminium alloys is similar to intergranular corrosion in that the materials grain boundaries are attacked. The most likely sites are in material that has been extruded or rolled as the grain boundaries are flattened and elongated in the process. Corrosion may then be initiated at any weakness especially at external surfaces and abrupt edges where the material can delaminate along the grain structure. This problem has been partly resolved by avoiding materials that are susceptible to this type of attack and in the development of heat treatments that help reduce this susceptibility.

3.7 GALVANIC, DISSIMILAR METAL OR ELECTROLYTIC CORROSION

3.7.1 This type of corrosion can occur in any part of the structure or on items of equipment where two dissimilar metals are in contact with one another. For corrosion to occur there must be a path for a flow of electrons between the two materials. The material with the less noble metal forms the anode of the electrical cell and suffers the greatest amount of corrosion damage while the material with the more noble metal forms the cathode and remains largely unaffected. The greater the difference in the two metals electrical potential the greater the amount of damage to the anode. The corrosion is exhibited by severe surface corrosion damage to the anodic material and possibly less severe surface corrosion damage to the cathodic material. Prevention relies on the initial design of the components and the way that they are incorporated into the overall structure. The design must minimise the galvanic potential of the two contacting materials and provide effective barrier coatings in the form of chromate based primers and metal pre-treatment such as anodising aluminium alloys and the use of jointing compounds (wet assembly).

3.8 CREVICE CORROSION

3.8.1 Crevice corrosion is effectively another form of galvanic corrosion as previously described and can occur in all types of material used in aircraft manufacture. The electrical cell is initiated through a corrosive liquid gaining access to the crevices that occur naturally between components within structures or equipment. The entrapped liquid acts as an electrolyte and provides the environment for the development of an anodic and cathodic region. The loss of material from the anode forms a corrosion pit at the bottom of the crevice that continues to grow in depth by the electrolytic action on the anodic material. This type of damage can be extremely difficult to detect and will only become obvious on the surface of the item when the material local to the corrosion site is disrupted. Crevice corrosion may be combatted by the use of wet assembly of skin joints, filleting or sealing of mating surfaces after assembly and the spraying of structure with water displacing fluids which themselves leach into crevices and prevent moisture ingress.

3.9 FILIFORM CORROSION

3.9.1 Filiform corrosion damage is another type of surface corrosion attack on the metal and can occur on all types of material used in aircraft manufacture. It varies from surface corrosion by spreading out over the surface in random spidery patterns that have very little depth to them. The head or tip of the line of corrosion is still producing surface damage while the remainder is the dead corrosion product. Filiform corrosion should not be ignored and should be treated as any other form of corrosion as it can cause corrosion pitting with the subsequent consequences described above.

3.10 FRETTING CORROSION

3.10.1 Fretting corrosion damage occurs when two surfaces in contact with each other and under load vibrate, flex or slip - even though the movement may be microscopic. The surfaces of both components are subject to wear which allows any protective oxide to be destroyed and the loss of material from each component. The wear debris forms a hard abrasive that accelerates the wear rate and promotes the formation of stress-raising pits on the interfacing surfaces. These pits are potential sites for the initiation of fatigue cracking. Fretting corrosion may be detected by traces of wear debris staining at the edges of joints where it has been extruded or around fastener heads. On steels this is normally a dark brown colour while on aluminium alloys it is a black smoky colour. The staining on exterior surfaces will normally be spread back from the fastener head in the direction of the airflow.

3.11 CORROSION FATIGUE

3.11.1 Corrosion fatigue may be initiated in structure or components where there is a simultaneous exposure to corrosion attack and significant cyclic stresses. The damage normally occurs at free surfaces and at abrupt changes of section that produce local stress raisers such as fillet radii and fastener holes. These conditions are similar to many of those described above where breakdown in surface protection promotes loss of material strength through loss of material (corrosion) and pitting damage produces large highly localised stress gradients. The most serious consequence of any corrosion fatigue damage is the potential reduction in fatigue life of critical/vital structural components. The results of fatigue testing (carried out in a non-corrosive environment) from which the airframe or component fatigue lives are calculated may be seriously compromised. It is therefore vital that any corrosion pitting damage to critical components is repaired (if permissible and within the limits stated) or the component replaced.

3.12 MICROBIOLOGICAL CONTAMINATION

3.12.1 This form of contamination occurs primarily within aircraft integral fuel tanks. The contaminant enters the tank through the fuel and forms a fungal growth within the tank at any fuel/water interface. The fungal growth forms an acid that corrodes the tank structure and detection is often only possible when the interior of the tank is exposed. The problem is exacerbated in hot and humid conditions. Prevention through treating fuel with icing inhibitors reduces the risk due to its biocide property and attention to regular water drain checks will also help combat the problem.

3.13 STRESS CORROSION CRACKING (SCC)

3.13.1 SCC requires three specific conditions to be present for it to occur, the absence of any one of these will prevent it. The three conditions are:

- A susceptible material
- A corrosive environment
- A sustained tensile stress

3.13.2 The simplest way in which SCC may be eliminated is to ensure that susceptible materials are not used in the manufacture of any aircraft part. A significant amount of research has been carried out to identify susceptible materials and to prohibit them from being specified. The second requirement is for a corrosive environment to exist. This is far more difficult to control and fundamentally the processes and procedures for EDPC, if applied correctly, should prevent it from occurring.

3.13.3 The final requirement for a sustained tensile stress is more difficult to control than the previous two conditions. Stress raisers may be introduced during manufacture of the component, such as in a forging or during the assembly process. Others may occur through normal stresses in the structure caused by the weight of the aircraft. Stress corrosion cracking is very difficult to detect and predict and will only usually become apparent when the cracking breaks through the surface of the item.

3.14 TECHNICAL INFORMATION

3.14.1 AP119A-0200-1, Aircraft Corrosion Handbook [3] provides excellent basic information on the various forms of corrosion, its treatment and re-protection.

4 FINDINGS: HEAVY AIRCRAFT & COMMUNICATION

4.1 HEAVY AIRCRAFT AND COMMUNICATION PLATFORMS

4.1.1. The following heavy aircraft and communication aircraft platforms (HA&C) have been reviewed.

- Islander and Defender
- Sentry
- Sentinel
- Airseeker
- BAe 125 and BAe 146
- Voyager
- A400M Atlas
- C17 Globemaster and C130J Hercules completed through a review of the documentation provided and telephone discussion, no meetings took place.

4.1.2. The Shadow/King Air PT was unable to support the meeting request.

4.2 ISLANDER/DEFENDER

4.2.1. The meeting with the Islander /Defender PT took place at Abbey Wood on 13th September 2012 and prior to this meeting the PT had provided the documents listed in Appendix D:. At the meeting the PT presented a copy of their local database for corrosion damage which contained details of corrosion defects found against each aircraft listed by tail number. A review found no obvious trend as to corrosion prone areas of the aircraft all of which undergo a corrosion inspection every two years (in accordance with Service Bulletin (SB) 190 [6] and a full paint strip and repaint every six years. One issue that had previously given concern was corrosion found under the wing leading edge de-icing boots on one particular aircraft (ZG848) found for the first time on the port wing in April 1995 and then on the starboard wing in April 2005. This led to the introduction of an inspection requirement into the maintenance schedule during the six yearly paint programme.

4.2.2. All corrosion arising's are reported by MOD Form 760, Narrative Fault Report, action as required by the Mandatory Fault Reporting Instructions (MFRI) issued by the PT. The PT believes that there are no current problems regarding corrosion damage to the aircraft and that the current inspection programme is successfully finding and correcting corrosion defects before they can cause major problems.

4.2.3. The author also conducted a review of the Civil Aviation Authority (CAA) and European Aviation Safety Agency (EASA) web sites to check for any related airworthiness directives relating to corrosion issues on the type in civil use and none were found.

4.3 SENTRY

Prior to the meeting the PT had provided the documents listed in Appendix D:. This had enabled a review to be carried out upon which much of the discussion was based. The meeting with the PT took place on 19th February 2013 at RAF Waddington.

The current EDPC issues affecting the aircraft were discussed and are described below.

4.3.1 Keel beam corrosion to electrical earth bonding points

The keel area, which gets heavily soiled in normal service, has many locations that are difficult to clean satisfactorily and these create an ideal environment for corrosion to take hold. A number of corrosion occurrences have been found at electrical earth bonding points due to the breakdown in the local protective sealing of the earth point attachment on the structure. Although the earth point must be free of any protective treatment to allow a satisfactory earth to be made, once made the earth point is then coated with a polysulphide sealant (PRC) that now appears to be failing and allowing moisture ingress to initiate galvanic corrosion.

It should be noted that the same issues have been found on BAe 125 and BAe146 and previously on VC10 and Nimrod. There is also the potential for this damage to degrade the electrical bonding efficiency of the aircraft creating the potential for serious consequences in the event of an electrical malfunction or lightning strike.

4.3.2 Front spar cracking

The wing front spars are manufactured from 7075 aluminium alloy. These have been found cracked on two aircraft and corroded on all aircraft in the RAF fleet and one of these aircraft required extensive off-site repairs. The damage is caused through intergranular/exfoliation corrosion possibly exacerbated through stress corrosion cracking. The Materials Integrity Group (MIG) (who are part of 1710 Naval Air Squadron (1710 NAS)) are currently carrying out a forensic investigation of the cracked item. Although an option exists to replace the spars with items manufactured from an improved material, the PT currently considers this option unaffordable.

This type of intergranular/exfoliation corrosion stress corrosion cracking is a fairly common problem with this generation and type of material. Although the problem is being managed through inspection the opportunity to remove this material from the airframe would significantly reduce airworthiness risk and maintenance costs, in the longer term.

4.3.3 Wing plank corrosion on beaver tail

Corrosion has been found around the countersunk heads of steel fasteners passing through the wing plank adjacent to the beaver tail. The damage is caused through galvanic corrosion between the aluminium alloy skin and the steel fasteners that have lost their protective cadmium coating. The PT is replacing the current fastener material with a corrosion resistant steel item. This type of corrosion damage has been found on many other platforms including VC10 and BAe 125.

4.3.4 Magnesium alloy flying controls

Various flying controls on the aircraft are manufactured from magnesium alloy and are suffering corrosion damage causing repair and availability issues.

There are modified control surfaces available manufactured from improved materials but these are currently considered unaffordable.

The use of magnesium alloys in aircraft of the Sentry generation was fairly common, however, the maintenance burden that it places on operators when it suffers corrosion damage makes its use on more modern platforms questionable[3].

4.3.5 Aircraft wash facilities

There has been an on-going problem with aircraft washing facilities at RAF Waddington. It was thought at the time of the meeting (February 2013) that the situation would now begin to improve with the purchase of suitable aircraft washing equipment.

Other stations such as RAF Coningsby and RAF Marham have had similar problems and as aircraft washing is a fundamental pre-requisite to avoiding EDPC it is surprising that this situation is so widespread and persistent.

4.3.6 Bleed air duct corrosion

Small areas of pitting corrosion have been found on the external surface of leading edge bleed air ducts. There is also evidence of this issue affecting other platforms such as Typhoon and this is currently being investigated by 1710 NAS MIG.

4.3.7 Hydraulic reservoir corrosion

The hydraulic reservoirs on the aircraft have suffered internal corrosion caused by moisture in the engine bleed air used to pressurise them. Although there is a modification for the fitting of a water separator in the supply line from the engine this modification is not being considered for incorporation at this time.

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[3] Def Stan 00-970 Part 1/11 Part 4 Section 4.1.29, 4.1.30 and 4.1.31 gives specific details on the allowable usage of Magnesium alloys in all new designs.

4.3.8 Electrical connectors

The electrical interconnect system on the aircraft has suffered from surface corrosion in the past and corrosion preventative compounds (CPCs) were applied to alleviate the problem. However, the expected reduction or prevention of the problem has not been realised and there is anecdotal evidence that the current CPCs may have exacerbated the problem. 1710 NAS MIG are currently carrying out work to determine whether the CPCs have had a deleterious effect on the connectors. Similar problems have also been identified on electrical connectors on other platforms such as Tornado, Typhoon, Merlin, BAe 125 and BAe 146.

4.3.9 Repair Assessment Programme (RAP)

As the aircraft go through the routine repaint programme a repair assessment programme (RAP) is being carried out to the fuselage structure once it has been stripped back to bare metal. An internal RAP is also being conducted during the maintenance 'C' check cycle (every 18 months) on the aircraft. This requires a close visual inspection of the airframe and will enable the corrosion damage on each individual aircraft to be assessed.

4.3.10 ZH105 Ageing Aircraft Programme Laboratory (AAPL) (Sentry)

ZH105 was transferred to Dstl in January 2012 and converted into the Ageing Aircraft Programme Laboratory (Sentry). The AAPL(Sentry) has since been used to support a wide range of Sentry-specific integrity tasks (funded by the Sentry PT) and pan-platform investigations which have included the following subject areas:

- Thermal acoustic blanket replacement
- Hydraulic pipe corrosion
- Auxiliary Power Unit (APU) support structure assessment of overheat damage
- Environmental Conditioning System (ECS) duct recovery
- Life Extension Programme (LEP) de-risking
- EWIS integrity investigation

The AAPL programme remains in progress.

4.3.11 Repair database

Musketeer Solutions Limited is also using ZH105 as a trial for the development of a structural repair database under contract to Dstl. The aim is to produce a generic tool that will be available for use on all other platforms to enable a rapid assessment and classification of corrosion prone areas to be made.

4.4 SENTINEL

The meeting with the Sentinel PT took place at RAF Waddington on the 19th February 2013. Prior to the meeting the PT had provided the following documentation listed in Appendix D:. The current EDPC issues affecting the aircraft were discussed in detail and are recorded below.

4.4.1 Engine intake cowls

Damage and corrosion had been reported to the engine intake cowls. On investigation it was found that the external damage to the inlet cowl had been caused through the poor engineering practice of leaning access ladders against the intakes. Damage to the internal cowl skin was attributed to a maintenance error (i.e. poor tool/Foreign Object Damage (FOD) control) when carrying out engine fan/intake inspections. This practice has now been stopped, the damage cowlings replaced and the unserviceable items returned to the Original Equipment Manufacturer (OEM) for repair/refurbishment.

4.4.2 Transition fairing structure

A surface corrosion problem had been identified on several aircraft that was caused by lack of surface finish and treatment to the transition structure and the interface with the fuselage belly fairing. Repairs and painting had been carried and a repeat inspection introduced at every maintenance 4C (6 years) check to ensure that the repair had been successful in preventing reoccurrence.

4.4.3 ZJ694 horizontal stabilizer and elevator upper surface

This composite structure had been found suffering from poor surface finish and rectification has been deferred until the aircraft scheduled repaint programme. Until then, an inspection regime has been introduced to monitor for any further deterioration and to rectify any localized deterioration.

At the time of the meeting the PT was awaiting confirmation as to whether the Sentinel platform was to be retired from service by 2015. The uncertainty over the decision was consequentially delaying confirmation of contracts for such services as aircraft painting.

4.4.4 Carbon brake unit runway de-icer ingress

The PT confirmed that there was a maintenance procedure in place to inspect the brake units and landing gear whenever the aircraft was operated following the application of runway de-icer fluid.

4.4.5 Main Landing Gear Assembly Axle end cap sealant

Bombardier Business Aircraft (BBA) informed all operators and maintainers of the possible ingress of moisture to the stub axle identified on an aircraft undergoing an 8C (18 month periodicity) maintenance check. The requirement involved inspection, a repair procedure and preventative measures (the addition of sealant), to stop the ingress of moisture into the stub axle via the wheel speed transduce cables access port at the leading edge of the main landing gear. Corrosion to this component had been found on one Sentinel aircraft resulting in a repair scheme being requested and preventative measures implemented.

At the time of the meeting the PT was in discussion with BBA regarding the need to introduce an on-going inspection of the affected area.

4.4.6 Repair assessment programme (RAP)

It was noted from the Minutes of the Structural Integrity Working Group (SIWG) [14] that a RAP to the external surfaces is carried out when the aircraft go through the repaint programme and are stripped down to bare metal. Similar to the Sentry this will require a close visual inspection of the airframe and will enable an assessment of the corrosion damage on each individual aircraft.

4.5 AIRSEEKER

A meeting was held at Abbey Wood with the PT on the 13th March 2013. At this meeting the PT gave details of the contractual arrangement for the procurement of the aircraft and how they were being prepared for RAF use from a structures and EDPC perspective. The philosophy that would be adopted, once the aircraft entered RAF service, was also explained and the documents listed in Appendix D: were presented at the meeting and were subsequently reviewed.

The MOD has purchased 3 Rivet Joint (RJ) type aircraft which are currently being prepared at the L-3 Communications facility Greenville, Texas. The aircraft are being converted from late batch KC-135 (ex tanker aircraft, 1964 vintage) to the current Block 10, RJ standard and will be to the same build standard and specification as the United States Air Force (USAF) RJ fleet so that they may be operated and maintained to the same Aircraft Documentation Set (ADS). The 3 aircraft have approximately 20000 flying hours and between 3000-4000 landings each. The current service utilization history of the 135 types is close to nine and a half million flying hours of which over nine hundred thousand are on the RJ fleet. With this amount of historical data available the maintenance and inspection programme has substantial underpinning. In addition to the in-service data and knowledge, three aircraft are currently going through a forensic teardown programme being conducted at Oklahoma City Air Logistics Centre, Tinker Air Force Base the first report of which was provided for information [26].

The conversion and installation of the mission system is being carried out by L-3 Communications who are the “Design Agent” for the programme. L-3 has been the systems integrator on the RJ programme since its inception with design support for the original aircraft being provided by Boeing, the Original Equipment Manufacturer (OEM) and basic air vehicle Design Organisation (DO).

The conversion entails the aircraft being stripped to bare metal and the removal of all the previous tanker role equipment along with the replacement of all but one of the original magnesium alloy manufactured structural items. It was unclear to the author as to the identification of this one remaining magnesium component. There is also a major programme of replacement of fuselage and wing skins along with complete replacement of all flying control cables and control rods, air conditioning ducting and electrical cabling. Hydraulic pipes are only replaced if their condition requires it. The details of the work being carried out to the first aircraft was detailed in the Aircraft Condition Assessment of Aircraft RJ-18 Report [25] and this gave a comprehensive description of the degree of structural strip and the repairs required to bring the aircraft up to the required delivery standard.

4.5.1 Comparison with Sentry

Although the Sentry and Airseeker share a common heritage the operational arrangements with the UK RJ aircraft are completely separate. USAF documentation will be used throughout, as will the USAF airworthiness processes and procedures. The UK will hold their own Structural Integrity Working Group/Systems Integrity Working Group/Propulsion Integrity Working Group (SIWG/SyIWG/PIWG) meetings and meet UK airworthiness requirements either through UK procedures or an alternative acceptable means of compliance (AMC). It is understood that discussions are in progress with the MAA on how issues regarding the airworthiness assurance process might be resolved. Airseeker will be returned to the USA every 4 years for its Periodic Depot Maintenance (PDM) and mission system upgrade. In order for the UK to obtain and be part of the maintenance support package, there are also other obligations that must be met and two specific requirements of the contract have a particular impact on EDPC as listed below.

4.5.1.1 Operational/Contractual Requirements - Change in Waddington runway de-icing fluid

As found on other aircraft, the present UK specified runway de-icing fluid (Clearway 3™) has been attributed with causing damage to carbon brake packs. In order for the UK to obtain spares, including brake packs from the USAF RJ spares pool, the current runway de-icing fluid must be changed to a USAF specified type.

4.5.2 Aircraft washing facility

The aircraft washing facility currently available at RAF Waddington is not considered suitable and will need improvement to meet the contractual obligations specified for USAF aircraft washing standards.

4.5.3 REACH (Registration, Evaluation, Authorisation and restriction of CHemical substances)

The PT was aware of the introduction of the REACH regulations in the UK but was delaying making any decisions until the outcome of high-level discussion and possible corporate policy was announced. This situation is somewhat at odds with the process and procedure being adopted for the C17A discussed below which is also a Boeing designed and built aircraft.

4.6 C17A GLOBEMASTER III

The C17 PT supplied the comprehensive document set listed in Appendix D: allowing the author to decide that a meeting was unnecessary. However, a telephone conference was held with the PT representative at Wright Patterson Air Force Base USA to gain a better understanding of issues as reported in the Minutes of the13th SIWG Meeting [29]. The current corrosion issues affecting the aircraft were identified and are discussed below.

4.6.1 Wing to Fuselage Fillet Attachment Point

Significant corrosion damage had been found on one aircraft in this area and after blending it was found that doubler plate repairs were required to restore the static strength of the structure. The corrosion damage has been attributed to inadequate drainage of the local area allowing water to remain entrapped and surface corrosion to develop. The damage not only affected the metal structure but had also degraded the composite fillet fairing. To solve the problem a modification that introduces extra drainage holes to the area was being embodied on all aircraft.

4.6.2 Fuselage Skin at Fuselage to Wing Fillet Attachment Point

Corrosion damage to the fillet fairing attachment points has also been found in the same area. Each attachment point comprises an anchor nut bonded to the local structure around the attachment fastener hole. These have been found disbonded and corroded when the fillet fairings are removed. A new type of “sleeved” anchor nut is being fitted that is designed to prevent moisture ingress into the threaded portion of the attachment point nut. (Author’s comment: these are similar to the sealed anchor nuts used on integral fuel tank access panels).

4.6.3 Analytical Condition Survey (ACI)

The fillet fairing attachment point problem had been known to exist for several years but corrective action had not been taken. The problem was identified during the Analytical Condition Inspection (ACI) programme that has been running since 1998. The ACI programme samples a number of aircraft each year from the USAF fleet and inspects the condition of the airframe and systems in regard to corrosion and cracking damage. The most significant airframe corrosion findings from the programme so far have been damage to Flap Pivot Joints and Flap Actuator Attachment Joints, Wing Repair Straps and the Fuselage to Vertical Stabiliser (Fin) Interface. It is planned that an RAF aircraft will be subject to the programme within the next two years to coincide with the Ageing Aircraft Audit also due at this time.

4.6.4 PT Corrosion Management

The PT have a member of the team based at the Depth maintenance facility in the USA which allows for good liaison to be maintained when RAF aircraft are undergoing maintenance and also enables issues that are affecting other users to be seen and understood at first hand.

The information that has been provided to the author, especially the presentations made at meetings to describe how corrosion issues are being addressed is considered to be an example of beneficial practice. A further source of information was the Technical Order (TO) 1C-17A-23, Systems Peculiar Corrosion Control for C17A Aircraft [33]. The TO contains all the relevant information required to identify, treat and repair corrosion damage to structures and systems on the aircraft. The presentation of all this information is considered by the author to be an example of beneficial practice.

The PT also has a post holder responsible for progressing the implications of the REACH regulations and especially on the implications for Corrosion Preventative Compounds (CPCs) and paints. The PT have a contractual arrangement with the Design Organisation (DO), Boeing who have responsibility in ensuring that all material used on the aircraft conforms to US and/or European Legislation requirements. The appointment of a post to deal specifically with REACH regulation and implications for the platform is considered by the author to be an example of beneficial practice.

4.7 A400M ATLAS

A meeting was held with the PT on 19th June 2013 at Abbey Wood. With the aircraft about to enter service with the French Air Force on 1st August 2013, the PT provided an overview of how they will manage structural integrity aspects including EDPC. Post the meeting, examples of the Maintenance Steering Group (MSG) 3 Reliability Centred Maintenance (RCM) analysis were provided and are listed in Appendix D:.

The documents described in detail the structural aspects (materials, heat treatments, corrosion protection etc) the surface finish, sealants and drain paths. Each individual item is analysed as to its vulnerability to accidental/environmental damage, the prevention/control and therefore the level of maintenance that will be required to maintain its airworthiness. The manner in which this data is presented, its clarity and detail will provide a powerful tool for the future support of the aircraft.

To satisfy the MAP requirements the policy requires that an AMC will be provide by using the civil airworthiness processes and procedures as much as possible. This will mean that all changes to the aircraft configuration will be through the DO modification process and Service Bulletin (SB) procedure. The corrosion control detailed inspection programme will begin when the aircraft is six years old and inspections will then be repeated every 6 years to align with the maintenance C check. The corrosion control programme will be recorded in a detailed corrosion control map and a dent and buckle log that is currently under development.

Each aircraft is fitted with its own data recording system that will be further enhanced by the application of the sortie profile codes that will be automatically recorded in the data set. Data will be collected from all the nations operating the aircraft and will be analysed and fed to the "Industrial Steering Committee" for review. The outcome of the review will enable adjustments to the maintenance programme to be made across the whole fleet or to suit a particular aircraft. With such a large data set available the limitations of statistical analysis from operating a small fleet in isolation are very much reduced.

4.8 C130 J HERCULES C4/5

The C130 PT supplied the comprehensive document set listed in Appendix D: allowing the author to decide that a meeting was unnecessary. A small number of queries that arose from the review were clarified by email exchange and telephone.

From the Minutes of the EDPC Meetings [40] and the SIWG Meeting [41] the current corrosion issues affecting the aircraft were identified and are discussed below:

4.8.1 Wing trailing edges

During the embodiment of STI/170 to increase the number of drain holes in the trailing edges of the wings, corrosion was found that required further repair. This was caused through poor drainage of the structure in the area that the Special Technical Instruction (STI) was intended to resolve.

4.8.2 Aileron Control Rods

In the March 2013 EDPC meeting [40] it was briefed that there had been corrosion and wear related issues recently found on Aileron pushrods. The PT had recently issued an Urgent Technical Instruction (UTI) for both C-130J and C-130K and was awaiting results. The meeting was informed that despite the application of dry film lubrication on the C-130J rods and ZX-55 grease on C-130K, the tolerances and the set up of the rod clearance through the eccentric cams of the roller supports may have been contributing to wear.

4.8.3 Main Landing Gear (MLG)

The PT was concerned with the damage found on the MLGs caused by stone chips and other debris when operating from unprepared runways, an on-going issue over the period of the EDPC Meeting Minutes [40]. The most significant concern was in measuring the severity of the damage being found by the operating squadrons. This was due to lack of guidance in the maintenance manuals. Instructions for the damage assessment were contained in the overhaul manual but the criteria given were difficult to apply in the “on aircraft” condition. Discussion with the overhaul organisation had found that although MLG legs had been received in poor condition due to corrosion, repair was possible and none had been scrapped. Work remained on-going with both 1710 NAS MIG and QinetiQ tasked with investigating alternative coatings that might provide better surface protection. The debate had also taken into consideration the possibility that this type of damage in landing gear can result in stress corrosion cracking which had been the cause of a MLG failure on a QinetiQ operated Andover aircraft in 2003 [47].

4.8.4 Aircraft Washing

During the period covered by the EDPC Minutes [40] there had been issues with washing the aircraft both at the main operating base at RAF Brize Norton and when on deployment. The maintenance schedule requirements for washing were often being granted extensions either due to lack of facilities or due to operational requirements. The shortfall in facilities included a lack of suitable wash equipment and restrictions on the use of certain detergents due to environmental issues. At the EDPC meeting held in October 2012 the issue had been resolved both for equipment in use at RAF Brize Norton and also in-theatre.

4.8.5 Dehumidification

Issues with both the dehumidification equipment and with the policy on its use were the subject of debate throughout the period covered by the EDPC Minutes [40]. The original aircraft problem was due to a lack of suitable adaptors for the equipment available at RAF Brize Norton (it should be noted that the C130 fleet had recently transferred from RAF Lynham) this was further compounded by issues with the published PT policy. The equipment issue had been resolved by October 2012 but in the meeting held in March 2013 [40] it was reported that the equipment was not in regular use due to the Air Engineering Standing Orders (AESO) and Topic 2(R)1 Policy [45] “not being tight enough”. Furthermore, the current policy had “loopholes” which allowed the operator discretion on whether the equipment was used or not.

4.8.6 REACH

At each of the meetings reviewed the subject of REACH had been given a considerable amount of discussion led by1710 NAS MIG. The issues were clearly stated and various strategies were proposed including the setting up of a steering group to identify, review and assess the impact on the aircrafts approved materials. It was agreed that REACH concerns should be reported upwards for discussion at the SIWG.

4.9 BAe 125 and BAe 146

A meeting was held on 17th April 2013 with the PT to discuss current EDPC issues on both aircraft types. The documents listed in Appendix D: were provided for information.

Both the aircraft are operated to maintenance schedules produced by the Design Organisations (DO) for the type. The schedules are updated from data that the DO collects from the worldwide fleet and not just data from the four 146s and six 125 aircraft in service with the RAF. The schedules are supplemented by the issue of Service Bulletins (SBs) that mandate inspection or modification action within certain timeframes. This ensures that airworthiness issues found on the worldwide fleets, including corrosion damage, are addressed and implemented as required on the RAF fleet aircraft. Current issues affrcting the two fleets are discussed below.

4.9.1 Engine washing

The most significant issue that was applicable to both aircraft types was the availability of aircraft washing equipment in the deployed operating base in the Gulf. It had taken a significant amount of effort to obtain and then supply the equipment in-theatre. During this period, two BAe 146 engines had been damaged due to sand erosion and contamination.

4.9.2 BAe 125 wing skin/fastener corrosion

The BAe 125 aircraft had suffered issues with corrosion around countersunk head steel fasteners passing through aluminium alloy wing skins. Following repair of the corrosion damage the area had been protected by restoration of the surface finish and the application of an epoxy filler to the fastener heads. This is thought to have solved the problem by excluding moisture from between the skin and the fastener head and is currently being monitored by routine inspection.

4.9.3 BAe 146 Sealed for Life Bearings

An elevator control restriction occurred on a BAe 146 aircraft in 2005 and was traced to seizure of so called “sealed for life” bearings fitted in the elevator trim and servo tab system. The bearings, which have no maintenance applied other than on-condition inspection, are of a plain spherical type and have a dust seal fitted each side of the bearing housing designed to prevent moisture ingress and loss of lubrication. Over time the lubrication had been lost and the bearings susceptible to moisture penetration past the dust seal and consequentially seize. It is thought that one of the main causes of the moisture penetration may have come from heavy use of aircraft de-icing treatment during winter operations. As a result of this failure the DO introduced an inspection, via Airworthiness Directive (AD) G-2005-0014 [67], and a life of eight years.

4.9.4 BAe 146 Service Bulletin Review

There have been a large number of SBs published over the years relating to inspection for corrosion issues found on the worldwide fleet. Some of the most recent have concerned the following:

- Stress corrosion cracking to main landing gear shock absorber attachment pin (AD 2010-0201 [68])
- Stress corrosion cracking to engine pylon pick-up bracket (AD 2012-136 [69])
- Fuselage skin crevice corrosion at cabin pressure dump valve outlet (AD 2011-0099 [70])

These inspection requirements have all been applied to the RAF fleet and no damage reported. All of the inspections listed above have been incorporated into the aircraft maintenance schedule.

4.9.5 BAe 125 Service Bulletin Review

The aircraft has also had a large number of SBs published over the years relating to corrosion found on the worldwide fleet and these have been incorporated into the maintenance schedule. There has also been cross-fertilisation with the Dominie PT during earlier service. The last occasion when this occurred was an inspection requirement for the rudder top hinge bracket that had exfoliation corrosion damage. An inspection of the RAF BAe 125 aircraft was introduced under BAe125/RTI/18 and no damage was found on any aircraft.

4.9.6 Ageing Aircraft Audit Condition Survey

The author is aware that as part of the Ageing Aircraft Audit procedure both aircraft types have recently undergone a Condition Survey. The results of this programme are about to be published but early results indicate a generally poor standard of husbandry that has lead to a number of observations of poor upkeep of surface finish which has allowed corrosion to develop. There was particular reference to the poor standard of maintenance and corrosion found on electrical connectors and bonding and earthing points on both types. A further observation was the possibility of dissimilar metal corrosion occurring under the earth bonding point sealant especially where steel pipes had copper braded connectors attached.

4.10 VOYAGER

A meeting was held with the Voyager PT on 23rd April 2013 at RAF Brize Norton. At the time of the meeting the PT was in the process of compiling its processes and procedures and therefore no documentation was available for review or discussion. The policy being adopted is based on the civilian airworthiness requirements for the aircraft driven by the unique operating plan that will see the aircraft being transferred between the military and civilian registers as operational requirements dictate. Once the policy and procedures are compiled they will be presented to the MAA as an alternative AMC.

4.11 SHADOW/KING AIR

Due to a heavy work load the PT were unable to participate in any discussion or to provide any documentation for review.

5 FINDINGS: FAST JET & TRAINING AIRCRAFT

5.1 FAST JET AND TRAINING AIRCRAFT PLATFORMS

The following fast jet and training aircraft have been reviewed.

- Tornado
- Typhoon
- Tucano,
- Vigilant and Viking gliders

Note: It was not possible to arrange a meeting with the Hawk Mk 1 and Mk 2 PT.

5.2 TORNADO

The meeting with the Tornado PT took place at RAF Marham on 3rd October 2012. Prior to the meeting the documents listed in Appendix D: were provided. The meeting discussed the following significant corrosion issues that were currently affecting the aircraft.

5.2.1 Nose and Main Landing Gear (N/MLG)

The PT was dealing with corrosion damage affecting the N/MLG. This had been found on equipment going through bay maintenance following removal from storage. The equipment had originally been removed from retired Tornado F3 aircraft and held in storage. The bay maintenance program was finding corrosion where the cadmium plating had failed and allowed surface corrosion to develop on the bare metal surface. Although it was unclear how this damage had initiated in the cadmium coating, it was suggested that it may have been caused through poor handling during the spares recovery process. It was considered that the damage might have worsened as a result of the conditions under which the components were kept while in storage. The components had been stored in wooden Special to Type Containers (STC) without any other protection (such as enclosing the equipment in polythene wrapping) and this may also have contributed to the corrosion problem. It was explained that a corrosive atmosphere could be created within the containers by the wood sap and its vapour if the interior of the container was left unpainted.

5.2.2 Runway De-icing

The recent hard winters had seen the application of a considerable amount of runway de-icing fluid applied to keep airfields operational and this may have had an adverse effect on aircraft and equipment, including the corrosion problem on the N/MLG. The issue with de-icing fluids has previously been discussed in HA&C Section 4.

5.2.3 Electrical Systems

Corrosion of the electrical connectors used throughout Tornado is seen not so much as the loss of electrical continuity or system function but rather as a potential health and safety hazard to personnel from handling corroded cadmium components. The PT were in the course of issuing a Topic 2(R)1 Leaflet “Cadmium Corrosion: Assessment and Handling” [73] reviewed by the author prior to the meeting. This contained comprehensive information on the identification of cadmium corrosion and the health and safety procedures to be adopted when dealing with it. This leaflet is considered by the author to be an example of beneficial practice.

5.2.4 Wing pivot diffusion joint

This has been an on-going issue for approximately 2 years. Corrosion had been found developing in the multi-layered structure around the wing diffusion joint, which is a part of the wing pivot area. Corrosion had been found around several of the fasteners in the assembly. There was concern as to how widespread the corrosion might be and whether it may have initiated fatigue cracking in this highly loaded region of the structure. A non-destructive test (NDT) technique has been developed using Andscan™ technology to scan and analyse the joint for any evidence of corrosion damage[4]. Although the capability of the Andscan

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[4] Further information on Andscan is available from QinetiQ NDE Department Farnborough

™ equipment is to be extended to identify fatigue cracks, in the meantime, supporting analysis is underway to determine critical crack length limits in order to understand the nature of the risk to airworthiness. It was noted that this corrosion issue represents a significant structural risk and is recorded in the Tornado Platform Airworthiness Risk Register.

5.2.5 Wing Carry-Through Box (WCTB)

There was concern of a possible corrosion problem with the WCTB back-up structure. The WCTB is attached by four "dog-bone" links (two either side) to structure in the centre fuselage. The structure comprises of doubler plates attached to the fuselage frames, with the area of concern sandwiched between the engine intake ducts and the external skin making satisfactory examination very difficult. Cracking and corrosion has also been found in the dog bone links. At the moment a sampling programme is underway to try and quantify the extent of any corrosion damage.

5.2.6 Cockpit Canopy Frame and Canopy

Canopy frames have been found suffering corrosion damage caused through water ingress. However, damage appears to only affect frames that have not been completely saturated thus creating a humid microenvironment ideal for the initiation and growth of corrosion. On frames that had been found completely filled with water the corrosion did not appear to have progressed.

5.2.7 Aircraft Washing

The aircraft washing requirements were discussed and the PT revealed that there had been a recent period of 9 months when the aircraft were washed with a compound that was later found to be unsuitable for use on aircraft. However, the PT considered that this had not had a detrimental affect or initiated corrosion damage. The PT also considered that the new aircraft cleaning compounds, although more environmentally friendly, appeared to be more aggressive to the aircraft surface finish.

5.2.8 Storage

A general discussion covered the lack of adequate Special To Type storage containers (STC) as this may have influenced the corrosion damage found on the N/MLG. Furthermore, there was no longer an organisation responsible for ensuring that the storage of equipment was correctly carried out or that STCs are properly maintained and this has caused difficulties for the PT. However, this is not just a Tornado specific problem but one possibly applicable to all platforms.

5.3 TYPHOON

The meeting with the Typhoon PT took place at RAF Coningsby on 18th October 2012. The documents listed in Appendix D: were supplied for review prior to the meeting.

The Typhoon PT is the only PT visited where there is a post holder nominated with the sole responsibility of managing EDPC across the fleet. This is considered beneficial practice by the author. The meeting discussed the following significant issues that were currently affecting the Typhoon.

5.3.1 Husbandry

One of the main priorities of the EDPC post holder was the promotion and enforcement of good aircraft husbandry and in making personnel aware that despite the aircraft being a mainly composite skinned airframe the issue of ED protection remained a significant requirement. A large amount of effort had been directed to an awareness campaign on the operating squadrons to ensure that panel edge sealing tape and surface finish remained in good condition. It was being emphasised that any signs of loss of these elements should be corrected as soon as possible to avoid the risk of delamination to the item. Each Typhoon had an Environmental Damage Register in which all surface damage was recorded, managed and repaired, this information was also entered onto the aircraft maintenance database.

As a practical aid to good husbandry the PT had published an RTI/TYPH/POL/5109A entitled “Aircraft Structure, Surface Finish [80], Authority for use of SEMPEN Application to address surface finish issues on the Typhoon fleet”. The RTI explained that the reason for the issue of the RTI was *“To address on-going surface finish husbandry problems on Typhoon aircraft, TSC EA Structures has authorised use of Sempen paint application system to provide an easy to use method of carrying out temporary surface finish repairs at first line”*. The Sempens provided an easy to use paint pen that contained either a primer or topcoat paint that could be used to protect small areas of the aircraft that had suffered surface finish damage - effectively a first aid kit for surface finish. The pens contain only a small amount of paint and when the task is complete the pen is disposed of as normal waste.

5.3.2 Cockpit windscreen frame

Four windscreen frames had recently been found with corrosion damage around the transparency attachment holes. The corrosion appeared to be surface corrosion possibly initiated by crevice or galvanic action between the steel bushing and the aluminium alloy of the windscreen frame. The concern was that the damage was difficult to detect with the windscreen in-situ and work was in progress to determine the significance and threat to SI that this damage poses.

5.3.3 Nose Landing Gear (NLG)

Corrosion had been found on numerous nose landing gear legs where the surface protection was being damaged by careless attachment of the aircraft tow bar. An awareness campaign has been run to inform the aircraft technicians and ground handlers of the airworthiness risk and cost that this damage causes. The material from which the leg is manufactured is ultra high tensile strength steel (spec 300M), which is susceptible to stress corrosion cracking. The situation was being managed by the application of RTI/TYPH/0390 [81], that was a modification to the tow bar through the application of hyrodrean[5] paint to the tow bar head. The paint is designed to absorb and lessen the impact of the head striking the NLG during fitting and removal, thus reducing damage to the leg surface finish.

5.3.4 Brake unit oxidation

Corrosion damage to the carbon brake units was discussed and at the time of the meeting the brake unit OEM was carrying out an engineering investigation into possible causes.

The prime concern was to identify the cause of the degradation which was suspected to be have been produced by runway de-icing fluid contaminating the brake packs. The ingress of the fluid changes the heat dissipation performance of the brakes through loss of mass of the brake pack material and an excellent Paper on this issue was provided for information. The Paper entitled, "The Impact of Airport Pavement De-icing Products on Aircraft and Airfield Infrastructure" [82], contains detailed analysis of the effects of modern de-icing fluids on both aircraft and aircraft components. The Paper also addresses the impact on airfield infrastructure along with environmental considerations.

The second concern was the potential for the brake wear indicators to give false, low-wear indication due to the damage described above causing the brake pack to erode unevenly.

5.3.5 Environmental Control System (ECS)

Corrosion had been found on unions in the ECS water injection pipelines and RTI/Typh/00189 had been issued to gather information from an inspection programme that sampled six aircraft. Of the six sampled, five were found to have corrosion damage to the pipes and the ECS ducting was also found to have pitting corrosion damage.

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[5] Hyrodrean Paint NSN 8030-99-0112828 (as used on RHAG tapes) (Reference RTI/TYPH/0390)

5.3.6 Electrical Equipment

Significant concerns had been raised due to corrosion and moisture ingress into electrical wiring and equipment in the nose landing gear bay caused by spray from the nose wheel being thrown up into the bay and settling on wiring looms. The moisture was then permeating the cable looms and equipment causing various electrical problems and corrosion. One aircraft was reported to have suffered an electrical fire caused through wet-arc tracking in the nose landing gear bay area. An RTI (RTI/TYPH/0314) had been issued to address the problem.

Moisture ingress had also been reported in “dry bays” behind the nose landing gear bay that housed electrical/avionic equipment. The equipment fitted in these bays does not have the same environmental protection as equipment fitted in the more exposed areas. There was concern that this moisture laden environment had the potential to cause not only corrosion but electrical faults in these items of equipment.

5.3.7 Armament Role Equipment

There had been a significant corrosion issue with armament role equipment, including the electrical connectors, the cause of which was being addressed in two separate investigations by the PT. Although the DO had proposed that the corrosion was caused during periods of storage in wooden crates, corrosion had since been found on equipment that was not normally stored in this type of container. A second possibility was that poor cleaning of the launcher equipment following missile firings could leave a highly corrosive residue on the launcher & surrounding surfaces. (As also recorded by the Apache PT, Section 6.7)

It was also suggested that the plastic storage containers purchased to replace the wooden containers might be creating a corrosive environment from the vapour being released from the plastic material. 1710 NAS MIG are currently undertaking a study to confirm how this problem might be correctly identified and remedied.

5.3.8 Aircraft Washing

The aircraft wash pan at RAF Coningsby had been out of commission for over a month at the time of the meeting (October 2012) due to water supply and drainage issues. Although this had caused a knock on effect to aircraft cleaning and husbandry it was later confirmed that the situation had been resolved.

5.3.9 Hotspots List

A hotspots inspection list was being developed and contained the following information.

- Under wing fuel drains and jacking points
- Delamination to fin tip area
- Gun bay door leading edge
- Panel edge tape condition
- Nose cone lower hinge
- Erosion to slat leading edges
- Wing Apex Aerial Panels
- DASS pod tips

The purpose of the hotspots list was to focus the attention of maintainers on issues that were currently causing increased maintenance costs in rectification, excessive spares consumption and loss of aircraft availability,

5.4 TUCANO AND VIGILANT/VIKING GLIDERS

The Tucano, Vigilant and Viking aircraft are managed by part of the Training Aircraft PT based at the main operating station for the Tucano at RAF Linton-on-Ouse. The meeting with the PT was held on 19th March 2013 and prior to this the documents listed in Appendix D: were provided for information.

5.4.1 Tucano

The Tucano PT consider the aircraft a mature platform that has not suffered from any major corrosion problems in the past and had no significant corrosion issues at the time of the meeting. However, a recent example affecting only one aircraft was corrosion damage to a main landing gear door that was found during a routine visual inspection. The door had exhibited surface corrosion on its external surfaces, which had caused the door skin to bulge along the door skin rivet lines. When the door was removed and de-skinned it was found that the internal surfaces of the door skins were very heavily corroded and that the solid foam material that is fitted between the door inner and outer skins was saturated. The PT considered that this had initiated the corrosion damage on this particular door and they had been unable to determine how the moisture ingress had occurred. A fleet check had found no further evidence of this type of damage.

5.4.2 Gliders

Both the Vigilant and Viking are manufactured predominantly from composite and are considered mature platforms. However, issues have occurred in metallic structural attachments and system components and there have been three significant corrosion damage issues.

5.4.3 Vigilant undercarriage leg/skid

The aircraft’s undercarriage leg (or skid) were found to be suffering from surface corrosion and pitting. Repair by blending was insufficient to remove all of the damage so a replacement programme had been undertaken.

5.4.4 Vigilant elevator control rod cracking

Damage to the elevator flying control system was found on a civilian aircraft that was caused by water ingress into the elevator control rod. A significant volume of water had accumulated in the bore of the rod and split the control rod when it froze. Although not a corrosion damage problem, the event demonstrates the outcome of compromised environmental protection.

5.4.5 Viking tailplane attachment bracket

An NDT inspection had been introduced to monitor pitting corrosion and cracking to the metallic tailplane attachment fitting. As the Vigilant uses a similar bracket, the same inspection regime had also been introduced on that aircraft.

5.4.6 Common to Tucano, Vigilant and Viking

5.4.7 REACH (Registration, Evaluation, Authorisation and Restriction of Chemical substances)

The implications of REACH were discussed with regard to the possible changes and restrictions on the supply of certain paints, sealants and other substances used on the platforms. At the time of the meeting the PT had not yet developed a strategy to manage this.

5.5 HAWK MARK 1 AND MARK 2

The Hawk PT was unable to participate in this programme.

6 FINDINGS: ROTARY WING AIRCRAFT

6.1 ROTARY WING AIRCRAFT PLATFORMS

The following rotary wing platforms were visited during the course of this Paper.

- Puma
- Lynx
- Wild Cat
- Merlin
- Sea King
- Apache
- Chinook
- Gazelle

Note: The Augusta A109, Bell 212, Griffin, Squirrel aircraft managed by SPMAP PT were unable to participate in the programme.

6.2 PUMA

The first meeting with the Puma PT took place at Abbey Wood on 14th August 2012. It should be noted that at the time the Mk1 aircraft was undergoing a major life extension programme (LEP), that would see the aircraft emerge as a new Mk2. Although the issues discussed with the PT have occurred on the Mk1 they may have implications into the future for the Mk2. There were no relevant documents provided prior to the meeting and the following environmental damage/corrosion issues were discussed.

There were three significant issues affecting the platform:

- Top deck corrosion
- Engine and gearbox cowlings ageing issues
- Environmental sealing of access panels and doors

6.2.1 Top deck corrosion

Although this problem had been known for a considerable time on Puma, the LEP involved replacement of the structure in this area. Discussion regarding the corrosion initiator did not identify the cause. The author suggested that this was a question that should be addressed to prevent the same occurrence on the Mk2 either through a change in maintenance procedures or better material protection. It was accepted that any improvements in protection would be too late for consideration now that the LEP was underway.

6.2.2 Engine and gearbox cowlings ageing issue

The PT was experiencing problems in providing sufficient numbers of serviceable engine and gearbox cowlings for the aircraft going through LEP. Many of the cowlings had been fitted to the aircraft since new (a period of around 40 years) and were causing two particular issues as follows:

6.2.3 General wear and tear

The cowlings see a significant amount of handling during normal operating of the aircraft, being opened and closed for routine servicing to the engine and main rotor gearbox. The PT was considering a purchase of new items to avoid possible maintenance and availability issues later on in service.

6.2.4 Delamination

The cowlings were also suffering from delamination. This was not confined to one particular area of the cowlings but was occurring in different parts of the structure. It was considered by the PT that the damage was caused through moisture ingress into the honeycomb and/or failure of the honeycomb-bonding adhesive.

6.2.5 Environmental sealing of access panels and doors

Effective sealing and weather proofing of the airframe access panels and doors was an on-going problem with the aircraft. There were two specific issues:

- The cowlings and hatches on the upper surfaces
- Lower surfaces particularly around nose transparencies and avionic bay doors

The panels on the upper surfaces, particularly the engine and gearbox cowlings leaked allowing moisture and water to enter the aircraft followed by penetration and pooling in the lower areas of the structure. The nose avionics bay suffered particularly from this issue.

The cockpit and nose area transparencies were also prone to leaking with moisture and water penetrating and pooling particularly in the nose avionic bay.

The poor sealing of the upper surface panels was partly attributed to the original design of the sealing system but it was also considered that the problem, as with the lower surface panels, was due to general degradation of the sealant and the panel interfaces. The PT considered the efforts to resolve the problem had not been effective. This was of particular concern for the Mk2 aircraft nose avionics bay. This now has additional electronic/avionic equipment installed and the moist and humid conditions that would be created could have an adverse effect on the reliability of this equipment. The PT considered that a partial resolution to the problem would be the mandating of dehumidification equipment being used when the aircraft was hangared.

6.2.6 Landing gear bay pintle housing

There have been several occurrences of surface corrosion in the main and nose landing gear pintle housings, which are a particularly difficult area of the aircraft to clean satisfactorily due to the restricted access. Dirt and moisture can become trapped in crevices and joints providing ideal conditions for corrosion to develop, particularly on surfaces' where the barrier coating has been damaged or lost.

6.2.7 Ageing Aircraft Research Programme

Based upon the success of the AAPL(Sentry), the development of an AAPL(Puma) has been commenced, with the agreement of the Puma PT, using one or more of the Puma Mk1 aircraft that will not be upgraded during the Puma

Mk2 LEP. The AAPL(Puma) is managed by Musketeer Solutions Limited, with support from Aerospace & Airworthiness Consultancy Enterprises Limited (AACE). 1710 NAS MIG has agreed to provide forensic support to the Puma PT for this programme. The programme is currently in the establishment phase but it is the intention to follow a similar approach to that adopted for the AAPL(Sentry).

6.3 LYNX

The meeting with the Lynx PT was held at DE&S Yeovilton on 21st August 2012. Prior to the meeting the PT provided the documents listed in Appendix D:.

6.3.1 Radio Altimeter aerial mounting panel

The PT consider the Lynx to be a mature platform with the environmental damage/corrosion aspect under control and well known. There were no significant problems with corrosion, the most recent corrosion report to the PT being surface corrosion found on the radio altimeter aerial mounting panel of a Royal Navy operated aircraft. The aerial panel must be dry assembled to the aircraft to provide satisfactory electrical bonding. All aircraft had been inspected but no further arising's had been reported.

6.4 SEA KING

The meeting with the Sea King PT took place at Yeovil on 4th December 2012. Prior to the meeting the PT had provided the documents listed in Appendix D:.

The PT considered the Sea King a mature platform with the majority, if not all, EDPC issues identified and being controlled by the existing maintenance and engineering management programme. The following specific issues were discussed:

6.4.1 Cabin floor panel sealing/water ingress to lower hull

There has been an on-going problem with the unsatisfactory sealing of the cabin floor panels that allows water and moisture to track down into the sub-floor structure and initiate corrosion damage. The cause of the problem was due to the failure of the floor-sealing gasket and various materials have been trialled with limited success. A new product, Av-dec Hi-Tak™ tape, is currently undergoing evaluation.

6.4.2 Implications of REACH (Registration, Evaluation, Authorisation & restriction of CHemical)

At the time of the meeting the PT were experiencing problems in the supply of Alochrome 1200 used as a pre-treatment for aluminium alloy before the application of primer and paint. It was not known if the problem was due to constraints introduced by REACH regulations.

The PT had discussed with M1710 NAS IG the effects the REACH regulations would have on the current materials used on Sea King. The work is continuing along with the development of a strategy to manage its affects.

6.4.3 Water ingress to nose avionics bay

The ingress of moisture into the nose avionics bay on Sea King has been an issue with the aircraft for a considerable period and as with the cabin floor, various attempts, (mainly unsuccessful) had been made to cure the problem. Consideration was being given to using the sealing tape being trialled on the cabin floor panels as described above.

6.4.4 Application and removal of Blade tape, plus blade erosion issues[6]

The discussion covered the difficulty of maintaining rotor blade erosion tape in hot and sandy conditions where much time was being spent in repairing and replacing tape that was being damaged by these conditions. Difficulties had been encountered with getting satisfactory adhesion due to the high ambient temperatures.

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[6] Blade erosion issues have been addressed by the PT with a report having been prepared by Augusta Westland - a copy has been provided to Dstl

6.4.4.1.1 Varying husbandry standards between RAF and RN aircraft received into Depth

The PT also raised the issue of the volume of emerging corrosion repair work seen on RAF aircraft compared to aircraft operated by the RN. It was thought that general aircraft husbandry standards may not be applied as diligently to the RAF operated aircraft.

6.4.5 EDPC management

The Sea King PT had undertaken several initiatives over the years to eradicate corrosion issues and an example of this was a PT produced report on the Sea King Lower Hull Structure [98]. This described the issues encountered, the solutions that had been applied and others that were proposed.

The PT provided a copy of an excel spreadsheet entitled “Sea King Environmental Damage Candidate List” [99]. This was a list that the PT had collated from a download of all the databases on which Sea King rectification is recorded (BAAN D1 and D2 database, Zonal Inspections and WRAM records). The report gave a concise view of the current problems (covered above) together with a rating of the occurrence against four categories covering:

- Cost of rectification
- Aircraft availability
- Difficulty of rectification
- Frequency of arising

The presentation of data in this form provided an invaluable insight into how the Sea King PT is managing and prioritizing their resources to address EDPC issues. This information and the way in which it was presented is considered by the author to be an example of beneficial practice and could be used as a template for use on other platforms where EDPC costs need to be assessed and priorities established.

6.5 WILDCAT

The meeting with the Wildcat PT took place on 11th December 2013 at Royal Naval Air Station (RNAS) Yeovilton. At the time there were only 5 aircraft actually in-service with a 6th about to be delivered. At the time of the meeting and due to the initial stage of the project, the Structural Integrity Strategy Document was still being prepared and was not available for review. As there were no EDPC issues, a brief discussion took place on the possible engineering maintenance strategy and the way in which the aircraft would be managed when fully operational. It was planned that the Army and Royal Navy aircraft would have their Depth maintenance carried out at RNAS Yeovilton.

The Wildcat is a derivative of the Lynx but the amount of design improvement for EDPC that may have been incorporated based on lessons learned from Lynx was unclear to the author. This is an area that may warrant further investigation in the future.

6.6 MERLIN

The meeting with the Merlin PT took place at Yeovil on 11th September 2012. The documents listed in Appendix D: were provided prior to the meeting. The following EDPC issues currently effecting Merlin aircraft were discussed.

6.6.1 Torsion box

The aircraft torsion box on some aircraft had been found to be suffering from corrosion that had been attributed to unsatisfactory removal of the cutting fluid used during the manufacturing machining process. A major repair programme was underway to recover the affected aircraft. The problem had not been caused through ED but as a result of a breakdown in manufacturing process control.

6.6.2 Mark 1 tail fold

There were corrosion problems with the tail fold structure on Mk 1 aircraft. This has now been resolved through a change of material to the tail fold attachment bracket bushes and an inspection, including NDT every 36 months.

6.6.3 Salt spray contamination

The Mk1 (Naval version) of the aircraft had suffered from corrosion caused by the ingress of salt laden spray into the Rotor Ice Protection Unit (RIPU) intake. This caused a build up of salt crystals on flying control rods situated on the transmission deck leading to flying control malfunctions on some aircraft. Increased cleaning operations and application of CPCs had alleviated the problem.

6.6.4 Mark 3 aircraft ECS intake and ramp erosion

The Mk 3 (RAF version) aircraft were suffering from corrosion and ingestion of sand into the Environmental Control System (ECS) intake and an erosion issue with the trailing edge of the ramp. These problems had been caused through the type of sand being encountered in the current theatre of operations which has a high salt content and a potentially greater corrosion threat.

6.6.5 Electrical Wiring and Interconnect System (EWIS)

On both marks of aircraft problems had been experienced with moisture ingress into electrical cable connectors. This was being addressed with a programme to replace all the affected cable connectors.

6.6.6 Blade tape issues

Although the problems with fitting blade tape in a hot environment were also discussed details of the maintenance penalties and cost that this caused could not be verified.

6.6.7 Paint husbandry

The limitations imposed on paint touch-up as stated in RA.4257 [102] and MAP-01 Chapter 6.6 [2] were discussed. The PT's concern was that the policy stated in Chapter 6.6, Paragraph 3.2 including Table 1 "Maintenance Definitions for Paint Application" and Paragraph 3.3 including Table 2, "Maintenance

Definitions for Paint Removal" were too restrictive leading to difficulties in maintaining surface finish at Forward operating units.

6.7 APACHE

The meeting with the Apache PT took place at Yeovil on the 12th October 2012. The documents listed in Appendix D: were provided for information. The current EDPC issues being addressed by the PT were discussed.

6.7.1 Marine deployment

Recent operations had required the aircraft to be deployed at sea, a role for which the aircraft had not been specifically designed. However, the PT stated that the airframe had stood up to the marine environment well despite it having been dry-assembled. To alleviate this issue, prior to deployment the allotted aircraft had been through a "marinisation" programme that included the application of sealant to the external skin lines and interior joints to seal them against moisture ingress. Further protection was added to external surfaces by the application of AV15 Corrosion Preventative Compound (CPC) and maintained whilst at sea. Other specific areas, such as Main Rotor Head spherical bearings and electrical connectors were treated with WS14138 TY2 a dry lubrication type compound. The aircraft were also fresh water washed after the last flight of the day and/or before being hangared.

6.7.2 Main Rotor Head (MRH) Strap Pack

The original MRH Strap Pack which attaches the blades to the rotor head had suffered from corrosion and a modification had been introduced whereby a slightly thicker strap pack (known as the "Fat Boy") and having different material treatments was now being fitted. The PT had sampled one of the modified Strap Packs that had completed 1000 flying hours and tasked Augusta Westland Material Laboratory to carry out a forensic examination of it. The outcome of the investigation had yet to be published. It is the PTs intention to sample a second modified Strap Pack at 1500 hours.

6.7.3 Corrosion reporting

The PT policy on corrosion reporting is published in Leaflet 013A of the Topic 2(A)1 [104], a copy of which was provided at the meeting. Corrosion reporting is further emphasised by a Mandatory Fault Reporting Instruction (MFRI) that requires all corrosion arising's to be reported by MOD Form 760 action. For all corrosion damage repair work a specific corrosion fault code is entered on the Maintenance Work Orders (MWO) MOD Form 707. This enables the aircraft electronic maintenance recording database, (GoldESP), to be interrogated for corrosion occurrences. The MFRI is currently being reviewed with the intention of reducing corrosion reporting so that only damage occurring to primary structure, aircraft systems or equipment rejected specifically for corrosion damage will be reported, rather than the current requirement of reporting all corrosion occurrences. A separate Corrosion Sub-working Group is held by the PT that sets EDPC policy, reviews and discusses current corrosion issues and reports as necessary, to the SIWG.

6.7.4 Weapons pylons

The aircraft weapons pylons are currently suffering from corrosion damage that could be described as a normal operating hazard caused from weapons firing (rocket pods). The residue from the rocket exhaust contains sulphuric acid that unless it is removed promptly and completely, attacks the pylon surface and structure. Good housekeeping by prompt washing of the contaminated areas should prevent corrosion damage occurring. The PT has initiated a husbandry awareness campaign among Forward units to help combat this issue.

6.8 CHINOOK

The meeting with the Chinook PT took place at Abbey Wood on 5th December 2012. Prior to the meeting the PT supplied the document listed in Appendix D:.

The PT assessed that the Chinook was a mature platform and considered that the EDPC issues with the aircraft were know and being controlled by the existing maintenance and engineering management programme. The following current issues were discussed.

6.8.1 Water ingress to fuselage and ramp, particularly to Special Forces aircraft (often saline)

In one particular role the aircraft is required to hover very close to the surface of water which can ingress the lower fuselage structure. Several aircraft flown in this role have been found to have corrosion damage in this area despite the application of CPCs and additional maintenance operations carried out post this type of operation.

6.8.2 On-going issues with ramp hinge corrosion (material (magnesium alloy) issue)

Magnesium alloy is used for the manufacture of the ramp hinge assemblies and has been found to suffer from corrosion. The opportunity to remove magnesium alloy and avoid its use on new build aircraft has not been taken and consequentially the issue requires on-going maintenance and EDPC management.

6.8.3 Recent failure of Left Hand rear landing gear drag strut attachment lug

In a recent incident a left hand rear landing gear drag strut failed on an aircraft and an investigation into the cause is currently being undertaken by 1710 NAS MIG. Initial assessment of the fracture surfaces suggests that it may have been caused through intergranular corrosion.

6.8.4 SI/Chinook/119A Application of AV15 CPC [109]

To combat the corrosive conditions being found in the current hot and sandy operational environment a Special Instruction (SI) introduced the application of corrosion preventative compound (CPC) Dinatrol/Ardrox AV15 to various corrosion prone areas of the aircraft. This is applied primarily to the fuselage under floor area, the ramp and ramp floor area and the combining transmission mounting beam assemblies.

6.8.5 Chinook Integrity Database

The Chinook Integrity Database (CHID) is used to record and map all areas of airframe damage including corrosion. A copy of the latest map [110] showed that the majority of corrosion damage was being found in the lower fuselage beneath the floor panels. This is considered to be an example of beneficial practice.

6.8.6 EDPC Plan

The Chinook PT was the only PT visited that has a published EDPC Control Plan [108] which was arranged with the following subject headings:

- Policy
- Initiatives
- Current problems,
- General tasks
- Closed tasks and
- Schedule of corrosion preventative maintenance
- Four annexes contain,
- Terms of Reference for the EDPC working group
- EDPC meeting agenda
- Corrosion control preventative maintenance reports
- Minute of the EDPC working group meeting

This document is considered by the author to be an example of beneficial practice. EDPC Plans are further discussed in Section 9.4.5.

6.9 GAZELLE

A meeting was held with the PT on 16th April 2013 prior to which the documents listed in Appendix D: were provided. The following issues were discussed.

6.9.1 Main Rotor Head Torsion Bars

The PTs most significant concern was damage to the main rotor head torsion bars. Cracking had been found to the external polyurethane protective covering applied over the top of the torsion bar’s metal wires that form the torsion bar. The cracking to the covering had allowed moisture to penetrate the wires with the potential to cause corrosion. The seizing of the torsion bar attachment pins within the torsion bar attachment bushings had also exacerbated the problem. The PT had introduced UTI/GAZ/1032 to provided "a before next flight" inspection of the Torsion Bars (removed from aircraft) followed by RTI/GAZ/2084 that introduced a 200 flying hour/12 month calendar inspection, although this was to be superseded by a further RTI reducing the calendar inspection periodicity to 6 months.

6.9.2 Airframe surface finish

The PT considered that the surface finish policy of a re-spray every Major was satisfactory to provide the correct level of protection to the airframe. The frequency of the Major is every 3200 Flying Hours/ 3650 Days (10 years).

6.9.3 EDPC awareness

The PT uses a process known as "Techs to see" (short for "Technicians to see") to communicate current aircraft engineering and maintenance topics including EDPC. The process provides information in the form of short articles that all personnel are required to read and then sign for having read and understood the particular issue. The author is aware of similar initiatives on other platforms and considers this an example of beneficial practice in hi-lighting current engineering management airworthiness issues to the maintenance staff.

6.10 REMAINING PLATFORMS

The SPMAP PT responsible for the platforms listed below was unable to participate in this programme.

- Augusta A109
- Bell 212
- Griffin
- Squirrel

7 REGULATORY ARTICLES

7.1 AIRCRAFT ENVIRONMENTAL DAMAGE PREVENTION AND CONTROL (EDPC) REGULATORY ARTICLE (RA) 4507

Regulatory Article (RA) 4507 [1] is the foundation for all platform environmental damage prevention and control and is the policy on which this Paper has been based. The RA states the following; *"Environmental damage (ED) is the term used to describe the physical degradation of material properties as a direct result of interaction with the climate or the environment. ED includes corrosion, erosion and the degradation of surface finish and composite material properties. The method of minimising the effects of ED on metallic and composite materials have commonality in that prevention relies heavily on the effective maintenance of protective systems such as coatings, tapes and corrosion preventative compounds (CPCs)"*.

7.2 REVIEW OF RA 4507

MAP-01 Chapter 11.6 [2][7] provides the detailed AMC for RA 4507 and has been used in this Paper as an aid in reviewing how platform PTs manage their responsibilities in its application. The AMC was used to produce the Agenda in Annex A that was used for meetings with the PTs to establish both their corrosion problems and their EDPC management processes.

Paragraph 1 – General - The paragraph defines what environmental damage is and the ways that it can be minimised through careful design and good husbandry once the aircraft is in use.

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[7] Chapter 11.6 was subject to amendment during the production of this Paper. A line-by-line review has been completed and apart from changes to organisation descriptions (TAA instead of PT) along with the requirement for the TAA and CAMO to liaise and identification of the Corrosion Control Coordinators course, the fundamental EDPC requirements remain the same. The comments concerning the need for a better delineation of responsibilities between PTs (TAAs) and the CAMO also stand.

Paragraph 2 - Regulatory Governance refers to RA 4507 for which this procedure provides the AMC.

Paragraph 3 - EDPC Programmes

This paragraph provides guidance on what an EDPC programme is required to consider and when it should be initiated.

Paragraph 4 - Timing of EDPC Programmes

The paragraph states that the EDPC programme is a through-life approach and therefore must be established early in the life of a programme and must be in place no later than the introduction into service.

Paragraph 5 - EDPC Management activities

This paragraph provides an introduction to the subject and explains in sufficient detail how corrosion prevention and control should be initiated from the outset with reference to the applicable section within Def-Stan 00-970. The section also covers the use of CPCs, removal and neutralisation of corrosion agents and husbandry procedures, including aircraft washing and dehumidification.

It is a requirement for PTs to have ED Control Plans that should be reviewed by the appropriate working groups and updated to reflect any changes required to manage emerging ED issues. However, whilst this is discussed in Paragraph 5.2.2 there is no clear guidance on what it should contain.

Paragraph 5.2.3 - ED management and reporting

Together with Paragraph 8.2 (discussed later), this paragraph constitutes the basis used in this review when discussing management policy and procedures for EDPC with PTs. The author considers that if the individual line items identified in this section were to be rigorously applied and managed, then the methods of detection, cause, remedy and cost of rectification of EDPC would be far easier to quantify than has been found in this review. Table 2 provides a summary of findings against each of these line items.

Paragraph 5.2.4 - EDPC forum,

This paragraph describes how EDPC meetings should be constituted and managed. The meetings should provide a suitable opportunity for all interested parties to discuss and identify actions required to resolve EDPC issues.

Paragraphs 6, Resourcing EDPC and Paragraph 7, Training of Personnel

This paragraph clearly describes the responsibilities of the various organisations tasked with operating and maintaining the platform. However this Paper found a number of discrepancies with what PTs considered to be their responsibilities and what they felt belonged to others.

Paragraph 8 - Responsibilities

This paragraph lists a number of organisations that have a role in EDPC and this Paper has used Paragraph 8.2, “Project Teams responsibilities” (As at the time of the start of this Paper, now Type Airworthiness Authority (TAA)) as the second set of criteria (along with Paragraph 5.2.3 above) on which to base the assessment of the PTs processes for EDPC management. Table 3 provides a summary of the findings against this paragraph requirement.

Paragraph 9 - References

This paragraph provides a list of publications that provide further policy and guidance on EDPC matters.

Summary of PT responses to the requirements of MAP Chapter 11.6 Paragraph 5.2.3 ED Management and Reporting

Requirement	Platform Groups			Remarks
	HA&C	**FJ&T**	**RW**	
Collect manage and interpret ED arising data	Considered normal PT business	Considered normal PT business	Considered normal PT business	
Consider ED data reports in order to direct prevention and remedial programmes through:				
Identifying new ED arisings	Considered normal PT business	Considered normal PT business	Considered normal PT business	
Consider the significance and effect of ED arisings	Considered normal PT business	Considered normal PT business	Considered normal PT business	Various aircraft have ED risks in their risk registers. Tornado for example on wing diffusion joints
Control and direct progress on structural and system ED issues through:				
Review and update ED control Plans	No ED control plans held by any platforms in this group	No ED control plans held by any platforms in this group	Only the Chinook PT have an ED Control Plan	Chinook ED Control Plan covers all the expected elements that a ED plan should have. **Considered beneficial practice**
Implementation of controlled humidity procedures	All PTs have a 2(N/A/R)1 leaflet but evidence suggests that Forward units decline to use the equipment much of the time	All PTs have a 2(N/A/R)1 leaflet but evidence suggests that Forward units decline to use the equipment much of the time	All PTs have a 2(N/A/R)1 leaflet and RN units do generally use the equipment provided, however evidence suggests that RAF and Army units do not	There appears to be an overall reluctance by the majority of operators to use the equipment provided
Review of SF systems and techniques	Considered normal PT business	Considered normal PT business	Considered normal PT business	Evidence suggests that many PTs have not recognised the effects that REACH regulations will have on their platforms SF and CPCs
Use of CPCs	Considered normal PT business	Considered normal PT business	Considered normal PT business	PTs will only authorise CPCs that have been approved by the DO for the type
Review of Preventative and Corrective maintenance procedures	Considered normal PT business	Considered normal PT business	Considered normal PT business	Corrosion data is a fundamental consideration for any Maintenance Schedule Review carried out using RCM analysis
Review of composite materials maintenance issues	Considered normal PT business	Considered normal PT business	Considered normal PT business	Not specifically included in this Paper, but issues with applying blade tape in hot and dusty conditions are a significant issue with deployed units

Requirement	Platform Groups			Remarks
	HA&C	FJ&T	RW	
Review selection and authorisation of “exposure incident” recovery husbandry materials	Requirement not understood by PTs	Requirement not understood by PTs	Requirement not understood by PTs	A clear definition is required for this term. Many PTs made suggestions of what it may mean but none could show a policy for dealing with an “exposure incident”
Co-ordination of Forward and Depth ED Reporting	Generally Poor	Generally Poor	Generally Poor	Evidence suggests that this is not well managed. PTs appear to have difficulties in getting the correct level of attendance at EDPC meetings
Monitor and adjust the efforts expended at Forward and Depth to ensure that ED prevention and remedial programmes are optimised to provide best value for money and aircraft operational capability and availability	Not considered a PT responsibility	Not considered a PT responsibility	Not considered a PT responsibility	In many cases the PT does not control the Depth maintenance contract and therefor has no mandate to provide input. PT’s claim that they have never had any control over what is carried out at Forward.
Review the collection, management and suitability of ED data and ensure suitability for:				
Structure and System lifing reviews	Difficult to assess until the information is required in earnest.	Difficult to assess until the information is required in earnest.	Difficult to assess until the information is required in earnest.	All PTs require damage maps to be completed, however the information is very rarely verified by the PT for accuracy and upkeep
Reporting requirements to higher-level management forums	Considered normal PT business	Considered normal PT business	Considered normal PT business	Some PTs hold separate EDPC meetings, evidence seen of upward reporting to the SIWG .
Type structural and systems airworthiness	Considered normal PT business	Considered normal PT business	Considered normal PT business	

Table 2: Summary of PT application of MAP-01 Chapter 11.6 Paragraph 5.2.3

Summary of PT responses to the requirements of MAP Chapter 11.6 Paragraph 8.2
Project Team Responsibilities

Requirement	Platform Groups			Remarks
	HA&C	FJ&T	RW	
Aircraft PTs are responsible for:				
1. Ensuring that the Master Maintenance Schedule contain inspections and procedures defined at intervals that are appropriate to the operating environment and that meet the threat of ED to aircraft structures and components	Considered normal PT business	Considered normal PT business	Considered normal PT business	Schedule reviews are carried out and on several platforms evidence was seen where additional maintenance operations were applied when the aircraft was operated outside of its normal operating environment
2. Ensuring that any component requirements within the EDPC Programme are addressed by the appropriate equipment/commodity PT	Considered normal PT business	Considered normal PT business	Considered normal PT business	Very little evidence was seen of this actually occurring. The Minutes of EDPC and SIWGs showed on many occasions that Commodity/Equipment PTs were not in attendance
3. Ensuring that the appropriate ED capture system are employed by Forward and Depth organisations	Considered normal PT business	Considered normal PT business	Considered normal PT business Difficulty with retrieving corrosion rectification data from contractor, Lynx and Gazelle for example	The author is aware from previous work carried out on Ageing Aircraft Audit activity that although the PTs utilise the normal MOD air platform maintenance recording systems, this is not always the case when aircraft are maintained at a contractor. Possibly due to an oversight some maintenance organisations have used their own systems to record work that is then incompatible with the platforms normal maintenance recording system. In these circumstances review of the type of rectification work carried out, including ED repairs can be lost or time consuming to retrieve
4. Ensuring that EDPC is addressed by an appropriate Working Group (WG)	Considered normal PT business	Considered normal PT business	Considered normal PT business	Where separate EDPC meetings were held the Minutes of the Meetings provided a good insight into the problems being discussed. However, where PTs elected to include EDPC in the SIWG/SysIWG the detail provided in the Minutes was very limited.
5. Producing and maintaining ED Control Plans, as required and ensuring their review at an appropriate WG.	Not carried out by any PT in this group	Not carried out by any PT in this group	Only carried out by Chinook PT	Apart form the Chinook PT no other PTs had ED Control Plans. The majority view was that the requirement was not clearly defined and that the regular EDPC/SIWG meeting constituted a plan.
6. Approving husbandry procedures, materials and equipment	Not considered PT responsibility	Not considered a PT responsibility	Not considered PT responsibility	The PTs consider that the DO is responsible for the approval of CPCs. They would not want to use any material on the aircraft that had not been approved in this way due to the potential for damage that the application of an unauthorised CPC may cause
7. Defining the requirements for EDPC specialist training at Forward and Depth for their aircraft	Not considered PT responsibility	Not considered PT responsibility	Not considered PT responsibility	All PTs declared that training requirements were not their responsibility and lay with the CAMO.

Requirement	Platform Groups			Remarks
	HA&C	FJ&T	RW	
8. Determining the requirement for and where appropriate, resourcing EDPC focal points	Considered normal PT business	Considered normal PT business	Considered normal PT business	The majority of PTs include EDPC responsibilities on the Structures desk officer. Only one PT (Typhoon) has a dedicated EDPC post holder. This is considered to be beneficial practice. The C17 PT have appointed a specific post to manage REACH regulations on the platform
9. Maintaining the level of awareness of ED issues across Forward and Depth organisations where collocated	Considered normal PT business	Considered normal PT business	Considered normal PT business	The application of this requirement is somewhat variable
10. Ensuring that Depth support arrangements address the need to :				
10.1. Carry out appropriate EDPC management techniques as specified by the PT	Not considered PT responsibility	Not considered PT responsibility	Not considered PT responsibility	The majority of PTs do not consider that they have the authority to impose this requirement as in many cases it is the CAMO that has control and responsibility for the Depth maintenance contract
10.2. Maintaining a single ED data capture system as defined by the PT	Not considered PT responsibility	Not considered PT responsibility	Not considered PT responsibility	There are several examples across all groups showing that contracts for Depth maintenance did not address this issue. Hence Depth organisations use their own documentation and the recorded information must be transferred onto the PTs own system (e.g. GoldESP, LITS)
10.3. Appoint an EDPC focal point within the Depth Organisation	Not considered PT responsibility	Not considered PT responsibility	Not considered PT responsibility	As 10.1
10.4. Adequately train personnel in EDPC techniques	Not considered PT responsibility	Not considered PT responsibility	Not considered PT responsibility	As 10.1
10.5. Provide support to PTs on EDPC at appropriate WGs	Not considered PT responsibility	Not considered PT responsibility	Not considered PT responsibility	As 10.1

Table 3: Summary of PT application of MAP-01 Chapter 11.6 Paragraph 8.2

7.3 RELATED RAS

The 10 RAs listed below also have an influence on EDPC policy and management. The outcome of a review of them is given in Appendix E:.

1. RA 4103 Decontamination of aircraft after spillage of body fluids
2. RA 4150 Training and competence
3. RA 4208 Dehumidification of aircraft
4. RA 4210 Anti-deterioration maintenance of equipment in store
5. RA 4214 Support Policy Statement (SPS)
6. RA 4257 Surface finish of military air environment equipment
7. RA 5720 Structural Integrity Management
8. RA 5721 Systems Integrity Management
9. RA 5723 Ageing Aircraft Audits
10. RA 5724 Life Extension Programmes

8 CONTACT WITH OTHER ORGANISAITONS

During the course of this work the organisations detailed below were contacted to discuss aspects of the programme for which they may have some input relevant to EDPC.

8.1 1710 NAVAL AIR SQUADRON (1710 NAS)

1710 NAS provide a number of engineering and scientific support functions to the entire current RW fleets. This Paper has considered the repair service to the RW platforms and the role of the Materials Integrity Group (MIG).

1710 NAS carry out a significant amount of repairs to the rotary wing platforms collecting data that might help to identify EDPC repair requirements. A presentation of the database on which this information is held was given to the author in December 2012 at Portsmouth Dockyard. The database contained 243 entries identified as corrosion repairs dating back to March 1992.

8.2 1710 NAS MATERIAL INTEGRITY GROUP (MIG)

One formal and two informal meetings were held with 1710 NAS MIG who have played a significant role in supporting the RW platforms with EDPC advice. This role has now been expanded to cover all of the air platforms and during the course of this Paper they have provided information regarding work that has been completed on various EDPC initiatives across RW platforms primarily. 1710 NAS MIG also provided a copy of a Report carried out by the Rotary Wing Support Group in March 2011 that examined the issue of environmental degradation across the Helicopter Operating Centre Project Teams [128]. This has been reviewed by the author to help gain a better understanding of the problems that PTs have been challenged with in the recent past and the solutions that were identified for their resolution.

8.3 QINETIQ

An informal meeting was held with QinetiQ in early February 2013 to liaise on aspects of the work that they are undertaking for Dstl on various research programmes into EDPC issues and developments. One of the tasks that QinetiQ is undertaking, (Task AA1204/3 – The Impact of REACH Legislation on Paint Products used on MOD Aircraft), is very timely and will assist PTs to understand the implications and impact that the regulation will have on the paints, sealants and CPCs currently approved for use on their platforms.

8.4 TIMBER RESEARCH AND DEVELOPMENT ASSOCIATION (TRADA)

TRADA was contacted in early March 2013 to obtain help and/or advice on the corrosive effects of wood resins and vapour on ferrous and non-ferrous materials particularly when items manufactured from these materials are stored in wooden containers. Unfortunately and despite a further request this assistance was not forthcoming. Reviewing the information available on the internet, the author found several articles describing the deleterious affects that wood can have on various metals and the preventative measures necessary to inhibit these. The article that was found most useful in providing this information is “Guides to Practice in Corrosion Control, Corrosion of Metals by Wood” [129].

8.5 TRAINING ESTABLISHMENTS

All three Services training establishments were visited to gain an appreciation of the depth and scope of the EDPC syllabus being delivered. All three services personnel undergoing training to be aircraft mechanical technicians receive training on EDPC based on the information contained in AP 119-0200-1 [3] and AP119-0202-1 [131]. Both APs are up-to-date and contain sufficient information for the subject to be understood and its importance appreciated. This information is further reinforced through detailed repair procedures contained in platform Structural Repair Manuals (SRM) and other equipment overhaul manuals. During the delivery of the training the students also have time to carry out practical exercises in the removal, treatment and re-protection of a corroded item. The RAF facility at Cosford also provides a training course for personnel appointed to the RAF specific corrosion control coordinator posts. However, there did not appear to be a similar course or requirement within the Royal Navy or Army organisations. Although the training syllabuses were similar there did not appear to be any coordination between the establishments to ensure that current in-service issues where introduced to make the training package more relevant. The training packages also lacked information relating to the particular requirements for the protection of composite materials.

During the visit to RAF Cosford, instructing staff raised a concern on the amount of negative feedback that they were receiving from participants on the corrosion control coordinators (CCC) course as to the practical application of the EDPC training that both technicians and Non-commissioned officers receive. The perception of the instructing staff was that EDPC aspects of aircraft maintenance receive low priority in a number of RAF Units and that in a few cases the corrosion control coordinator role was little more than a box ticking exercise. Discussion on this matter with the staff at HMS Sultan and at SAAE Arborfield did not confirm this perception, possibly because the Navy and Army do not use the CCC role. It was suggested, however, that in a lot of cases technicians suffer more from skill fade because of the limited opportunity for them to practice and maintain their skills in carrying out corrosion repairs. This was not necessarily down to a lack of corrosion repair opportunities but the frequency with which repairs were deferred to be done later at Depth.

9 DISCUSSION

9.1 INTRODUCTION

The meetings held with the various platform PTs produced a substantial amount of information. In some cases the PT felt that they had corrosion issues under control and that the low level of reporting that they were receiving from the maintenance organisations at Forward and Depth indicated that there were no significant issues. However, in contrast to this approach, other PTs required positive reporting whenever corrosion was identified, necessitating the maintenance organisation to submit a MOD Form 760, Narrative Fault Report.

9.2 REVIEW OF EDPC MANAGEMENT

The meetings with the PTs were all based on an agenda derived from the AMC of MAP-01, Chapter 11.6 [2] and the Agenda is reproduced in Appendix B:. During many of the meetings it was found that PTs either did not have a procedure in place to cover a specific requirement or considered this to be a function of the Continuing Airworthiness Management Organisations (CAMO). A summary of these findings is shown in Section 7 Table 2 and Table 3. During the time that this Paper was being written the CAMO organisations were being formed as a new concept in UK military aviation and the interface with PTs was still being developed. Formal arrangements have still to be made on a number of platforms for managing certain parts of the EDPC procedures and it is possible that this change was causing some of the uncertainty reported here.

9.3 ANALYSIS OF RESULTS

A total of 90 separate issues were identified from the discussions with the PTs. Therefore to provide analysis of the information collected at these meetings a Table of Results has been produced for each platform group, Table 4, Heavy Aircraft & Communications Table of Results, Table 5, Fast Jet & Training Aircraft Table of Results, Table 6, Rotary Wing Aircraft Table of Results. The results have been categorised under seven specific headings: Design Issues, Corrosion Protection, Husbandry, Training, Beneficial practice, Dual Classification and Not Classified and are presented in Table 7; Heavy Aircraft & Communications Results by Categorisation, Table 8; Fast Jet & Training Aircraft Results by Categorisation and Table 9; Rotary Wing Aircraft Results by Categorisation. The outcome of these classifications is then presented in a Table 10, Consolidated Table of Results. The specific issues with regard to the Regulations have already been provided in Table 2: Summary of PT application of MAP-01 Chapter 11.6 Paragraph 5.2.3, Table 3: Summary of PT application of MAP-01 Chapter 11.6 Paragraph 8.2. It is accepted that the Authors categorisation of the issues is subjective, however, the aim is to give the Reader an appreciation of where the issues lie. This will provide a focus of where effort is required and how an issue might be resolved.

9.4 CATEGORISATION OF ISSUES

In categorising an issue the intent was to allocate it to a single criterion, however, it has not always been possible. There are a total of 11 individual arising's that have been "dual classified". Of these, 7 relate to the Husbandry/Training category, a further 2 relate to Husbandry/Corrosion Protection, a single arising categorised as Corrosion Protection/Design Issue and one categorised as Corrosion Protection/Beneficial practice. Reference to these has been made in the appropriate category discussion that follows.

The definition of the criteria used is given below;

Design Issues – Issues that are part of the original design, such as choice of materials and qualification of design.

Corrosion Protection – This descriptor has been used to capture all instances caused through the breakdown in the surface protection. It is possible that a number of the issues covered by this descriptor are the result of the product reaching the end of its useful or certified life. However no investigations have been carried out to ascertain a products certified life.

This criterion has also been used to include the issues being caused by Clearway 3™ runway de-icing fluid and the provision of suitable alternative products for items affected by REACH regulations.

Husbandry – This descriptor has been used to cover arising's where the original problem has been caused or prolonged through poor husbandry.

Training – This descriptor identifies where a possible training shortfall may exist. On many occasions it is intrinsically linked to husbandry.

Beneficial practice – The Author considers that a regulation has been applied to the full intent or a unique solution to a problem has been identified that is worthy of wider dissemination.

Dual Classification – An issue that the Author considers to be a combination of more than one of the above criteria.

Not Classified. There are three arising's categorised as "Not Classified". These relate to an issue on a specific Sentinel aircraft, the second on Merlin aircraft where poor production control caused corrosion issues and the final occurrence on a Chinook where an undercarriage component failed. The engineering investigation into the failure at the time that this report was being prepared had not been completed.

9.5 HEAVY AIRCRAFT & COMMUNICATIONS (HA&C) PLATFORMS PTS

Ten different aircraft PTs having responsibility for eleven different aircraft types[8] were interviewed. Of these, the A400M Atlas and Airseeker were not yet in service while the Voyager had only just begun to enter service. At the time of the meeting with the Sentinel PT it was unclear if the published out of service date (OSD) of 2015 was to be extended.

The analysis of the discussions with the PTs is given in Table 4, Heavy Aircraft & Communications Table of Results and Table 7; Heavy Aircraft & Communications Results by Categorisation with the total of each arising

[8] A branch of the C17 PT manages the BAe 125 and BAe 146 while the Islander and Defender aircraft are both managed by a branch of the SPMAP PT

presented in Table 10, Consolidated Table of Results. There were 7 cases where the issue is attributed to “Design Issues” and a further 12 attributed to “Corrosion Protection”. Four arising’s were classified as “Husbandry” related and a further 1 to a possible “Training” shortfall. There were also 9 cases of “Beneficial practice” identified. Two arising’s have been given the “Duel Classified” status and 1 arising “Not Classified”.

9.6 FAST JET & TRAINING (FJ&T) AIRCRAFT PLATFORM PTS

The three PTs that were interviewed in this group cover five aircraft types with the Tucano PT also being responsible for the Viking and Vigilant glider’s.

The analysis of the discussions with the PTs is given in Table 5, Fast Jet & Training Aircraft Table of Results and Table 8; Fast Jet & Training Aircraft Results by Categorisation with the total of each arising presented in Table 10, Consolidated Table of Results. There were 2 cases where the issue was attributed to “Design Issues” and 11 attributed to “Corrosion Protection”. One arising was classified as “Husbandry” related and a further arising to a possible “Training” shortfall. There were also 2 cases of “Beneficial practice” identified. Five arising’s have been given the “Duel Classified” status. There were no “Not Classified” arising’s.

9.7 ROTARY WING (RW) PLATFORMS PTS

Although there were a total of eight RW platform PTs interviewed for this Paper, Wildcat was only just entering service and as yet there had been no corrosion reporting.

The analysis of the discussions with the PTs is given in Table 6, Rotary Wing Aircraft Table of Results and Table 9; Rotary Wing Aircraft Results by Categorisation. The total of each arising is presented in Table 10, Consolidated Table of Results. There were 7 cases where the issue was attributed to “Design Issues” and 13 attributed to “Corrosion Protection”. One arising was classified as “Husbandry” related and no “Training” shortfalls were identified. There were also 5 examples of “Beneficial practice” identified. Four arising’s have been given the “Duel Classified” status and there were 2 arising’s “Not Classified”.

9.8 FINDINGS

9.8.1 DESIGN ISSUES

The selection of the correct material at the initial design phase is fundamental to how the equipment will survive the threat of environmental damage in service. However, some legacy equipment's and later marks of the same platform manufactured with vulnerable materials remain in service. Magnesium alloy components come in this category as identified on the Sentry, Airseeker and Chinook platforms. The possibility of replacing them through modification action on the platforms affected is considered too costly in the case of Sentry and Chinook. On Airseeker the refurbishment programme prior to delivery has replaced the majority of this material. Some aluminium alloys, such as material to specification 7075 also present problems particularly its susceptibility to intergranular corrosion. In all cases, identification and a robust maintenance regime to protect them is paramount.

Other than the choice of materials, poor design features has a significant impact on ED protection. Particular areas of concern include RW platforms cockpit glazing and compartment sealing, RW and HA&C fuselage cargo floor and toilet areas. There is also evidence of dissimilar metal (galvanic) corrosion on some platforms, either through a breakdown in the protective coatings of the items concerned as well as structural and equipment features where moisture can become trapped creating the ideal conditions for corrosion to develop.

On some large platforms, such as C17 and C130, poor structural drainage has lead to corrosion damage. This issue only becomes obvious once a platform has been in service for some time and the pooling of moisture or fluid becomes apparent during maintenance activity. This may be exacerbated in inaccessible areas such as the lower sections of fuselages, wings and undercarriage bays. In these areas dirt and grime can accumulate thus blocking drainage paths and trapping fluid and moisture to provide the ideal breeding ground for ED to occur. It is thought that water becoming trapped in a civilian Vigilant elevator flying control system control rods, caused a rod to fail after the water froze. Spray thrown up from landing gear wheels can also cause problems. In the case of

Typhoon, equipment located behind the nose landing gear has suffered as a result of this. Moisture generated from sources within the aircraft can also be an issue. On Sentry, the hydraulic reservoirs are pressurised by engine bleed air. Corrosion problems found to the interior of the reservoirs is believed to have been caused through moisture in this air supply. A DO modification to remove the moisture is available but is not currently fitted to RAF aircraft.

Other features such as intakes have their own particular vulnerability to the potential for ED. Damage to intake coatings and to equipment located downstream of them are all areas for potential ED damage.

The difficulty experienced by some RW platforms in applying blade erosion tape on deployed operations has also been categorised as a Design Issue. Although the original requirement may not have envisaged operating in such elevated temperatures, fundamentally the design of the tape was not capable of meeting the requirement, requiring extra maintenance activity to try and alleviate the shortcoming.

A further issue, reported on BAe146 aircraft concerns "sealed for life" bearings. This hi-lights an issue with equipment that apparently requires no maintenance action due to its design. In this case the DO alerted operators to the problem, however there may be implications for other fleets using similar types of bearings.

An issue reported on Apache concern the redesign of the strap pack to the main rotor head. The strap pack has been modified with a thicker gauge of material and improved corrosion protection; the PT is currently evaluating the performance of the redesigned head.

9.8.2 CORROSION PROTECTION

Many of the platforms visited have been in-service for over 20 years. During this time the ageing process to various protective systems has had an effect. Although some ED protection systems are maintained by regular maintenance action, such as repainting, others such as sealants and original metal surface protections offer a far bigger challenge, access panels and cockpit glazing sealing systems for example. RW platforms in particular suffer from moisture penetrating these apertures and entering the fuselage or equipment bays. This has the potential to cause corrosion to structures and mechanical components or failure of electrical equipment.

Both RW and HA&C cargo carrying aircraft have further issues with floor panel sealing. The constant loading and unloading of cargo places fluctuating loads into the structure and also the possible contamination that this cargo can introduce, be it from the equipment being carried or human interaction such as casualty evacuation and around toilet equipment.

The breakdown of panel sealing systems allows fluids and moisture to build up in the lower parts of the structure as discussed in Design Issues. If the structural drainage is not effective, moisture can increase the likelihood of further corrosion damage occurring to equipment in areas where the protective treatment may have become degraded through age. An example of this is corrosion being found on electrical connectors and earth bonding points. Electrical connector corrosion is widespread on all three of the platform categories, while corrosion on earth bonding points has been reported on TA&C aircraft. Improved sealing systems such as those produced by Av-dec are available and have been identified by 1710 NAS MIG to help resolve the floor sealing system on Sea King[9].

Further aging effects are manifesting themselves through the corrosion being reported at the interface of steel fasteners passing through aluminium alloy components such as wing skins. In the majority of cases the steel fastener is countersunk into the alloy skin. This forms an ideal site for moisture to become trapped should the external paint coating become degraded or damaged. If the surface protective treatment to either component is also damaged, possibly through a wear/fretting type action, this results in surface and galvanic/dissimilar metal corrosion, as has been reported on several of the TA&C platforms. Wear

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[9] The Author has since been informed by 1710 NAS MIG that the same product has been used previously on Chinook (2004) with good results (email M. Mishon– D. Taylor 131114 at 17.00 Hrs)

fretting type damage leading to the loss of surface protection is also more likely to occur on RW platforms due to their inherent structural vibration signature. The Puma top deck corrosion problem is an example of this. The Puma is also suffering from dis-bonding to the engine and gearbox honeycomb panels. Although the problem is considered to be the result of general wear and tear (some of the original panels are close to 40 years old) the ingress of moisture passed degraded panel sealing may be a contributory cause.

The Typhoon windscreen attachment has also suffered from galvanic corrosion at the interface of the steel bushes fitted into the aluminium alloy frame. Although possibly not an ageing issue in this case, it is an example of the vulnerability that platforms have to corrosion where two different metals interface.

The breakdown of surface protection can have increased airworthiness risk along with significant maintenance penalties that require costly recovery action or NDT requirements. The breakdown in the surface protection to the Main Rotor Head Torsion Bars on Gazelle is an example of this, as is the corrosion being found in the Tornado Wing Carry Through Box attachment back-up structure and the Wing Pivot diffusion joint. Other vulnerable areas are landing gears, and their mounting structure. C130 landing gear has suffered from corrosion damage through stone chips when operating from unprepared runways while the Vigilant glider landing skid have been replaced due to surface and pitting corrosion damage. Sentinel has had corrosion damage to the interior of the stub axel due to the protective sealant on the axel end cap failing and allowing moisture ingress, while Puma has experienced corrosion issues in and around the landing gear pintle housing caused through poor access to clean the area effectively.

All of the platforms visited rely on their respective DO to authorise the various materials used for corrosion prevention and protection. However, if 1710 NAS MIG identify a product that they suggest would resolve an EDPC issue on a platform, the PT still has to obtain clearance from the DO for its use. Anecdotal evidence suggests that this can sometimes take a significant amount of time and staffing effort. This situation is a concern, as the implications of the impact that REACH will have on the availability and use of existing corrosion preventative and protection products, begins to take effect. It is also possible that REACH will have other unexpected consequences. An example of this is the impact that a more environmentally friendly runway de-icing fluid (Clearway 3™) is possibly having on many platforms landing gear and carbon brake units. Research into clarifying this issue is in progress.

To enhance the corrosion protection on Chinook when on deployed operations the PT developed a supplementary set of short-term measures. These include extra protection to specified areas of structure and equipment prior to the aircraft being deployed and another set of measures to inspect and record/repair following the aircrafts return. With regard to preserving protective coatings the Gazelle PT had made a positive decision not to increase the periodicity of the platforms repainting schedule even though the arising's of corrosion were low. The PT believe that the time period between repaints was partly responsible for this and therefore did not consider the potential cost saving worth the risk of jeopardising this satisfactory situation.

The Apache and Islander PT's required formal reporting of corrosion arising's through MOD Form 760 action. However, the author was unable to verify how much use was then made of these data.

9.8.3 **HUSBANDRY**

Although verification of husbandry standards was not part of this task, various PT's expressed concerns that standards at Forward were not as high as required. This was manifested in the inadequate or unsuitable aircraft washing facilities at many operating bases and in one case, inadequate engine washing facilities caused the replacement of two engines from a BAe146.

There was also anecdotal evidence of differences in the application of the standards of husbandry between RAF and RN Sea Kings. The greater amount of corrosion rectification identified, as "emergent work" during Depth maintenance on RAF aircraft was an example of this. It is likely that the requirement to include a Condition Survey on a sample of a fleet undergoing an Ageing Aircraft Audit can generate a large amount of data describing the actual physical condition of aircraft within a platform group. This data can be compared with reports to the EDPC or SIWG meetings to verify whether management reporting reflects the actual conditions being found by the survey. Depending on the depth of the Condition Survey the data can also provide a more accurate indicator of where the corrosion prone areas of a particular platform are, allowing a more focused campaign of corrective actions.

A corrosion preventative measure that PTs can take is mandating the use of de-humidification equipment. From the evidence seen the application of a robust de-humidification policy is at best inconsistent. There appears to be reluctance at Forward units to use the equipment and in one instance a poor excuse concerning the regulation was given as a reason not to employ it. The variation in approach that the different services took was evident with RN operated platforms more likely to see its routine use compared with RAF operated platforms.

Various other issues relating to husbandry standards such as corrosion on electrical connectors and items placed into storage are also a cause for concern. Some of these issues may be the result of poor surface protection in the original design but some are caused through poor cleaning and maintenance and a loss of expertise with knowledge of storage requirements.

The maintenance of surface finish is a fundamental husbandry task, however the implications of REACH and the interpretation of regulations have been given by some Forward units to their PTs as a reason not to carry it out.

9.8.4 TRAINING

All three services training establishments were visited during this task. All based the training syllabus on the two APs that address the subject [3] and [131]. This training certainly provides personnel with the basic knowledge required to carry out EDPC tasks at their units. However, training school staff reported that the feedback they got from students (specifically RAF personnel) returning to do either refresher training or for training in the Corrosion Control Co-ordinator post, was that at many units ED was seen as a secondary task. This had lead to a lack of time to carry out the task satisfactorily and an opportunity for personnel to gain experience and develop skill. Often ED arising's were being deferred to Depth maintenance, thus acerbating this situation.

Other training shortfalls identified that had caused corrosion damage was the incorrect handling of Sentinel engine intake cowls, while the washing of Tornado aircraft for a period of some nine months with the incorrect washing compound possibly highlights lack of knowledge and supervision of the aircraft wash team. The Tornado PT does not believe that any harm had been caused to the aircraft once the issue was identified.

A further possible training shortfall was identified by a number of PTs with regard to the preparation for storage and storage of aircraft components. This has been recognised when items removed from storage were found with corrosion damage. A number of causes have been attributed to this situation. These include lack of pre-storage cleaning and poor handling during preparation for storage. The wooden containers that some components have been stored in have also been suspected due to inadequate treatment of the wood to prevent possible wood vapour corrosion. As stated in Paragraph 9.8.3 above, some PTs felt that a loss of the specialists that previously carried out these tasks was a contributory factor.

9.8.5 **"BENEFICIAL PRACTICE"**

Despite the issues discussed above there were a number of examples of "beneficial practice" seen. Of particular merit was the Typhoon PT who had a post specifically for the management of EDPC. This provided a focal point for all corrosion related issues and enabled them to be addressed as a matter of priority. It also permitted a far more proactive approach to corrosion issues at both Forward and Depth. The C17 PT had a post holder located at the Depth maintenance facility. This allowed not only issues on their fleet to be easily scrutinised but also provided first hand information with other operator's problems that were undergoing maintenance at the facility.

Other initiatives such as the Tornado PTs management of corrosion on electrical connectors by the issue of a comprehensive Topic 2(R)1 Leaflet and the Typhoon PTs development of the use of SEMPENs is worthy of wider consideration. Documentation such as the Chinook PTs EDPC Control Plan and the Sea King “Environmental Damage Candidate List” would also provide templates for other PTs needing to address similar issues. There does not appear to be any formal means for the distribution and sharing of this information. 1710 NAS MIG certainly provide a good cross-platform distribution of information and solutions to actual EDPC issues but on the more managerial aspects the author is unaware of any similar means.

The author is aware that many RW platforms made use of “hot spots” lists to highlight corrosion/husbandry issues to maintenance personnel. The list in most cases was an informal document used by units to emphasis issues that were causing concern or requiring particular attention. However, the Typhoon PT had formalised their list and used it as an aid to help focus EDPC effort. The Gazelle PT has a similar solution for keeping their maintenance personnel briefed on current engineering issues, not just corrosion. They have developed a “Techs to see” system whereby current topics are circulated in a controlled document requiring personnel to read and sign for having read.

Although many platforms that are in MOD service are relatively small fleets quite often the type is operated by other air forces. Both the C17 and the Airseeker PT have formal arrangements in place for the sharing of technical information, thus providing awareness of issues that are currently affecting other operators’ fleets and may have relevance or implications for RAF aircraft. The participation of the RAF C17 in the USAF C17 Analytical Condition Survey programme will further enhance the corrosion management and maintenance of the type. The same information sharing arrangement is in place for the A400M when it enters service. The author is also aware that civilian types operated by the MOD (BAe125 and BAe146, Voyager (Airbus A330)) will also be made aware of potential problems occurring in civilian operations by the relevant DO issuing Service Bulletins.

There were several examples of PTs positively managing their EDPC issues and taking advantage of whatever opportunity or facility enabled them to do this. The Sea King PT had engaged with 1710 NAS MIG to address a problem with the supply of protective coatings, possibly caused by the application of REACH regulations. The C130 PT had assigned the task of managing REACH issues to a specific post holder within the PT. The Chinook PT had developed a database for the recording of all airframe damage, including corrosion. The Sentry and Sentinel PT had taken advantage of the aircraft repaint programme to carry out a RAP as each aircraft was repainted. This had been expanded on Sentry to assess the internal condition during heavy maintenance checks.

On Airseeker the PT had agreed to a stipulation of the USAF as to the type of runway de-icing fluid used at the main operating base at RAF Waddington. The USAF specified fluid was considered to have none of the possible issues associated with Clearway 3™. By adopting this fluid the RAF are able to participate in a pooling arrangement for the maintenance and supply of landing gears. The aircraft had also been extensively modified in terms of the use of magnesium alloys, reducing the maintenance burden that this material has caused on Sentry.

Tabulation of Platform Specific Issues and Observations

Heavy Aircraft and Communications			
Reference in Report		Platform :Issue and Observations	Remarks/Comments
Para'	Page		
4.2	29	**Islander**	
4.2.1	29	Leading edge corrosion under de-icing boots	Corrosion damage to the leading edges of one particular aircraft over a period of 10 years. Aircraft re-sprayed every 6 years. All corrosion arising's reported on MOD Form 760. **Corrosion Protection**
4.3		**Sentry**	
4.3.1		Keel beam corrosion to electrical earth bonding points	Difficult to clean and reach areas. Breakdown of local protective coating to earthing point. Also reported on BAe 125 and BAe 146(Previously found on Nimrod and VC10). **Corrosion Protection**
4.3.2		Front spar cracking	Material issue 7075 Al Alloy. Intergranular/Exfoliation corrosion. **Design Issue**
4.3.3		Wing plank corrosion on beaver tail	Steel fasteners passing through aluminium alloy skins, galvanic corrosion. **Corrosion Protection**
4.3.4		Magnesium alloy flying controls	Material issue - Magnesium alloy, corrosion damage. **Design Issue**
4.3.5		Aircraft wash facilities	On going issues with RAF Waddington aircraft wash facilities. **Husbandry**
4.3.6		Bleed air duct corrosion	Pitting corrosion in leading edges ducts. **Corrosion Protection**
4.3.7		Hydraulic reservoir corrosion	Internal surface corrosion. **Design issue**
4.3.8		Electrical connectors	Surface corrosion on electrical connectors. **Corrosion Protection**
4.3.9	32	Repair Assessment Programme	External and internal RAPs being conducted during paint and 'C' checks respectively. **Beneficial practice**
4.4		**Sentinel**	
4.4.1		Engine intake cowls	Poor handling causing damage. **Training**
4.4.2		Transition fairing structure	Poor surface finish protection. **Corrosion Protection**
4.4.3		ZJ694 horizontal stabilizer and elevator upper surface	Specific problem to this one aircraft – composite material **Not Classified**
4.4.4		Carbon brake unit runway de-icer ingress	Possible damage to brake units and undercarriages caused through runway de-icing fluid – Inspections carried out. **Corrosion Protection**
4.4.5		Main Landing Gear Assembly Axle end cap sealant	Problem identified in SB from manufacturer – one aircraft found damaged. **Corrosion Protection**

Heavy Aircraft and Communications			
Reference in Report		**Platform :Issue and Observations**	**Remarks/Comments**
Para'	**Page**		
4.4.6		Repair assessment programme (RAP)	RAP on opportunity basis as aircraft pass through repaint programme. **Beneficial practice**
4.5	36	**Airseeker**	
4.5.1	37	Comparison with Sentry	At time of meeting aircraft just being introduced into service, majority of magnesium alloy materials replaced by alternative aluminium alloy items. **Beneficial practice**
4.5.2	38	Operational/Contractual Requirements - Change in Waddington runway de-icing fluid	Specific requirements for USAF specified runway de-icer fluid to be used at main operating base (MOB) (RAF Waddington). **Beneficial practice**
4.5.3	38	Aircraft washing facility	Specific requirement for USAF standard of aircraft washing facilities to be available at MOB. **Husbandry**
4.5.4	38	REACH (Registration, Evaluation, Authorisation and restriction of CHemical substances)	PT delaying decision on impact of REACH to platform specific materials. **Corrosion Protection**
4.6	38	**C17A Globemaster**	
4.6.1	39	Wing to Fuselage Attachment points	Poor local area drainage. **Design Issue**
4.6.2	39	Fuselage skin at Fuselage to Wing Fillet Attachment Points	Poor local area drainage. **Design Issue**
4.6.3	39	Analytical Condition Survey (ACI)	USAF aircraft condition sampling programme – provides information from the worldwide fleet – not just RAF operated aircraft. **Beneficial practice**
4.6.4	40	PT Corrosion Management	PT have personnel located at the Depth Maintenance facility providing on-the spot information to problems on other operators aircraft. **Beneficial practice**
4.7	40	**A400M Atlas**	No issues – about to come into service
4.8	41	**C130 J Hercules C4/5**	
4.8.1	42	Wing trailing edges	Poor structural drainage. **Design Issue**
4.8.2	42	Aileron Control Rods	Wear and corrosion to aileron control rods. **Corrosion Protection**
4.8.3	42	Main Landing Gear (MLG)	Stone chip damage caused through operating from unprepared runways. Lack of damage limits in maintenance manuals. **Corrosion Protection**
4.8.4	43	Aircraft Washing	Problems with aircraft washing facilities at MOB (RAF Brize Norton). **Husbandry**
4.8.5	43	Dehumidification	Reluctance by Forward to use equipment. **Husbandry/Training**
4.8.6	43	REACH	PT positively managing REACH issues. **Beneficial practice**

Heavy Aircraft and Communications			
Reference in Report		Platform :Issue and Observations	Remarks/Comments
Para'	Page		
4.9	44	**BAe 125 and BAe 146**	
4.9.1	44	Engine washing	Lack of suitable equipment for engine washing when on deployment. **Husbandry**
4.9.2	44	BAe 125 wing skin/fastener corrosion	Steel fasteners passing through aluminium alloy skins, galvanic corrosion. **Corrosion Protection**
4.9.3	45	BAe 146 Sealed for Life Bearings	Seizure of bearings identified lack of maintenance policy for these items. **Design Issue**
4.9.4	45	BAe 146 Service Bulletin Review	Problems identified on other operators aircraft. **Beneficial practice**
4.9.5	45	BAe 125 Service Bulletin Review	Problems identified on other operators aircraft. **Beneficial practice**
4.9.6	45	Ageing Aircraft Audit Condition Survey (CS)	CS identified a number of husbandry shortcomings including corrosion on electrical connector, earthing and bonding points. **Husbandry/Corrosion Protection**
4.10	46	**Voyager**	No issues about to enter service
4.11	46	**Shadow/King Air**	Unable to participate

Table 4, Heavy Aircraft & Communications Table of Results

Fast Jet and Training Aircraft			
Reference in Report		**Platform :Issue and Observations**	**Remarks/Comments**
Para’	**Page**		
5.2	47	**Tornado**	
5.2.1	47	Nose and Main Landing Gear	Corrosion damage to legs – possibly caused through poor handling and storage conditions. **Husbandry/Training**
5.2.2	48	Runway de-icing	Possible cause of corrosion damage to undercarriage legs. **Corrosion Protection**
5.2.3	48	Electrical Systems	Surface corrosion on electrical connectors. 2(R1) Leaflet to manage issue. **Corrosion Protection/Beneficial practice**
5.2.4	48	Wing pivot diffusion joint	Corrosion in multi-layered structure - difficult to examine. **Corrosion Protection**
5.2.5	49	Wing carry through box attachment back-up structure	Corrosion in back-up structure for wing carry through box. **Corrosion Protection**
5.2.6	49	Cockpit canopy and frame	Water ingress into canopy frame structure causing corrosion damage. **Corrosion Protection**
5.2.7	49	Aircraft washing	Incorrect aircraft cleaning compounds applied during a 9 month period and possible detrimental effect on surface finish from new (approved) “environmentally friendly” compound. **Husbandry/Training**
5.2.8	49	Storage and Storage containers	Possible cause of corrosion damage to undercarriage equipment due to lack of upkeep of special to type storage containers and loss of personnel trained in storage methods and procedures. **Training**
5.3	50	**Typhoon**	
5.3.1	50	Husbandry	Positive PT management through nominated corrosion control post, post holder is first point of contact for operators helping to resolve EDPC issues as they arise – such as provisioning of first aid paint touch-up paint pens. **Beneficial practice**
5.3.2	51	Cockpit windscreen frame	Galvanic corrosion caused through steel bushes through aluminium alloy frame. **Corrosion Protection**
5.3.3	51	Nose landing gear	Corrosion damage caused through poor ground handling – damage caused through tow bar striking leg during attachment for towing operations. **Training/Husbandry**
5.3.4	52	Brake unit oxidation	Possible damage caused through runway de-icing fluid. **Corrosion Protection**
5.3.5	52	Environmental control system	Surface corrosion to unions on ECS water injection system pipelines. **Corrosion Protection**

Fast Jet and Training Aircraft			
Reference in Report		**Platform :Issue and Observations**	**Remarks/Comments**
Para’	**Page**		
5.3.6	52	Electrical equipment	Water ingress into electrical wiring and equipment in nose landing gear bay. **Design Issue**
5.3.7	53	Armament role equipment	Corrosion to armament role equipment – possibly through poor husbandry and storage conditions. **Husbandry/Training**
5.3.8	53	Aircraft washing	Poor aircraft washing equipment serviceability at RAF Coningsby. **Husbandry**
5.3.9	54	Hot spots list	PT initiative to proactively manage areas of current concern. **Beneficial practice**
5.4	54	**Tucano and Vigilant/Viking gliders**	
5.4.1	54	Tucano – Main landing gear door	Specific to one aircraft – door found internally corroded. **Corrosion Protection**
5.4.3	55	Vigilant undercarriage leg/skid	Surface corrosion and pitting – replacement of leg programme carried out. **Corrosion Protection**
5.4.4	55	Vigilant elevator control rod – cracking	Breakdown of sealing system allowed water ingress which froze and caused cracking – found on civilian aircraft **Design Issue**
5.4.5	55	Viking tailplane attachment bracket	Pitting corrosion, **Corrosion Protection**
5.4.7	55	Tucano, Viking and Vigilant	Implications of REACH – as the time no PT strategy. **Corrosion Protection**
5.5	56	**Hawk**	PT unable to participate

Table 5, Fast Jet & Training Aircraft Table of Results

Rotary Wing Aircraft			
Reference in Report		**Platform :Issue and Observations**	**Remarks/Comments**
Para'	**Page**		
6.2	57	**Puma**	
6.2.1	58	Top deck corrosion	Life extension programme (Mark 2 upgrade) replaces this structure although new structure to original specification of surface protection, issue may reoccur. **Corrosion Protection**
6.2.3 & 6.2.4	58	Engine and gearbox cowling ageing issues	Wear and dis-bonding of panels. **Corrosion Protection**
6.2.5	58	Environmental sealing to access panels and doors	Degradation of sealing system allowing water/moisture ingress. **Corrosion Protection**
6.2.6	59	Landing gear bay pintle housing	Difficult area to access and clean effectively. **Corrosion Protection/Design Issue**
6.3	60	**Lynx**	
6.3.1	60	Radio altimeter mounting panel	Breakdown of sealing at panel interface corrosion on one specific aircraft. **Corrosion Protection**
6.4	60	**Sea King**	
6.4.1	60	Cabin floor sealing	Degraded ineffective cabin floor sealing – water ingress to lower hull causing corrosion damage. **Corrosion Protection**
6.4.2	61	REACH	Possible supply difficulties caused through REACH regulations coming into force – PT in discussion with 1710 NAS MIG for advice. **Beneficial practice**
6.4.3	61	Water ingress to nose avionics bay	Water ingress past degraded/ineffective sealing system. **Husbandry/Corrosion Protection**
6.4.4	61	Blade protective tape and erosion issues to blades	Climatic conditions in deployed areas causing problems with blade tape adhesion and blade erosion issues. **Design Issue**
6.4.5	61	Variation in husbandry standards	Contrast of the amount of emergent work with regard to corrosion rectification on RN v RAF aircraft (greater on RAF aircraft). **Husbandry/Training**
6.4.6	62	EDPC management	PT proactive management of the cost of corrosion. **Beneficial practice**
6.5	62	**Wildcat**	No issues only just being introduced into service
6.6	63	**Merlin**	
6.6.1	63	Torsion box	Corrosion caused through poor manufacturing process control. **Not Classified**

Rotary Wing Aircraft			
Reference in Report		Platform :Issue and Observations	Remarks/Comments
Para'	Page		
6.6.2	63	Mark 1 aircraft tail fold	Corrosion to tail-fold bushes – material change to resolve issue plus increased inspection. **Design Issue**
6.6.3	63	Salt spray contamination	Salt laden spray being ingested onto flying control runs causing corrosion. **Design Issue**
6.6.4	64	Mark 3 aircraft ECS and ramp erosion	Ingestion of sand into intake causing corrosion and erosion to ramp trailing edge. **Design Issue**
6.6.5	64	Electrical connectors	Moisture ingress into cable connectors. **Corrosion Protection**
6.6.6	64	Blade erosion tape	Problems with application and upkeep during current deployed operations. **Design Issue**
6.6.7	64	Paint husbandry	Operator reluctance to maintain due to interpretation of restrictions within current regulations. **Husbandry**
6.7	65	**Apache**	
6.7.1	65	Marine deployment	Deployment of a "dry assembled" aircraft into a marine environment. **Corrosion Protection**
6.7.2	65	Main rotor head strap pack	Corrosion issue with original strap pack – redesigned users a thicker gauge material and material protective treatment. **Design Issue**
6.7.3	66	Corrosion reporting	PT requirement for all corrosion issues to be reported by MOD Form 760 action. **Corrosion Protection**
6.7.4	66	Weapons pylons	Corrosion damage to pylons – possibly poor post operation husbandry. **Husbandry/Training**
6.8	66	**Chinook**	
6.8.1	67	Water ingress to fuselage and ramp	Inadequate sealing of floor and ramp – exacerbated by specific role for some aircraft. **Corrosion Protection**
6.8.2	67	Ramp hinge - Magnesium alloy component	Material issue, on-going maintenance penalty of magnesium alloy component in corrosion vulnerable area. **Design Issue**
6.8.3	67	Failure of landing gear drag strut	Possible Intergranular corrosion failure. Investigation not yet completed. **Not Classified**
6.8.4	67	Short term special protective measures	Application of additional corrosion preventative compounds to aircraft on deployed operations. **Corrosion Protection**
6.8.5	68	Chinook integrity database	PT initiative to provide damage mapping of each aircraft including corrosion repairs. **Beneficial practice**
6.8.6	68	EDPC Plan	PT initiative to produce and use an EDPC control plan. **Beneficial practice**

Rotary Wing Aircraft			
Reference in Report		**Platform :Issue and Observations**	**Remarks/Comments**
Para’	**Page**		
6.9	68	**Gazelle**	
6.9.1	68	Main Rotor Head Torsion Bars	Damage to protective covering on torsion bars wire windings causing potential for moisture ingress and corrosion damage to ensue. **Corrosion Protection**
6.9.2	69	Airframe surface finish policy	PT initiative to preserve airframe surface finish periodicity. **Corrosion Protection**
6.9.3	69	EDPC awareness	PT initiative to promulgate corrosion issues to as wide an audience as possible. **Beneficial practice**
6.10	69	**Augusta A109, Bell 212, Griffin and Squirrel**	PT unable to participate

Table 6, Rotary Wing Aircraft Table of Results

Heavy Aircraft and Communications			
Reference in Report		Platform/Issue	Remarks/Comments
Para’	Page		
Design Issues			
		Sentry	
4.3.2		Front spar cracking	Material issue 7075 Al Alloy. Intergranular/Exfoliation corrosion.
4.3.4		Magnesium alloy flying controls	Material issue - Magnesium alloy, corrosion damage.
4.3.7		Hydraulic reservoir corrosion	Internal surface corrosion.
		Sentinel	
		Airseeker	
		C17A Globemaster	
4.6.1	39	Wing to Fuselage Attachment points	Poor local area drainage.
4.6.2	39	Fuselage skin at Fuselage to Wing Fillet Attachment Points	Poor local area drainage.
		C130J Hercules C4/5	
4.8.1	42	Wing trailing edges	Poor structural drainage.
		BAe125 and BAe146	
4.9.3	45	BAe 146 Sealed for Life Bearings	Seizure of bearings identified lack of maintenance policy for these items.
Corrosion Protection			
		Islander	
4.2.1	29	Leading edge corrosion under de-icing boots	Corrosion damage to the leading edges of one particular aircraft over a period of 10 years. Aircraft re-sprayed every 6 years. All corrosion arising’s reported on MOD Form 760.
		Sentry	
4.3.1		Keel beam corrosion to electrical earth bonding points	Difficult to clean and reach areas. Breakdown of local protective coating to earthing point. Also reported on BAe 125 and BAe 146(Previously found on Nimrod and VC10).
4.3.3		Wing plank corrosion on beaver tail	Steel fasteners passing through aluminium alloy skins, galvanic corrosion.
4.3.6		Bleed air duct corrosion	Pitting corrosion in leading edges ducts.
4.3.8		Electrical connectors	Surface corrosion on electrical connectors.
		Sentinel	
4.4.2		Transition fairing structure	Poor surface finish protection.
4.4.4		Carbon brake unit runway de-icer ingress	Possible damage to brake units and undercarriages caused through runway de-icing fluid – Inspections carried out.
4.4.5		Main Landing Gear Assembly Axle end cap sealant	Problem identified in SB from manufacturer – one aircraft found damaged
		Airseeker	
4.5.4	38	REACH (Registration, Evaluation, Authorisation and restriction of CHemical substances)	PT delaying decision on impact of REACH to platform specific materials.

Heavy Aircraft and Communications			
Reference in Report		**Platform/Issue**	**Remarks/Comments**
Para'	**Page**		
		C130J Hercules C4/5	
4.8.2	42	Aileron Control Rods	Wear and corrosion to aileron control rods.
4.8.3	42	Main Landing Gear (MLG)	Stone chip damage caused through operating from unprepared runways. Lack of damage limits in maintenance manuals.
		BAe 125 and BAe 146	
4.9.2	44	BAe 125 wing skin/fastener corrosion	Steel fasteners passing through aluminium alloy skins, galvanic corrosion.
Husbandry			
		Sentry	
4.3.5		Aircraft wash facilities	On going issues with RAF Waddington aircraft wash facilities.
		Airseeker	
4.5.3	38	Aircraft washing facility	Specific requirement for USAF standard of aircraft washing facilities to be available at MOB.
		C130J Hercules C4/5	
4.8.4	43	Aircraft Washing	Problems with aircraft washing facilities at MOB (RAF Brize Norton).
		BAe125 and BAe146	
4.9.1	44	Engine washing	Lack of suitable equipment for engine washing when on deployment.
Training			
		Sentinel	
4.4.1		Engine intake cowls	Poor handling causing damage.
Beneficial practice			
		Sentry	
4.3.9	32	Repair assessment programme	External and internal RAPs being conducted during paint and 'C' checks respectively
		Sentinel	
4.4.6		Repair assessment programme (RAP)	RAP on opportunity basis as aircraft pass through repaint programme.
		Airseeker	
4.5.1	37	Comparison with Sentry	At time of meeting aircraft just being introduced into service, majority of magnesium alloy materials replaced by alternative aluminium alloy items.
4.5.2	38	Operational/Contractual Requirements - Change in Waddington runway de-icing fluid	Specific requirements for USAF specified runway de-icer fluid to be used at main operating base (MOB) (RAF Waddington).
		C17 Globemaster	
4.6.3	39	Analytical Condition Survey (ACI)	USAF aircraft condition sampling programme – provides information from the worldwide fleet – not just RAF operated aircraft.

Heavy Aircraft and Communications			
Reference in Report		**Platform/Issue**	**Remarks/Comments**
Para'	**Page**		
4.6.4	40	PT Corrosion Management	PT have personnel located at the Depth Maintenance facility providing on-the spot information to problems on other operators aircraft.
		C130J Hercules C4/5	
4.8.6	43	REACH	PT positively managing REACH issues.
		BAe125 and BAe146	
4.9.4	45	BAe 146 Service Bulletin Review	Problems identified on other operators aircraft.
4.9.5	45	BAe 125 Service Bulletin Review	Problems identified on other operators aircraft.
Dual Classification/Not Classified			
Husbandry/Training			
		C130J Hercules C4/5	
4.8.5	43	Dehumidification	Reluctance by Forward to use equipment.
Husbandry/Corrosion Protection			
		BAe125 and BAe146	
4.9.6	45	Ageing Aircraft Audit Condition Survey (CS)	CS identified a number of husbandry shortcomings including corrosion on electrical connectors, earthing and bonding points.
Not Classified			
		Sentinel	
4.4.3		ZJ694 horizontal stabilizer and elevator upper surface	Specific problem to this one aircraft – composite material

Table 7; Heavy Aircraft & Communications Results by Categorisation

Fast Jet and Training Aircraft			
Reference in Report		Platform/Issue	Remarks/Comments
Para'	Page		
Design Issues			
		Typhoon	
5.3.6	52	Electrical equipment	Water ingress into electrical wiring and equipment in nose landing gear bay.
		Tucano and Vigilant/Viking gliders	
5.4.4	55	Vigilant elevator control rod – cracking	Breakdown of sealing system allowed water ingress which froze and caused cracking – found on civilian aircraft
Corrosion Protection			
		Tornado	
5.2.2	48	Runway de-icing	Possible cause of corrosion damage to undercarriage legs.
5.2.4	48	Wing pivot diffusion joint	Corrosion in multi-layered structure - difficult to examine.
5.2.5	49	Wing carry through box attachment back-up structure	Corrosion in back-up structure for wing carry through box.
5.2.6	49	Cockpit canopy and frame	Water ingress into canopy frame structure causing corrosion damage.
5.4.7	55	Tucano/Viking and Vigilant	Implications of REACH – at the time no PT strategy.
		Typhoon	
5.3.2	51	Cockpit windscreen frame	Galvanic corrosion caused through steel bushes through aluminium alloy frame.
5.3.4	52	Brake unit oxidation	Possible damage caused through runway de-icing fluid.
5.3.5	52	Environmental control system	Surface corrosion to unions on ECS water injection system pipelines.
		Tucano and Vigilant/Viking gliders	
5.4.1	54	Tucano – Main landing gear door	Specific to one aircraft – door found internally corroded.
5.4.3	55	Vigilant undercarriage leg/skid	Surface corrosion and pitting – replacement of leg programme carried out.
5.4.5	55	Viking tailplane attachment bracket	Pitting corrosion,
Husbandry			
		Typhoon	
5.3.8	53	Aircraft washing	Poor aircraft washing equipment serviceability at RAF Coningsby.
Training			
		Tornado	
5.2.8	49	Storage and Storage containers	Possible cause of corrosion damage to undercarriage equipment due to lack of upkeep of special to type storage containers and loss of personnel trained in storage methods and procedures.

Fast Jet and Training Aircraft			
Reference in Report		Platform/Issue	Remarks/Comments
Para’	Page		
Beneficial practice			
		Typhoon	
5.3.1	50	Husbandry	Positive PT management through nominated corrosion control post, post holder is first point of contact for operators helping to resolve EDPC issues as they arise – such as provisioning of first aid paint touch-up paint pens.
5.3.9	54	Hot spots list	PT initiative to proactively manage areas of current concern.
Dual Classification/Not Classified			
		Tornado	
5.2.1	47	Nose and Main Landing Gear	Corrosion damage to legs – possibly caused through poor handling and storage conditions. **Husbandry/Training**
5.2.3	48	Electrical Systems	Surface corrosion on electrical connectors. 2(R)1 Leaflet to manage issue, **Corrosion Protection/Beneficial practice**
5.2.7	49	Aircraft washing	Incorrect aircraft cleaning compounds applied during a 9 month period and possible detrimental effect on surface finish from new (approved) “environmentally friendly” compound. **Husbandry/Training**
		Typhoon	
5.3.3	51	Nose landing gear	Corrosion damage caused through poor ground handling – damage caused through tow bar striking leg during attachment for towing operations. **Husbandry/Training**
5.3.7	53	Armament role equipment	Corrosion to armament role equipment – possibly through poor husbandry and storage conditions. **Husbandry/Training**

Table 8; Fast Jet & Training Aircraft Results by Categorisation

Rotary Wing Aircraft			
Reference in Report		**Platform/Issue**	**Remarks/Comments**
Para'	**Page**		
Design Issues			
		Sea King	
6.4.4	61	Blade protective tape and erosion issues to blades	Climatic conditions in deployed areas causing problems with blade tape adhesion and blade erosion issues.
		Merlin	
6.6.2	63	Mark 1 aircraft tail fold	Corrosion to tail-fold bushes – material change to resolve issue plus increased inspection.
6.6.3	63	Salt spray contamination	Salt laden spray being ingested onto flying control runs causing corrosion.
6.6.4	64	Mark 3 aircraft ECS and ramp erosion	Ingestion of sand into intake causing corrosion and erosion to ramp trailing edge.
6.6.6	64	Blade erosion tape	Problems with application and upkeep during current deployed operations.
		Apache	
6.7.2	65	Main rotor head strap pack	Corrosion issue with original strap pack – redesigned users a thicker gauge material and material protective treatment.
		Chinook	
6.8.2	67	Ramp hinge - Magnesium alloy component	Material issue, on-going maintenance penalty of magnesium alloy component in corrosion vulnerable area.
Corrosion Protection			
		Puma	
6.2.1	58	Top deck corrosion	Life extension programme (Mark 2 upgrade) replaces this structure although new structure to original specification of surface protection, issue may reoccur.
6.2.3 & 6.2.4	58	Engine and gearbox cowling ageing issues	Wear and dis-bonding of panels.
6.2.5	58	Environmental sealing to access panels and doors	Degradation of sealing system allowing water/moisture ingress.
		Lynx	
6.3.1	60	Radio altimeter mounting panel	Breakdown of sealing at panel interface corrosion on one specific aircraft.
		Sea King	
6.4.1	60	Cabin floor sealing	Degraded ineffective cabin floor sealing – water ingress to lower hull causing corrosion damage.
		Merlin	
6.6.5	64	Electrical connectors	Moisture ingress into cable connectors.

Rotary Wing Aircraft			
Reference in Report		**Platform/Issue**	**Remarks/Comments**
Para'	**Page**		
		Apache	
6.7.1	65	Marine deployment	Deployment of a "dry assembled" aircraft into a marine environment.
6.7.3	66	Corrosion reporting	PT requirement for all corrosion issues to be reported by MOD Form 760 action.
		Chinook	
6.8.1	67	Water ingress to fuselage and ramp	Inadequate sealing of floor and ramp – exacerbated by specific role for some aircraft.
6.8.4	67	Short term special protective measures	Application of additional corrosion preventative compounds to aircraft on deployed operations.
		Gazelle	
6.9.1	68	Main Rotor Head Torsion Bars	Damage to protective covering on torsion bars wire windings causing potential for moisture ingress and corrosion damage to ensue.
6.9.2	69	Airframe surface finish policy	PT initiative to preserve airframe surface finish periodicity.
Husbandry			
		Merlin	
6.6.7	64	Paint husbandry	Operator reluctance to maintain due to interpretation of restrictions within current regulations.
Training			
		None identified for RW	
Beneficial practice			
		Sea King	
6.4.2	61	REACH	Possible supply difficulties caused through REACH regulations coming into force – PT in discussion with 1710 NAS MIG for advice
6.4.6	62	EDPC management	PT proactive management of the cost of corrosion.
		Chinook	
6.8.5	68	Chinook integrity database	PT initiative to provide damage mapping of each aircraft including corrosion repairs.
6.8.6	68	EDPC Plan	PT initiative to produce and use an EDPC control plan.
		Gazelle	
6.9.3	69	EDPC awareness	PT initiative to promulgate corrosion issues to as wide an audience as possible.
Dual Classification/Not Classified			
		Puma	
6.2.6	59	Landing gear bay pintle housing	Difficult area to access and clean effectively. **Corrosion Protection/Design Issue**
		Sea King	
6.4.3	61	Water ingress to nose avionics bay	Water ingress past degraded/ineffective sealing system. **Husbandry/Corrosion Protection**

Rotary Wing Aircraft			
Reference in Report		**Platform/Issue**	**Remarks/Comments**
Para'	**Page**		
6.4.5	61	Variation in husbandry standards	Contrast of the amount of emergent work with regard to corrosion rectification on RN v RAF aircraft (greater on RAF aircraft). **Husbandry/Training**
		Apache	
6.7.4	66	Weapons pylons	Corrosion damage to pylons – possibly poor post operation husbandry. **Husbandry/Training**
		Merlin	
6.6.1	63	Torsion box	Corrosion caused through poor manufacturing process control. **Not Classified**
		Chinook	
6.8.3	67	Failure of landing gear drag strut	Possible Intergranular corrosion failure. Engineering investigation not yet completed **Not Classified**

Table 9; Rotary Wing Aircraft Results by Categorisation

Consolidated Table of Results

	Category							
Platform Type	**Design Issues**	**Corrosion Protection**	**Husbandry**	**Training**	**Beneficial practice**	**Dual Classified**	**Not Classified**	Total
Heavy Aircraft & Communications	7	12	4	1	9	2	1	36
Fast Jet & Training Aircraft	2	11	1	1	2	5	0	22
Rotary Wing	7	13	1	0	5	4	2	32
Totals	**17**	**36**	**6**	**2**	**15**	**11**	**3**	**90**

Table 10, Consolidated Table of Results

10 CONCLUSIONS

With the wide variety of platforms visited during this work it is not surprising that many of the issues found were occurring on more than one type and in many cases across more than one of the three groupings. The issues have been identified and discussed in Section 9 and summarised in Tables 4 through to Table 10. Regulations were discussed in Section 7 and summarised in Table 2 and Table 3.

10.1.1 DESIGN ISSUES

There are two significant factors identified in this category, the original choice of materials and damage arising in-service. Both of these can be managed by a robust maintenance policy. Reviewing a platforms maintenance policy is outside of the scope of this Paper but the efficacy of “on-condition” inspections applied to parts of the structure does appear to have allowed some structural sealing systems to become ineffective in preventing corrosion damage.

The shortcomings of many materials are well known, but whether this is “common knowledge” should not be taken for granted. Having this type of information readily available and maintained up-to-date as a platform matures is important if painful lessons are not to be repeated later in its life. With many platforms remaining in-service beyond their original OSD the implications of the any life limits given to an item or product must be fully understood so that the true cost of extending ownership can be calculated. It is suggested that it would be beneficial if the life limiting factors for EDPC protection and products was stated in the ADS, possibly the Structural Integrity Strategy Document. If this information was readily available it would make the feasibility and scoping of possible LEP more straight forward.

A specific issue found on BAe 146 aircraft concerning “sealed for life” bearings may have implications for other platforms. It also highlights a generic concern as to the “life” of components and products used on a platforms corrosion protection. A further specific issue on RW aircraft on deployed operations in very hot conditions concerned the poor adhesion properties of rotor blade anti-erosion tape. This required increase maintenance input to try and manage the problem. Although this is not a corrosion issue per-se, EDPC does include erosion protection so it is in this context that it has been included in this Paper.

10.1.2 **CORROSION PROTECTION**

A consequence of ageing is the deterioration in the effectiveness of some corrosion protection products. Evidence of this has been found in the poor condition of panel and floor sealing systems and metal treatments. Many of the issues such as the build up of fluid, moisture, dirt and grime in lower fuselage and undercarriage areas has caused or contributed to the corrosion damage found in such areas. The corrosion to earth bonding points is an example of this. There are however, modern replacement systems available such as the Av-dec™ system being trialled on Sea King floor panels[10]. Bleed air ducts and intakes are also areas vulnerable to pitting corrosion damage, particularly from contaminants contained in the airflow through them, as is the equipment located downstream.

The loss of surface protection however, represents a bigger challenge, particularly where the original metal surface treatment has broken down. The cadmium corrosion found on electrical connectors and dissimilar metal corrosion between steel fasteners interacting with aluminium wing skins are examples of this.

Further issues with electrical cable systems were identified where they were exposed to a harsh environment such as in landing gear bays and in areas where moisture and water may possibly ingress into the cable bundles. One occurrence on a Typhoon has been attributed to the effect and the cause of a wet-ark tracking electrical fire.

The impact that changes to regulation can have is exemplified in the impact that REACH has had across all three of the platform groups. This has not only

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[10] see footnote page 84

manifested itself in the lack of availability of certain products but is also causing an increasing workload for PT desk officers tasked with addressing a platforms particular problem. With this piecemeal approach there is a likelihood of duplication of effort and the possibility that the best available product or solution to a particular problem may remain unknown to a PT. A further consequence in changes to regulations may be due to the use of more “environmentally” friendly products, such as Clearway 3™ runway de-icing fluid, being used at a number of airfields. A significant number of issues with landing gear, brakes and landing gear equipment have been attributed to this product.

10.1.3 **HUSBANDRY**

A number of problems with aircraft washing were identified. These related to equipment, materials and facilities. A further concern was the poor condition that some equipment had been found in when removed from storage containers. The problems were aggravated by lack of cleaning prior to storage and possible deterioration while in storage. The loss of trained personnel for the task was also a possible contributory factor.

Condition Surveys (CSs) are now being completed as part of a platform AAA. Those seen by the author provide an excellent source of independent assessment of the condition of a sample of the fleet and the standards of husbandry being employed on the aircraft. The results of these reports should provide a valuable source of information from an ED perspective and it is importantly that the lessons learned or trends identified are not lost and are made available to all those concerned with ED policy, regulation and research. They will also help focus platforms EDPC management efforts. The results should also be promulgated to those responsible for the platforms maintenance at Forward and Depth facilities to help identify where further maintenance effort is required.

PTs had found that the use of de-humidification equipment, although provisioned on the majority of platforms, was inconsistent at Forward units. A number of reasons were given for this but a lack of appreciation at unit level of the benefits that its use can provide in helping combat ED appears to be a factor.

10.1.4 TRAINING

Basic training for EDPC is based on two specific Air Publications. These provide a good level of detail to allow personnel employed on aircraft to be able to identify and deal with ED. At the platform level this is backed up by the detail provided in the ADS repair manuals or specific ED publications. It was worrying, however, that the RAF training staff reported that EDPC husbandry was perceived as a secondary task at many units. The situation was made worse by reports that many such tasks were being deferred until Depth maintenance. This not only had the potential for ED to progress further but it also resulted in "skill fade" through personnel having limited opportunity to apply their EDPC training and knowledge.

As identified under "Husbandry" above, there may be a need to examine the training that personnel have or receive prior to being tasked with storing equipment. The poor state of equipment being recovered from storage indicates a training shortfall at some level.

10.1.5 "BENEFICIAL PRACTICE"

In the effort that PTs apply to combat and manage ED a number of solutions were identified as "Beneficial practice" and worthy of wider dissemination. Of particular merit was the Typhoon PTs dedicated post for the task, thus providing a point of contact for Forward and Depth units and management focus for all EDPC issues. Also on Typhoon, the use of self-contained Sempens™ for surface finish "first aid" was proving beneficial. From a technical perspective 1710 NAS MIG participate in the majority of platform EDPC meetings and are therefor able to pass on solutions to other platforms that have been found effective. It is then down to that platform PT whether they adopt them or not. However, there does not appear to be a similar mechanism available for the managerial aspects, for example the Chinook EDPC Control Plan. This could provide a template for other PTs who have yet to produce such a document. At the moment the Author is unaware of any formal or informal mechanism of achieving this.

The use of “Hot Spot” lists provide an excellent method of keeping personnel informed of particular EDPC issues on their platform. This list should be formalised and regularly reviewed at the platform EDPC/SIWG meetings. It could also be updated from the results of Condition Surveys carried out as part of an AAA.

10.1.6 MAA REGULATION

Although all PTs had some form of policy that met the basic requirements for EDPC, its depth and application varied widely. Only one PT had published an ED Control Plan, while there was only one PT who had a post specifically tasked with the management of EDPC. Many PTs stated that they found some of the regulatory requirement poorly defined while other parts were considered to be not their responsibility. The embryonic stage of the CAMO on many platforms has possibly added to this confusion.

10.1.7 AGEING AIRCRAFT RESEARCH PROGRAMME LABORATORY (AAPL)

The retired Sentry and Puma airframes being used for this programme has allowed a number of ageing aspects on these particular types to be investigated further. It has also allowed for other more generic ageing issues to be explored and for practical solutions to be defined and scoped.

11 RECOMMENDATIONS

The following recommendations are made based on the significant generic issues identified and where further coordinated effort would provide cross-platform benefit and cost savings. There are also a number of recommendations made with regard to "Beneficial practice" identified during the course of this Paper. Finally recommendations with regard to regulatory improvements and possible training shortfalls are made. The recommendations are not presented in any order of priority and no attempt has been made to include recommendations for specific platform issues as many of these were being addressed during normal PT business.

The following recommendations are made and cross-referenced (as applicable) to the section of the report where they are discussed.

1. It is recommended that all ED susceptible materials used on a platform be identified within the ADS (10.1.1)
2. It is recommended that the maintenance policy for any identified susceptible materials is reviewed for its effectives at protecting and detecting ED (4.3.4), (4.5.1), (6.8.2)
3. It is recommended that the life of a product used for EDPC on a platform is recorded in the ADS (10.1.1)
4. It is recommended that prior to any life extension programme for a platform that the life of EDPC products is taken into account (10.1.1)
5. It is recommended that the consequence of any identified life expiration is taken into account at subsequent platform maintenance schedule reviews
6. It is recommended that a review of the usage applications, maintenance requirements and lifeing policy be carried out on all platforms where the use of "sealed for life" bearings are fitted (4.9.3)

7. It is recommended that the consequence of failure of "sealed for life" bearings is included in this review.
8. It is recommended that the temperature range specification for rotor blade anti-erosion tape is suitable for world-wide operations (6.6.6)
9. It is recommended that the use of "on-condition" maintenance for structural sealing systems be reviewed (6.2.1), (6.2.5), (6.4.1), (6.4.3), (6.8.1)
10. It is recommended that the use of improved sealing systems such as the Av-dec Hi-Tak™ tape product is investigated further (6.4.1)
11. It is recommended that the problems identified with cadmium corrosion on electrical connectors is further investigated (5.2.3) (5.3.6) (5.3.7)
12. It is recommended that the corrosion issues identified with electrical system earthing points is investigated further (4.3.1)
13. It is recommended that the consequence of failure of earth bonding points is included in this investigation
14. It is recommended that cost effective methods of repairing and/or re-protecting against dissimilar metal corrosion are investigated (4.3.3)
15. It is recommended that a procedure for a coordinated pan-platform approach to the implications of REACH regulations is devised (4.5.3), (4.6.4), (4.8.6), (6.4.2)
16. It is recommended that further investigation into the possible detrimental effects of Clearway 3™ runway de-icing fluid is undertaken (4.4.4), (4.5.1.1), (5.2.2), (5.3.4)

17. It is recommended that the current concerns with the possible damage that Clearway 3™ runway de-icing fluid may cause to carbon brake packs, undercarriages and associated equipment is promulgated to each platform PT (4.5.1.1), (5.2.2), (5.3.4)
18. It is recommended that the protection available to electrical wiring looms and cables in areas that are prone to moisture and water ingress should be investigated particularly where the risk of wet-arc tracking could be initiated (4.3.8), (5.2.3), (5.3.6), (6.6.5)
19. It is recommended that the problems associated with aircraft washing are investigated (4.3.5, 4.5.2, 4.8.4, 4.9.1, 5.2.7, 5.3.8)
20. It is recommended that the specific requirements for placing equipment into storage are stated in the ADS (5.2.1), (5.2.8), (5.3.7)
21. It is recommended that personnel tasked with performing storage tasks have the appropriate level of training and knowledge (5.2.8) (5.3.7)
22. It is recommended that the manufacture, repair and maintenance requirements for storage containers are referenced in the ADS
23. It is recommended that the result of Condition Surveys (CSs) Reports from a platforms AAA are made available to the EDPC research community (4.9.6)
24. It is recommended that CSs results are reviewed at EDPC/SIWG meetings to establish trends and to provide a lessons-learned analysis so that EDPC management might be better focused. (10.1.3)

25. It is recommended that the results of the CS Reports are disseminated to all Forward and Depth facilities responsible for the platforms maintenance and are formally incorporated into "Hot Spot" lists. (10.1.3)
26. It is recommended that the benefits of the use of de-humidification equipment is understood and applied at user unit level (4.8.5)
27. It is recommended that the role of corrosion control and rectification is understood and given the significance it deserves at all levels (8.5)
28. It is recommended that a method is found to promulgate "Beneficial practice" identified within this Paper (4.3.9, 4.4.6, 4.5.1.1, 4.6.4, 4.8.6, 5.2.3, 5.3.1, 5.3.9, 6.4.2, 6.4.5, 6.8.5, 6.8.6, 6.9.3)
29. In particular it is recommended that the Tornado 2(R)1 Leaflet for cadmium corrosion on electrical connectors is used as a template for other PTs requiring similar information for their platform (5.2.3)
30. Further it is recommended that the use of Sempen ™self-contained paint touch-up kit for platform surface finish husbandry should be promoted (5.3.1)
31. It is recommended that the comments made in this Report with regard to RA4507 and its associated AMC are considered during its next review (Table 2: Summary of PT application of MAP-01 Chapter 11.6 Paragraph 5.2.3) (Table 3: Summary of PT application of MAP-01 Chapter 11.6 Paragraph 8.2)
32. It is recommended that the PT/CAMO interface with regard to EDPC responsibilities is clearly defined within any review of RA4507 and the related AMC (10.1.6)

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58. Minutes of the 6th BAe125 Platform Integrity Day held at Hawker Beechcraft Chester 13th September 2012

59. Minutes of the 7th BAe125 Platform Integrity Day held at Hawker Beechcraft Chester 7th March 2013

60. BAe125 CC Mk3 Platform Integrity Strategy Document, Reference 20110712-PISD_BAe125_Ver0 2_U, 9th November 2011

61. AP101B-3900-2(R)1, General Orders and Special Instructions 7th Edition at Initial Issue April 2012, Leaflet 001 Support Policy Statement

62. AP101B-3900-2(R)1, General Orders and Special Instructions 7th Edition at Initial Issue April 2012, Leaflet 025 Dehumidification

63. AP101B-3900-2(R)1, General Orders and Special Instructions 7th Edition at Initial Issue April 2012, Leaflet 202 EDPC

64. AP101B-3900-2(R)1, General Orders and Special Instructions 7th Edition at Initial Issue April 2012, Leaflet 206 Surface Finish Policy

65. AP101B-3900-2(R)1, General Orders and Special Instructions 7th Edition at Initial Issue April 2012, Leaflet 208 Operating in Hot and Sandy Climates

66. AP101B-3900-2(R)1, General Orders and Special Instructions 7th Edition at Initial Issue April 2012, Leaflet 215 Spillage of Body Fluids

67. CAA UK AD ISB G-2005-0014 31st May 2005

68. EASA AD 2010-0201R1 21st December 2012

69. EASA AD 2012-0136 20th July 2012

70. EASA AD 2011-0099 26th May 2011

71. DAP 101B-4100-2(R)1 Tornado General Orders and Special Instructions, Part 1 November 2010, Leaflet 007 Corrosion Control

72. DAP 101B-4100-2(R)1 Tornado General Orders and Special Instructions, Part 1 January 2012, Leaflet 046 Dehumidification of Tornado Aircraft

73. DAP 101B-4100-2(R)1 Tornado General Orders and Special Instructions, Part 1 Leaflet (in Draft about to be issued) Cadmium Corrosion Assessment and Handling

74. Minutes of the 7th Typhoon EDPC Working Group Minutes Reference W\TSC\TSC Meetings\EDPC, 3rd April 2012

75. Typhoon Structural integrity Strategy Document, Issue 2, 21st August 2012

76. AP101B-5400-2(R)1, Leaflet 10, Typhoon EDPC

77. Typhoon Composite Awareness Training (AESOs)

78. The Cost of Corrosion on Typhoon, J Eaton 9th March 2011

79. Presentation of Requirements on Typhoon Husbandry, J Eaton, undated

80. RTI/TYPH/POL/5109A Aircraft Structure, Surface Finish, Authority for the Use of SEMPEN Applicators to Address Surface Finish Husbandry Issues in the Typhoon Fleet, undated

81. RTI/TYPH/0390 Typhoon Tow bar – Head Assembly – Application of Hydroprean Paint 15th October 2012

82. The Impact of Airport Pavement De-icing Products on Aircraft and Airfield Infrastructure, Airport Cooperative Research Program of the Transportation Research Board in the United States of America 2008 ISBN 978-0-309-09799-4, Library of Congress Control Number 2007910443

83. Minutes of the 59th Tucano Structures Integrity Working Group Meeting at RAF Linton on Ouse 23rd May 2012

84. Minutes of the 60th Tucano Structures Integrity Working Group Meeting at RAF Linton on Ouse 21st November 2012

85. Minutes of the 1st Tucano Systems Integrity Working Group Meeting, at RAF Linton on Ouse 1st March 2012

86. Minutes of the 2nd Tucano Systems Integrity Working Group Meeting at RAF Linton on Ouse 10th October 2012

87. AP101B-4901-2(R)1 Tucano General Orders and Special Instructions, Leaflet 001, Support Policy Statement for the Tucano Mk 1 Aircraft, Issue 4 April 2012 (Amendment 67)

88. AP101B-4901-2(R)1 Tucano General Orders and Special Instructions, Leaflet 017 Tucano Corrosion Control, April 2011, (Amendment 66)

89. AP101B-4901-2(R)1 Tucano General Orders and Special Instructions, Leaflet 028 Aircraft Decontamination after the Spillage of Body Fluids, April 2005 (Amendment 55)

90. DAP 101C-1300- 2(N/A)1A Lynx General Orders and Special Instruction 2nd Edition October 2010 at Amendment 1.04, June 2012

91. Minutes of the 7th Environmental Damage Working Group, held at Augusta Westland, 17th July 2012, Reference, SKPT/16/08/01/31/05

92. Sea King Structural Integrity Strategy Document, Reference SKPT/16/8/1/31/6.B, 19th December 2008, Amendment 2, 5th January 2010

93. Sea King Systems Integrity Strategy Document, 14th May 2012, Initial Issue

94. AP 101C-0400- 2(NR)1A1 Sea King General Orders and Special Instruction, Leaflet 032 Spillage of Body Fluids, October 2012, Amendment 33

95. AP 101C-0400- 2(NR)1A1 Sea King General Orders and Special Instruction, Leaflet 034 Dehumidification Procedures, October 2011, Amendment 21

96. AP 101C-0400- 2(NR)1A1 Sea King General Orders and Special Instruction, Leaflet 066 Corrosion Control, April 2012, Amendment 22

97. AP 101C-0400- 2(NR)1A1 Sea King General Orders and Special Instruction, Leaflet 089 Conditional Servicing/Maintenance Requirements in Cold, Hot and Dusty and Embarked Operations, October 2012, Amendment 23

98. Sea King Lower Hull Structure – The Way Ahead, No reference, undated word document

99. Sea King Environmental Damage Candidate List, No reference, copy of excel spread sheet

100. AP101C-1700-2(NR)1 Merlin General Orders and Special Instructions, Leaflet 116A Dehumidification Policy, Amendment state not known

101. AP101C-1700-2(NR)1 Merlin General Orders and Special Instructions, Leaflet 147A, Merlin Environmental Damage Prevention and Control Policy, 1st Edition, Amendment 6, August 2012

102. RA 4257 Surface Finish of Military Air Environment Equipment

103. Apache Structural Integrity Strategy Document, Draft, February 2012

104. AP101C-1901-2(A)1A Apache General Orders and Special Instructions, Leaflet 013A Corrosion Fault Reporting

105. Minutes of the 4th Chinook (All Marks) EDPC Meeting, held at RAF Odiham, 24th October 2012

106. Minutes of the 13th Chinook Structural Integrity Working Group Meeting held at Abbey Wood, 21st November 2012

107. Chinook All Marks Structural Integrity Strategy Document, Issue 2 1st September 2011, Initial Issue

108. RAF Chinook HC Mk2/2A/3/4 EDPC Control Plan, Initial Issue, undated

109. SI/Chinook/0119A Application of Dinitrol AV15 CPC to Restricted Areas, undated

110. Chinook Damage Map Showing Cracks and Corrosion sites, word document, undated

111. AP101C-0500-2(R)1 Chinook General Orders and Special Instructions, Leaflet 001 Support Policy Statement, December 2009

112. AP101C-0500-2(R)1 Chinook General Orders and Special Instructions, Leaflet 012 Spillage of Body Fluids, April 2009

113. AP101C-0500-2(R)1 Chinook General Orders and Special Instructions, Leaflet 037 EDPC Policy, November 2011

114. AP101C-0500-2(R)1 Chinook General Orders and Special Instructions, Leaflet 044 Operations in High Ambient Temperatures, February 2009

115. Gazelle AH Mk1 Structural Integrity Strategy Document, 24th July 2012, Issue 1

116. Gazelle AH Mk1 Structural Integrity Plan, 24th July 2012, Issue 1

117. RA 4103 Decontamination of Aircraft after Spillage of Body Fluids, Initial Issue

118. RA 4150 Training and Competence, Initial Issue

119. RA 4208 Dehumidification of Aircraft, Initial Issue

120. RA 4210 Anti-Deterioration Maintenance of Equipment In Store, Initial Issue

121. AP 100V-21 Aircraft Storage, 1st Edition February 2006, Amendment 1, December 2011

122. RA 4214 Support Policy Statements, Initial Issue

123. RA 4257 Surface Finish of Military Air Environment Equipment, Initial Issue

124. RA 5720 Structural Integrity Management, Issue 2

125. RA 5723 Ageing Aircraft Audit, Issue 2

126. RA 5721 Systems Integrity Management, Issue 2

127. RA5724 Life Extension Programme, Issue 2

128. C2195 Environmental Degradation Techniques Across the Helicopter Operating Centre Project Teams, Reference RWSG/C2195, J.P. Tatton, 31st March 2011

129. Guides to Practice in Corrosion Control, Corrosion of Metals by Wood, www.npl.co.uk/uploads/pdf/corrosion_of_metals_by_wood.pdf

130. EASA SIB 2008-19R2, Catalytic Oxidation of Aircraft Carbon Brakes Due to Runway De-icers, 23rd April 2013

131. AP119A-0202-1, Aircraft Corrosion Control for Deployed Units, 4th Edition 2009, Initial Issue

Heavy Aircraft and Communications	
Aircraft Type	Meeting Date
A400M	19th June 2013
Airseeker	13th March 2013
BAE 125	17th April 2013
BAE 146	17th April 2013
C17	Carried out by review of provided documentation
Hercules C4/C5	Carried out by review of provided documentation
Islander/Defender	13th September 2012
Sentinel	19th February 2013
Sentry	19th February 2013
Shadow/King Air	Unable to arrange meeting not carried out
Voyager	23rd April 2013
Fast Jets and Training Aircraft	
Aircraft Type	Meeting Date
Hawk MkT2	Unable to arrange meeting not carried out
Hawk T1/1A	Unable to arrange meeting not carried out
Tornado	3rd October 2012
Tucano	19th March 2013
Typhoon	18th October 2012
Vigilant	19th Mach 2013
Viking	19th March 2013
Rotary Wing	
Aircraft Type	Meeting Date
Apache	12th October 2012
Augusta A109	Unable to arrange meeting not carried out
Bell 212	Unable to arrange meeting not carried out
Chinook	5th December 2012
Gazelle	16th April 2013
Griffin	Unable to arrange meeting not carried out
Lynx	21st August 2012
Merlin	11th September 2012
Puma	14th August 2012
Sea King	4th December 2012
Squirrel	Unable to arrange meeting not carried out
Wild Cat	11th December 2012

Appendix B: PT Meeting, Standard Agenda

ED Management and Reporting In Accordance With MAP-01 Chapter 11.6 Paragraph 5.2.3

Item	Requirement	Outcome
1	Collect, manage and interpret ED arising data	See Table 2
2	Consider ED data reports in order to direct prevention and remedial programmes through:	
2.1	Identifying new ED arising's	
2.2	Considering the significance and effect of ED arising's	
3	Control and direct progress on structural and systems ED issues through:	
3.1	Review and update of ED Control Plans	
3.2	Implementation of controlled humidity procedures	
3.3	Review of Surface Finish systems and techniques	
3.4	Use of Corrosion Preventative Compounds (CPC)	
3.5	Review of Preventive and Corrective maintenance procedures	
3.6	Review of composite material maintenance issues	
3.7	Review of selection and authorization of "exposure incident" recovery husbandry materials	
3.8	Co-ordination of Forward and Depth ED reporting	
4	Monitor and adjust the efforts expended at Forward and Depth to ensure ED prevention and remedial programmes are optimized to provide best value for money and aircraft operational capability and availability	
5	Review the collection, management and suitability of ED data to ensure suitability for:	
5.1	Structure and systems lifing reviews	
5.2	Reporting requirements to higher-level management forums	
5.3	Structural and Systems airworthiness	
6	Establish and review the need for special-to-type EDPC training/Phase 2 and Phase 3 training	

EDPC Project Team Responsibilities in Accordance with Reference MAP-01 Chapter 11.6 Paragraph 8.2

Item	Requirement	Outcome
1	Ensuring that the Master Maintenance Schedule contains inspections and procedures defined at intervals that are appropriate to the operating environment and that they meet the threat to ED to aircraft structures and components	See Table 3
2	Ensuring that any component requirements within the EDPC Programme are addressed by the appropriate equipment/commodity PTs	
3	Ensuring that appropriate ED data capture systems are employed by Forward and Depth organizations	
4	Ensuring that EDPC is addressed by the appropriate Working Group (WG)	
5	Producing and maintaining ED Control Plans, as required, and ensuring their review by the appropriate WG	
6	Approving husbandry procedures, materials and equipment	
7	Defining the requirements for EDPC specialist training at Forward and Depth for their aircraft	
8	Determining the requirements for and, where appropriate, resourcing EDPC focal points	
9	Maintaining the level of awareness of ED issues across Forward and Depth organizations where collocated	
10	Ensuring that Depth support arrangements address the need to:	
10.1	Carry out appropriate EDPC management techniques as specified by the PT	
10.2	Maintain a single ED data capture system as defined by the PT	
10.3	Appoint an EDPC focal point within the Depth Organization	
10.4	Adequately train personnel in EDPC techniques	
10.5	Provide support to PTs on EDPC at appropriate WGs	

Appendix C: Points of Contact

Project Teams and Other Organizations Points of Contact used for this Paper

Platform	Contact Name	Phone Number	email address	Remarks	
RW					
Bell212	Nick Jones	030 679 82583	DESSPMAP-MRCO-Hd@mod.uk		
Griffin	Nick Jones				
Squirrel	Nick Jones				
Augusta A109	Nick Jones				
Gazelle	Chris Shakespear	030 679 82771	DESP2G-GazEngMechMgr@mod.uk		
Chinook	Sqn Ldr Mark Thorne	030 679 82823		Also Ken Baker 030 679 82817	
Puma	Fl Lt Paul Graham	030 679 82779	DESP2G-PumaEngMech1@mod.uk		
Merlin	Mrs Mandy Cox	01935 705499	mandy.cox@augustawestland.com		
Sea King	Lt Cmd Andrew (Errol) Flynn	01935 703566	DESSeaKing-MechMgr@mod.uk	Also John Gilroy 01935 702148	DESSeaKing-Mech4@mod.uk
Lynx	Mark Toman	01935 453538	DESLynx-EngMech1@mod.uk		
Wild Cat	Lt Cmd Paul Brunell	01935 453897	lynx-wildcat-edamechengauth@mod.uk		
Apache	Richard Simpson	01935 386095	desapache-engmech3@mod.uk		
FJ&T					
Typhoon	John Eaton	01526 348160	CON-TSCStructures01@mod.uk		
Tornado	Sqn Ldr Michelle Casey	01760 334514	DESFAST-Tor-EA-Struct@mod.uk		
Vigilant	Pete Simpson	01347 847017	DESUKMFTS-TA-TucanoMech1@mod.uk		
Viking	Pete Simpson	01347 847017	DESUKMFTS-TA-TucanoMech1@mod.uk		
Tucano	Pete Simpson	01347 847017	DESUKMFTS-TA-TucanoMech1@mod.uk		
Hawk T1/1A	Peter Key	030 679 80500	DESUKMFTS-Hawk-STR@mod.uk	Also C/T Christian Tasker 030 679 80021	
Hawk MkT2	Peter Key				
F35	Not contacted				
HA&C					
Sentry	Sqn Ldr Chris Akerman	01522 726604	desAS-AirISTARSptabilityEng@mod.uk		
Airseeker	Martin Parker	030 679 36680	DESAS-AirISTARAirseekerAM@mod.	Also Andy Douglas	DESAS-AirISTARAirseekerAv@mod.uk
Sentinel	Wg Cdr Andy Tait	01522 726722	desas-AirISTARSLAirvehicle@mod.uk		
C17	David Moore	01993 896329			
Hercules C4/C5	Fl Lt Ben Greenwood	01223 399977			
Voyager	Sqn Ldr Steve Ralph	01993 873289	DESSTAAR-KC30-EngAuth@mod.uk		
A400M	Tony Sutton	030 679 30067	DESA400M-ILSM4C@mod.uk		
BAE 125	Jim Gifford	030 679 82017	DESC17-CSCSAT-PAM@mod.uk		
BAE 146	Jim Gifford	030 679 82017	DESC17-CSCSAT-PAM@mod.uk		
Islander/Defender	Lt Cmd Dave Mealing	030 679 82572	DESSPMAP-SHADOW-HIST-HUSLE-Hd@mod.uk		
MIG	Dr Matt Mishon	02392 720956	matt.mishon145@mod.uk		
MIG	Andy Dutch	01935 452330	1710NAS-MIGCCHS2@mod.uk		
QinetiQ	Jay Patel	01252 397487	Paints and Coatings		
QinetiQ	Dr Don Bartlet	01252 392254	Corrosion		

Appendix D: Information Provided by PT

The documentation provided by the PTs during the course of this work is listed below. Some PTs were willing to provide a significant amount of information where as other felt constrained as to how much they were willing to share with a third party. The variance in the amount of information provided did not inhibit the discussion that took place during the meetings that were all conducted in a frank and open exchange.

Heavy Aircraft and Communications Platforms

Islander/Defender

Structural Integrity Strategy Document [4]
2(A)1 leaflet dealing with Spillage of Body Fluids [5].

Sentry

Minutes of the 41st Structural Integrity Working Group (SIWG) [7]
Record of Decisions Taken at 6th Environmental Damage Prevention and Control (EDPC) Working Group [8]
AP101B-5301-2(R)1A Part 1 Leaflet 001 Support Policy Statement [9]
AP101B-5301-2(R)1A Part 1 Leaflet 204 Aircraft Corrosion and Repair Reporting and Recording [10]
AP101B-5301-2(R)1A Part 1 Leaflet 212 Decontamination of Sentry AEW Mk1 Following the Spillage of Body Fluids [11]
AP101B-5301-2(R)1A Part 1 Leaflet 501 Sentry Electrical Wiring [12]
Sentry E-3D AEW Mk1 Structural Integrity Strategy Document [13]

Sentinel

Minutes of the 16th Structural Integrity Working Group (SIWG) (The meeting that covered EDPC issues) [14]
Minutes of the 4th Systems Integrity Working Group Meeting [15]
Structures Strategy Document [16]
Systems Strategy Document [17]
Topic 2(A/R)1, Leaflet 1, Support Policy Statement [18]
Topic 2(A/R)1 Leaflet 13 Dehumidification [19]
Topic 2(A/R)1, Leaflet 15 Aircraft Decontamination Procedure After Spillage of Body Fluids [20]
Topic 2(A/R)1, Leaflet 32 Operations from Austere Bases and Sandy Geographical Locations [21]
Topic 2(A/R)1, Leaflet 201 EDPC and Mechanical Damage Reporting [22]
Topic 2(A/R)1, Leaflet 500, Electrical Wiring [23]

Airseeker

QinetiQ Report on the Structures Information gained during a visit to Big Safari and L3 Greenville, Texas [24]

Aircraft Condition Assessment of Aircraft RJ-18 Serial Number 64-14833 [25]

KC-135 Teardown Report on Aircraft 1 (AC1) at Tinker Air Force Base [26]

Synopsis of Tier 1 Major Modification Breakdown [27]

C17A Globemaster III

Minutes of the 2012 C-17 Corrosion Prevention Advisory Board Conference [28]

Minutes of the 13th Structural Integrity Working Group (SIWG) Meeting [29]

Supplement to 13th SIWG Corrosion Issues and Corrosion Maintenance Plan [30]

Supplement to 13th SIWG Analytical Condition Inspection (ACI) report [31]

Minutes of the 5th Propulsion and Systems Integrity Working Group Meeting [32]

TO-1C-17A-23, Systems Peculiar Corrosion Control Manual [33]

Structural Integrity Plan 34]

Propulsion Integrity Strategy Document [35]

Systems Integrity Strategy Document [36]

A400M Atlas

At the time of the meeting, 19th June 2013, the aircraft was not yet in service and the relevant in-service documentation was still to be produced. Post the meeting, examples of the Maintenance Steering Group (MSG) 3 Reliability Centred Maintenance (RCM) analysis were provided. These covered the

Ramp [37]

Elevator [38]

Fuselage Centre Cargo Compartment Section [39]

C130J Hercules C4/5

Minutes of the Hercules C-130J EDPC Meetings held on the 2nd November 2011, 24th April 2012, 23rd October 2012 and the 28th March 2013 [40]

Minutes of the Hercules C-130J SIWG Meeting held on 14th November 2012 [41]

Minutes of the Structural Specialist Meeting held on the 2nd November 2012 [42]

Topic 2(R)1 Leaflet 005 EDPC Policy [43]

Topic 2(R)1 Leaflet 034 Spillage of Body Fluids Within the Cargo Compartment [44]

Topic 2(R)1 Leaflet 042 Aircraft Dehumidification [45]

Topic 2(R)1 Leaflet 045 Operations in Extreme Climatic Conditions – Additional Maintenance Requirements/Considerations [46]

BAe 146

Minutes of the 5th Platform Integrity Day 16th February 2012 [48]

Minutes of the 6th Platform Integrity Day 20th September 2012 [49]

Minutes of the 7h Platform Integrity Day 14th March 2013 [50]

Platform Integrity Strategy Document [51]

Topic 2(R)1 Leaflet 001 Support Policy Statement [52]

Topic 2(R)1 Leaflet 025 Dehumidification [53]

Topic 2(R)1 Leaflet 202 EDPC [54]

Topic 2(R)1 Leaflet 205 Aircraft Washing Policy [55]

Topic 2(R)1 Leaflet 208 Surface Finish [56]

BAe 125

Minutes of the 5th Platform Integrity Day 9th February 2012 [57]

Minutes of the 6th Platform Integrity Day 13th September 2012 [58]

Minutes of the 7th Platform Integrity Day 7th March 2013 [59]

Platform Integrity Strategy Document [60]

Topic 2(R)1 Leaflet 001 Support Policy Statement [61]

Topic 2(R)1 Leaflet 025 Dehumidification [62]

Topic 2(R)1 Leaflet 202 EDPC [63]

Topic 2(R)1 Leaflet 206 Surface Finish Policy [64]

Topic 2(R)1 Leaflet 208 Operating in Hot and Sandy Climates [65]

Topic 2(R)1 Leaflet 215 Spillage of Body Fluids [66]

Voyager

There were no documents available at the time of the meeting (23rd April 2013).

Shadow/King Air

No meeting was held and no information was provided.

<u>Fast Jet and Training Aircraft Platforms</u>

Tornado

Topic 2(R)1 Leaflet 007 Corrosion Control [71]

Topic 2(R)1 Leaflet 046 Dehumidification of Tornado Aircraft [72]

Topic 2(R)1 Leaflet (in Draft about to be issued) Cadmium Corrosion Assessment and Handling [73]

Typhoon

Minutes of the 7th Typhoon EDPC Working Group Minutes [74]

Typhoon Structural integrity Strategy Document [75]

Topic 2(R)1, Leaflet 10, Typhoon EDPC [76]

Typhoon Composite Awareness Training (AESOs) [77]

The Cost of Corrosion on Typhoon (Study written by Typhoon EDPC post holder) [78]

Presentation of Husbandry Requirements on Typhoon (Prepared by Typhoon EDPC post holder) [79

Tucano and Vigilant/Viking Gliders

Minutes of the 59th Tucano Structures Integrity Working Group Meeting [83]

Minutes of the 60th Tucano Structures Integrity Working Group Meeting [84]

Minutes of the 1st Tucano Systems Integrity Working Group Meeting [85]

Minutes of the 2nd Tucano Systems Integrity Working Group Meeting [86]

Tucano Topic 2(R)1 Leaflet 001 Support Policy Statement [87]

Tucano Topic 2(R)1 Leaflet 017 Tucano Corrosion Control [88]

Tucano Topic 2(R)1 Leaflet 028 Aircraft Decontamination after the Spillage of Body Fluids [89]

Hawk Mark 1 and Mark 2

No meeting was held and no information was provided.

<u>Rotary Wing Aircraft Platforms</u>

Puma

No documents were provided.

Lynx

Topic 2(N/A)1 [90] for the aircraft.

This included Leaflets on the:

Spillage of Body Fluids

Operations in Periods of Abnormal Use (Including Cold, Hot and Dusty, Embarked Saline Environment and Storage)

The support Policy Statement also contained details of the Dehumidification policy for the aircraft

Sea King

Minutes of the 7th Environmental Damage Working Group [91]

Structural Integrity Strategy Document [92]

Systems Integrity Strategy Document [93]

Topic 2(NR)1 Leaflets

Leaflet 032 Spillage of Body Fluids [94]

Leaflet 034 Dehumidification Procedures [95]

Leaflet 066 Corrosion Control [96]

Leaflet 089 Conditional Servicing/Maintenance Requirements in Cold, Hot and Dusty and Embarked Operations [97]

Wildcat

At the time of the meeting (11th December 2013) the aircraft was just being introduced into service. There were no relevant documents available for review.

Merlin

The following Topic 2(N/R)1 Leaflets were provided prior to the meeting.

Leaflet 116A Dehumidification Policy [100]

Leaflet 147A EDPC Policy [101]

Apache

Structural Integrity Strategy Document [103]

Topic 2(A)1 Leaflet 013A Corrosion Fault Reporting [104]

Chinook

Minutes of the 4th EDPC Meeting [105]

Minutes of the 13th Structural Integrity Working Group Meeting [106]

Structural Integrity Strategy Document [107]

EDPC Plan [108]

SI/Chinook/0119A Application of Dinitrol AV15 CPC to Restricted Areas [109]

Chinook Damage Map Showing Cracks and Corrosion sites [110]

Topic 2(R)1 Leaflets

Leaflet 001 Support Policy Statement [111

Leaflet 012 Spillage of Body Fluids [112]

Leaflet 037 EDPC Policy [113]

Leaflet 044 Operations in High Ambient Temperatures [114]

Gazelle

Structural Integrity Strategy Document [115]

Structural Integrity Plan [116]

Remaining Platforms

The SPMAP PT responsible for the platforms listed below was unable to participate in this programme.

Augusta A109
Bell 212
Griffin
Squirrel

RA 4103 Decontamination of aircraft after spillage of body fluids

RA 4103 [117] references MAP 0-1 Chapter 3.5 [2] as the AMC. The RA states that spillage of body fluids has the potential to be a significant corrosion hazard to aircraft structure and materials (primarily human urine, vomit and gastric juices) as well as the liquid products of decay such as the uric acid present in bird droppings. All these materials are highly acidic and their presence must be contained and removed or neutralised immediately. The most important aspect in dealing with these arising are the use of aircraft cleaning compounds and not the immediate use of disinfectant chemicals which can have an equally corrosive effect on aircraft structure. Details of the decontamination process are to be recorded in the MOD Form 700C.

The PT is responsible for ensuring that suitable cleaning techniques and materials are available and that the details are contained in the Aircraft Maintenance Manuals (AMM) or the Topic 2(N/A/R) 1. The PT is also to engage with Materials Integrity Group (1710 NAS MIG) for advice on existing cleaning compounds and for the identification of suitable alternatives where necessary.

RA 4150 Training and competence

The AMC for RA 4150 [118] is given in MAP 0-1 Chapter 4.1 where specific trade training is introduced in “Phase 2 Training” and enhanced in “Phase 3 Training”. From the review conducted of MAP 0-1 Chapter 4.1 the three service operators have their training delivery devised by the Defence College of Aeronautical Engineering (DCAE). Meetings were held with all three services training establishments to gain an understanding of the training course content with regard to corrosion, including its identification, treatment and repair. These meetings are reported in Section 8.5.

RA 4208 dehumidification of aircraft

The AMC for RA 4208 [119] is provided in MAP 0-1 Chapter 5.6, and although dehumidification is not mandated, the PT are required to carry out a cost-benefit analysis of the advantages of having a dehumidification policy. All PTs interviewed had a policy on dehumidification either in their SPS or a separate leaflet in the Topic 2(N/A/R)1. It was found that the application of policy on many platforms was inconsistent.

RA 4210 Anti-deterioration maintenance of equipment in store

The RA 4210 [120] requires that equipment in store should be subject to anti-deterioration maintenance activity as an exception rather than the rule based on the principle that storage conditions should be such that the equipment does not deteriorate. The AMC is given in MAP 0-1 Chapter 5.8 where the equipment that has historically required anti-deterioration maintenance (ADM) is listed. The PT should identify what equipment requires ADM and publish the frequency, depth and type of activity required in the Topic 2(N/A/R)1. JAP 100V-21 Aircraft Storage [121], provides a generic approach to placing aircraft and aircraft equipment such as engines and propellers into storage and also addresses the maintenance requirements during storage and the recovery from storage.

The problems found with components from Tornado and Apache that had been placed in wooden storage containers indicates that these requirements were either not considered or incorrectly applied.

RA 4214 Support policy statement (sps)

RA 4214 [122] states that the PTs are to publish a SPS in the Topic 2(N/A/R)1 for the platform and the associated AMC is found in MAP 0-1 Chapters 5.14, 5.14.1 and 5.14.2. The template for the SPS covers various factors that can have an effect on corrosion control such as anti-deterioration maintenance, surface finish policy, spillage of bodily fluids and under structural integrity management, describes the EDPC measures that are to be undertaken.

All PTs had complied with this requirement and most had expanded on the detail in their Structural/Systems Integrity Strategy Documents.

RA 4257 Surface finish of military air environment equipment

The associated AMC for RA 4257 [123] is found in MAP 0-1 Chapter 6.6 which describes the PT's responsibilities for directing how the surface finish policy for the platform is applied, maintained and removed. Surface finish not only relates to the painted surfaces of the platform but also covers temporary protective treatments, varnishes and conversion coatings. Surface finish materials and techniques are covered in AP119A-0601 series of publications.

MAP 0-1 Chapter 6.6 also details surface finish husbandry and how aircraft washing is an important aspect of this process. During the development of this paper the individual platform washing policy and the ability of the user units to carry it out effectively have been reviewed.

The issue with aircraft washing equipment and washing facilities at various operating bases have been discussed in Section 9.4.3 where the findings indicate that this particular requirement is not applied effectively on many platforms.

RA 5720 Structural integrity management

RA5720, [124] states *"the aim of Structural Integrity (SI) management is to minimise the risk to structural airworthiness"*. It contains a detailed process designed to ensure that SI is maintained throughout the life of the platform. For a number of years now SI has followed a process under the acronym ESVRE:

E Establish
S Sustain
V Validate
R Recover
E Exploit

EDPC in these categories is covered in "Establish" where the identification of Structurally Significant Items (SSIs) within the airframe leads to the consideration of the items vulnerability or otherwise to corrosion or environmental damage. The determination of SSIs and their subsequent inspection regime is contained in the platforms Master Maintenance Schedule (Topic 5A1) and the Sampling Requirements and Procedures (Topic 5V). Many SSIs will be the subject of directed inspections on a regular basis. However, it is not possible to adequately inspect some SSIs in-situ and these are the subject of sampling programmes detailed in the platforms Topic 5V.

EDPC is also covered in “Sustain” where structural integrity working group (SIWG) meetings and in some cases separate EDPC meeting are held. Here, the in-service issues regarding SI and EDPC should be discussed and managed. Sustaining activities also centre on the adoption of a Structural Examination Programme (SEP), a Structural Integrity Strategy Document and Structural Integrity Plan. All of these, when available have been reviewed for this Paper, firstly to gain an understanding of how individual PTs manage this responsibility and secondly to consolidate beneficial practice and common issues. Another activity that further provides evidence of SI sustainment is the conducting of Ageing Aircraft Audits, the process and procedures of which are given in RA5723 [125].

Under the heading “Validating”, structural sampling is prescribed as a method of validating SSIs which have been classified as “not at risk” from Accidental and Environmental Damage (AD/ED). These sampling activities, as described above, should be stated in the platform Topic 5V.

EDPC is also covered in the “Recover” part of the process where the use of a database is suggested to record structural configuration control. This should enable repairs, modification, accidental and environmental damage for each aircraft to be compared and assessed for common trends and structural health. Although most PTs had a policy for recording corrosion and other damage the availability, accuracy and effectiveness of these databases has not been verified during the work for this Paper. The author is also aware of a Dstl project being carried out by MSL to produce a generic, cross-platform repair database in which corrosion repairs would be recorded.

Although EDPC is not specifically mentioned in the final heading of “Exploit”, if the previous processes and procedures have been robustly adopted then any review for the application a life extension programme can be more accurately determined.

RA 5721 Systems integrity management

Systems Integrity (SyI) management as stated in RA 5721 [126] follows the same process adopted for SI management, i.e. the ESVRE process. The fundamentals of the systems integrity management have been studied at the same time that the SI management strategy was evaluated. It should be remembered that SyI is relatively immature compared to SI management with the requirements having formally existed only for approximately two years at the time of preparing this Report.

RA 5723 Ageing Aircraft Audits (AAAs)

Ageing Aircraft Audits (AAAs) were first mandated for structures over twenty years ago and a new requirement over the last two years has included the audit of both platform systems and propulsion units. This Paper has sought to examine the various platform audits that have been carried out to establish whether any EDPC arising's were identified.

A recent amendment to the RA 5723 [125] now requires a Condition Survey (CS) (a physical inspection) to be carried out on a sample of the fleet as part of the AAA. The author has had access to the recent CS carried out on the BAe 125 and BAe 146 aircraft and has found a number of ED issues - particularly with the standard of husbandry and the amount of corrosion being found.

RA 5724 Life Extension Programmes

RA 5724 [127] is a relatively new procedure that details the necessary steps to be considered before a life extension programme is undertaken. As discussed in RA 5720, if SI and SyI management has been robust then one of the most significant considerations when proposing such a programme is readily available. “Significant considerations” for example would be accurate repair information that contains damage maps and details of structural repairs including corrosion repairs, carried out during the aircrafts service usage. Should any part of the management of SI/SyI be lacking then a more costly programme would need to be implemented to evaluate the implications of putting the platform through such a programme.

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13. Abstract

Due to the need to keep aircraft in service beyond their original out of service date, concerns have been expressed with regard to the ageing effects on the structural and systems integrity caused through accidental and environmental damage. This Paper considers the impact of environmental damage to structures and systems. It has also evaluated how the Project Teams are managing these issues and identifies successful procedures that may have application to other platforms if adopted. It has also identified individual and common issue across fleets and made recommendations on how research programmes might be targeted to resolve them.

15. Keywords/Descriptors:

AAPWG, Ageing Aircraft, Corrosion, Environmental Damage Prevention and Control, EDPC, Project Team, Structural and Systems Integrity, Regulatory Article