Proactive Asset Management through Maintenance Condition Data

Bob Teunisse
Air Domain Centre
Capability, Acquisition & Sustainment Group
Department of Defence

Summary: In an increasingly cost-conscious environment, it is essential to be able to realise the inherent reliability of an asset through optimising the maintenance conducted on that asset. Maintenance Condition Data (MCD) plays a vital role in optimising maintenance to ensure safety, increasing availability and minimising operating costs – all of which are hallmarks of a robust asset management framework.

Over the past seven years the Aerospace Maintenance Policy Review Team (AMPRT), and now the Reliability & Aircraft Maintenance Programme (RAMP) Team, has led a variety of maintenance policy optimisation initiatives for fixed wing aircraft within the Australian Defence Force (ADF). Based on these initiatives and a wealth of additional related experience, this paper will outline the importance of MCD and its role in establishing a proactive asset management framework; identify current challenges within the ADF Air Domain related to capturing meaningful MCD; and provide strategies that can be employed to improve the quality of MCD collected and how it is used.

Keywords: maintenance condition data, performance evaluation, performance monitoring, condition monitoring, optimised maintenance

INTRODUCTION

The ISO 5500X International Standards provide an overview of asset management and asset management systems; and define requirements for an asset management system to enable the effective and efficient management of assets.[1] A key element of the ISO 5500X asset management framework is 'performance evaluation'[2], which is reliant on 'performance monitoring' or 'condition monitoring'.[3]

Within the ADF, it is a regulatory requirement to record defects on aircraft when discovered.[4] As such, when an item is unacceptable for in-service use due to its condition, an 'unserviceability' (U/S) is raised, which will prevent the item from being fitted to an aircraft. Further investigations resulting from a U/S can identify the type and level of degradation and the root cause of the U/S at the time it was identified/reported.

However, for most ADF aircraft there is minimal information recorded against a U/S item regarding the rectification to get a 'servicable' item back in-service; the format for a significant amount of the U/S-related data is paper-based; and there is no requirement to record the condition of a maintained item during scheduled maintenance inspections prior to the U/S being identified/reported. All of which limits the proactive asset management of ADF aircraft as promoted by the ISO5500X framework.

In 2011 the then Head of Aerospace Systems Division within the Defence Materiel Organisation formed the AMPRT, a 'tiger-team' specifically established to aid in-service aircraft platform managers to optimise the extant maintenance policies for their respective platforms.

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[1] ISO 55000:2014, pg. v.
[2] ISO 55000:2014, pg. 9.
[3] ISO 55000:2014, pg. 11.
[4] DAA, DASR 21.A.3A(a).

As a result of the First Principles Review in 2016, the RAMP Team was formed within the Air Domain of the Capability, Acquisition & Sustainment Group, which subsumed the AMPRT. The charter for the RAMP Team is to support Acquisition Projects Offices and System Program Offices with:

- Reliability, Availability and Maintainability (RAM) analysis to support informed decision making across procurement, logistic and engineering activities;
- Develop and review RAM requirements and specifications to support tender evaluation; and contractual negotiations; and
- Conduct/Support maintenance optimisation initiatives across the Capability Life Cycle of ADF aerospace platforms.

Based on the maintenance optimisation projects undertaken by the former AMPRT and current initiatives being led by the RAMP Team, the need has been identified for a robust condition monitoring system to collect MCD prior to and once a U/S occurs. As a result, the RAMP Team is currently pursuing a number of Maintenance Data Improvement Initiatives (MDIIs) to ensure relevant data is collected to support engineering decisions for the optimisation of ADF aircraft maintenance programs. This paper presents key aspects of MDIIs and how these initiatives can support a robust closed-loop asset management framework.

DISCUSSION

Importance of Maintenance Condition Data

Boito et al (2015) estimate that maintenance costs for military aircraft can range between 33% - 40% of the overall Operating and Support (O&S) costs for a given platform.[5] Since this is a significant portion of the overall O&S budget, great saving can be realised through optimising the Maintenance Program (MP) delivered by the Original Engineering Manufacturer (OEM).

Typically when an aircraft is acquired for in-service use, the OEM will provide a MP based on predetermined Configuration, Role and Environment (CRE) assumptions. However, within the ADF, experience has shown that the in-service CRE can vary from the assumed CRE that the OEM MP is tailored for. Therefore, to ensure the right maintenance is done at the right time for the right reasons, periodic reviews of the MP should be undertaken to verify the MP is optimised for any changes in CRE, and this requires relevant and accurate MCD.

Mathew et al (2006) indicate that the use of MCD will enable optimise maintenance, which can lead to potential reductions in maintenance and material costs.[6] However, the value of MCD also ensures that the aircraft remains safe to use in its intended roles because the intent of Preventative Maintenance (PM) tasks is to ensure the function of an item within a system is available when the system is in use. If the failure of an item has safety-related consequences, the effectiveness of the PM tasks performed on that item may determine if an unsafe circumstance could occur. Therefore, accurate and relevant MCD for an asset can affect the safety, the cost of ownership and the availability of an asset.

Current Challenges with Maintenance Condition Data

Flintsch et al (2009) identify that data collection is an integral aspect of Asset Management[7] and further state that data collection for asset management are often not designed to support the decision processes associated with specific assets.[8] This situation has slowly evolved within certain areas of the ADF Air Domain, i.e. volumes of data have been (and continue to be) collected, yet often this data is not utilised to support proactive asset management.

For example, from 2012 – 2015 the AMPRT conducted a detailed analysis of the major servicings associated with the Royal Australian Air Force (RAAF) PC-9/A aircraft. To access relevant data to support the optimisation of the servicings reviewed, the AMPRT requested access to servicing records for 15 aircraft over a five year period. As a result of this request the AMPRT received 15 boxes of paper based servicing records (one per aircraft) that had to be retrieved from a remote storage facility. Within these boxes were approximately 15 servicing packs, each of which contained up to 100 pages. To extract the relevant data from these data packs, four AMPRT members spent over a month extracting more than 5,000 U/S details. The effort to retrieve the data from storage, then extract the useful data into an electronic format indicates that although large amounts of data had been collected, it was not being actively reviewed to support proactive asset management.

This highlights two significant challenges with the collection of MCD, namely: MCD is not being collected to support a closed-loop asset management system; and the format of the MCD (i.e. paper-based reports opposed to electronic data) is not conducive for analysis, trending or interrogating.

Another challenge with the ADF Air Domain is that much of the data that is being collected lacks the level of detail required for asset managers to truly understand the nature of the U/S and how the U/S was rectified. This was noted

[5] Boito et al, 2015, Table 2.2, pg. 10.

[6] Mathew et al, 2006, pg. 2.

[7] Flintsch et al, 2009, pg. 9.

[8] ibid.

during the conduct of the MP review projects conducted by the AMPRT on the RAAF P-3C and PC-9/A fleets. Table I provides examples of U/S entries that lack sufficient detail to support asset management decision; and comments indicating why the provided information is not adequate. Table II provides examples of U/S entries that would provide asset managers a better understanding of the nature of failure or degradation and the root cause. With a better understanding of the failures, degradation and root causes, asset managers are better equipped to proactively manage those assets.

Unserviceability	Comment
RH aileron trim tab to be replaced.	Reasons why the component requires replacement should be described, i.e. the mode of failure or external symptoms of failure, e.g. 'shaft bent', 'shaft seized', etc.
Port outboard leading edge drop down access panel cracked as marked.	When this type of entry is reviewed away from the actual maintenance environment there is no way of knowing in what physical area 'as marked' is describing. Where possible the actual location of the crack and its dimensions should be described.
Corrosion inside of nose wheel well lip.	Where possible the degree of degradation should be described along with the size and type of corrosion evident, e.g. 'exfoliation corrosion evident on the inside of nose wheel well forward lip, approx. 2cm in size'.
Centre bottle & flex line found U/S.	Specific failure mode or symptoms should be described, e.g. cracked line, corroded line, leaking etc.

Table I: Examples of Vague Unserviceability Records[9]

Unserviceability	Comment
With ground power applied #3 engine flight idle stop fails to disengage.	Clearly identifies the context and the problem.
Pilot side windshield has delamination evident at the LH bottom edge approximately 2" wide and "5" vertical.	Clearly identifies the area of concern and the extent of degradation.
Flight station aircon unable to get temp below 19 degrees Celsius in auto or manual.	Clearly identifies the functional failure.
Wing flap control handle friction lock slips at 26lbs force.	Provides quantitative measurements of degradation.

Table II: Examples of Detailed Unserviceability Records[10]

The final MCD challenge to be addressed by this paper pertains to the collection of degradation data prior to a U/S being identified/recorded. Currently within the ADF there is no need to record the condition of an item being maintained unless a U/S is identified. So, regardless of the number of times an item may be inspected or examined during maintenance, no data is collected on the condition of that item unless a U/S is identified. This creates a 'digital' data point for a MP analyst (i.e. the item is either serviceable or U/S). If MCD is collected when PM tasks are performed on items, the analysts will have a more robust set of data to characterise the degradation of the items, thereby enabling improved maintenance optimisation opportunities for those items.

Maintenance Data Improvement Initiatives

To improve the ADF aircraft asset management framework and to enable the optimization of ADF aircraft MPs, the RAMP Team has established MDIIs to improve the collection of MCD at the coalface. The MDIIs will address the MCD challenges outlined about, namely:

- MCD collection does not support proactive asset management
    - maintenance data is collected to comply with regulations (opposed to supporting asset management objectives);

[9] Linton, 2014, slide 15.

[10] Linton, 2014, slide 16.

    - maintenance data is paper-based (opposed to electronic)
- MCD lacks quality and sufficient detail to support asset management decisions
- no progressive degradation data is being collected prior to a U/S being identified/reported.

To address the above MCD challenges, the MDIIs being pursued by the RAMP Team include the following:

1. providing Continuation Training (CT) for maintainers for the collection of appropriately detailed MCD;
2. establishing MCD reviews at maintainer facilities;
3. encouraging the collection of electronic MCD; and
4. collecting progressive degradation maintenance data prior to an item becoming U/S.

Maintainer CT

Maintainers of ADF aircraft are very professional and take great care to perform their duties to the highest standards. Instead of telling them how to maintain aircraft, the proposed CT is intended to provide the context of why MCD is important; and to educate maintainers in how their recorded maintenance data is utilised in decision making to ensure ongoing safety and airworthiness, cost of ownership optimisation and improved aircraft availability.

Often maintainers are pressured to get an aircraft serviceable as soon as possible. The propose CT will ensure maintainers continue to develop their skillsets and enable professionalism in what they do and support the aircraft for the duration of its service life; and the proposed CT can inform maintainers of the type of data that will support long-term proactive asset management of the aircraft.

CT was provided to maintainers of the RAAF PC-9/A fleet in support of the MP review project conducted by the AMPRT. Subsequent to the training, the AMPRT team observed a positive change in the detail provided in MCD. This enabled engineering decisions related to optimising maintenance tasks to be better substantiated. As a result of the PC-9/A MP conducted and the MCD collected, the RAAF PC-9/A fleet had approximately 800 hours of additional aircraft availability within the first year of implementing the revised MP.

Reviewing Maintenance Condition Data

The old adage “rubbish in; rubbish out” comes to mind when considering the need to review maintenance data for accuracy and vagueness. Aljumaili (2016) states that poor quality leads to poor decision-making.[11] Within the ADF, often the asset management analyst is not collocated in the same facility as the people who conduct maintenance and record maintenance data. As such, reviewing MCD at the maintenance facility will improve data quality; and clarify vague descriptions. This will ensure the data received by the asset management analyst is relevant and accurate. Although reviewing the data at the maintainer facilities may impose the need for additional personnel, the asset management benefits gained through improved data quality will support decisions related to aircraft safety, costs of ownership and aircraft availability.

Electronic MCD

As the PC-9/A MP review project illustrated, paper-based MCD significantly limits the ability of an analyst to manipulate data. The manipulation of data can enable trends to be observed and to identify anomalies that warrant further investigations.

Due to various contractual and security issues, a significant amount of MCD collected on ADF aircraft is paper-based. Although the more modern platforms utilise electronic maintenance management systems, a number of legacy platforms (such as the P-3C and PC-9/A fleets) rely on paper-based maintenance records. For legacy ADF platforms reliant on paper-based maintenance records, the RAMP Team encourages the transcription of particular maintenance records into an electronic MCD database. With electronic MCD the asset managers for legacy platforms will be able to observe trends and anomalies that affect aircraft safety, costs of ownership and aircraft availability.

Progressive Degradation Maintenance Data

ADF aircraft began utilising hand written maintenance condition code-type functionality in the early1990s to record the level of degradation observed during the performance of specific maintenance tasks. The collection of this type of data was specified for the conduct of ‘age explorations’ into the performance of a specific item over a specified interval. With the introduction of DEF(AUST) 5692 compliant Weapon System Databases (WSDB) in the late 1990s, the Failure Reporting Requirement (FRR) data field allowed the capture of a condition code information against a specific maintenance task. Although this functionality has existed for several years, it has not been typically exploited to proactively manage the platform assets because the condition code definitions set in the 1990s were limited to describe the degradation observed.

In 2012 the AMPRT revised the FRR Condition Codes to allow a more quantitative rating of degradation to be recorded. Previously, the original hand written codes required recording the form of degradation (e.g. wear, delamination, etc.) and

[11] Aljumaili 2016, pg. III.

if the degradation was within accepted limits or not. The revised FRR codes enable the recording of the form of degradation, as well as a qualitative assessment of the degree of degradation (e.g. no detected degradation; 25% of allowable limit; 50% of allowable limit; 75% of allowable limit; or U/S).

With this additional information degradation trends for a particular maintenance task can be mapped for a given aircraft on successive servicing, as well as across the fleet. These trends help enable the asset managers to make more informed decisions regarding maintenance optimisation options. However, for this approach to be effective it is essential to have this data in electronic form and candidate PM tasks must be selected for recording FRR codes.

Through applying the various MDIIs presented in this paper, significant benefits have been realised by the ADF, which include:

- increased aircraft availability through extended intervals for major servicings;
- reduced cost of ownership through reduce material and manpower costs from:
    - extended major servicing interval;
    - streamlined/standardised servicing tasks; and
    - the removal of superfluous maintenance activities from the MP;
- increased fleet planning flexibility due to reduced frequency of major servicings; and
- assured continued safety through identifying potential safety-related issues.

CONCLUSION

Through conducting a variety of maintenance policy optimisation projects, the AMPRT and RAMP Teams identified the value of collecting relevant MCD with appropriate levels of detail in an electronic format. This type of MCD has been demonstrated to enable asset managers to proactively manage their assets through:

1. trending/monitoring maintenance-related issues; and
2. determining the effectiveness and applicability of the existing maintenance policy.

Within the ADF Air Domain the RAMP Team is actively encouraging asset managers and maintainers to adopt the recommended MDIIs, which includes:

1. providing Continuation Training (CT) for maintainers for the collection of appropriately detailed MCD;
2. establishing MCD reviews at maintainer facilities;
3. encouraging the collection of electronic MCD; and
4. collecting progressive degradation maintenance data prior to an item becoming U/S.

It is acknowledged that for the above initiatives to be effective, there will be an impost on the asset management organisations with respect to providing personnel to action the above activities; providing training to personnel to ensure the activities are performed as required; and ensuring that processes are in place for the collection, storage and review of MCD in support of a proactive asset management framework. However, the benefits the ADF has already realised from employing these initiatives demonstrates a significant return on investment.

The ISO 5500X asset management framework identifies the need for performance monitoring and condition monitoring for a robust closed-loop asset management system. The MDIIs presented in this paper will aid proactive asset management practices as promoted by ISO 5500X.

REFERENCES

[1] Aljumaili, M., *Doctoral Thesis: Data Quality Assessment: Applied in Maintenance*, Dept. of Operation, Maintenance, and Acoustics Engineering, Luleå University of Technology, Luleå, Sweden, 2016.

[2] Boito, M., Keating, E.G., Wallace, J. DeBlois, B., Blum, I., *Metrics to Compare Aircraft Operating and Support Cost in the Department of Defense*, RAND Corporation, Santa Monica, California, USA, 2015.

[2] Defence Aviation Authority (DAA), *Australian Air Publication 8000.011, Defence Aviation Safety Regulations*, Australian Defence Force, 13 Dec 2017.

[3] Flintsch, G.W., Bryant, Jr, J.W., *Asset Management Collection*. US Department of Transportation, Federal Highway Administration, March 2009.

[4] International Standard Office, *ISO 55000: Asset management – Overview, principles and terminology*, Corrected version 2014-03-15, ISO 2014.

[5] Linton, I., *Continuation Training Presentation: Maintenance Data and the Trained Technician*. Aerospace Maintenance Policy Review Team, Defence Materiel Organisation, Department of Defence, 2014.

[6] Mathew, Avin and Zhang, Sheng and Ma, Lin and Earle, Tom and Hargreaves, Doug, *Reducing maintenance cost through effective prediction analysis and process integration*. [http://eprints.qut.edu.au], Krishtel eMaging Solutions, 2006.