
Interactive Electronic Technical Manuals: Improving the provision of technical information to ADF aerospace maintainers

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Introduction

1. Advanced technology is a key capability development principle of the Australian Defence Force (ADF).¹ Airpower capabilities are especially reliant on technology, but advanced technology aircraft systems are expensive to acquire, operate, and maintain. Furthermore, aircraft systems are susceptible to damage through poor or incorrect maintenance.

2. Aircraft maintenance has a significant impact to sustaining the ADF's airpower capability in terms of availability, technical airworthiness, and cost of ownership. The ADF's Technical Airworthiness Management Manual identifies that effective maintenance is based on competent maintainers with access to appropriate parts, technical data and procedures.²

3. Technical publications (tech pubs) provide the data and processes necessary for conducting scheduled and unscheduled, preventative and corrective maintenance tasks on aircraft and related equipment. Tech pubs provide 'checkout' procedures to test whether a system is serviceable or unserviceable. For unserviceable systems, tech pubs provide 'fault-finding' information to identify the particular part requiring replacement or adjustment. The procedures to remove, install, and adjust parts are also contained within tech pubs. Theory of operation information is provided to aid the maintainers' understanding of the system and better support their ability to fault-find.

4. Unless tech pubs are correct, comprehensive, understandable and accessible, the potential will exist for incorrect maintenance leading to an accident or significant aircraft damage. At a minimum, maintenance time and effort will increase, affecting aircraft availability and the cost of ownership. This has a direct effect on ADF airpower capability.

5. **Scope.** This paper will describe the shortcomings of current hardcopy tech pubs before providing an overview of Interactive Electronic Technical Manuals (IETMs) and the five IETM levels. IETM benefits and implications to maintenance capability will be examined from the perspective of the maintainer and sponsor. Potential opportunities arising from interfacing IETMs with related logistics and maintenance systems will also be examined. This paper will then analyse the cost/benefit balance of introducing IETMs for new aircraft systems and for aircraft systems already in service. This paper will conclude by recommending an appropriate strategy for the introduction of IETMs to the ADF.

Aim

6. The aim of this paper is to propose the most effective method of providing technical information to the ADF's aerospace technicians.

HARDCOPY PUBLICATIONS SHORTCOMINGS

7. Traditionally, tech pubs have been paper-based. Using a text-based format with supporting diagrams, figures and schematics, tech pubs have tables of contents and a structured format to aid readability. They have a number of shortcomings in the aircraft maintenance environment that increase maintenance time and increase the risk of maintenance errors.

Maintainer perspective

8. **Bulk.** Tech pubs can comprise hundreds of volumes for a modern complex aircraft. F/A-18 operational maintenance requires more than 100 tech pubs.³ Most maintenance venues need multiple copies of each publication. Thus tech pubs consume a lot of storage space. For the ADF, the bulk of tech pubs required for maintenance impacts on operational deployability: F/A-18 deployments require half a pallet load of tech pubs.⁴

9. **Finding and comprehending information.** The sheer bulk of information in tech pubs can make them difficult to use. Often maintainers need to access multiple pages or volumes to gain the required information, spending as much as 40 to 50 per cent of their time searching for information. The more complex the equipment and the less repetitive the task, the more time typically is spent researching.⁵ Tech pubs have limited search mechanisms: a table of contents and a consistent structure often the sole means. Formal training is often needed just to instruct maintainers how to use the publications.

10. **Version control.** Significant time is expended incorporating pub updates and auditing the amendment status of tech pubs. Incorporating amendments are often considered a punishment and are often not done in a timely manner or with due care. These problems, and the resultant risk to correct maintenance, have been issues at ADF Airworthiness Boards.⁶

11. **Timeframe addressing errors or improvements.** The technical publication improvement process often exhibits large delays before identified errors or improvements are addressed. These delays may result in maintainers adopting unauthorised maintenance practices. Some of these practices may be invalid and error inducing. Routine amendments to Hornet tech pubs have averaged over 4 years from when a publication improvement request has been raised to when the amendment is issued.⁷

12. **Different aircraft configurations.** Complex aircraft types normally include configuration variations due to role differences, production variations, and differences in modification status. Catering for these aircraft configuration variations increases the complexity in the tech pubs and therefore increases the risk that the maintenance will be conducted for an incorrect configuration.

Sponsor perspective

13. **Cost and timeliness to initially author.** Significant resources are required to initially author tech pubs with a large effort required to translate design data to useable maintenance information. Tech pubs are often on the critical path for fielding new equipment, as the authors need to wait until the design is frozen. Coupled to the high cost of development are large printing and distribution costs.

14. **Cost and timeliness to sustain.** Significant resources are also required for updates to reflect changes to the aircraft or support equipment configuration, to improve the effectiveness or efficiency of the maintenance procedures, and to correct errors. Even a simple change can affect many technical

publication sections or volumes. Thus updates are not only manpower intensive but also introduce the risk of creating inconsistencies and introducing errors.

What is an IETM?

15. Integrated Electronic Technical Manuals (IETMs) are digital technical manuals prepared using an automated authoring system, and are designed for electronic display. IETMs have been developed to overcome some of the paper-based pub deficiencies, and possess the following characteristics:

- a. The format and style of the presented information and the use of features such as scrolling, zooming, colour, motion, and sound are optimised to assure maximum comprehension.
- b. The elements of technical data constituting the IETM are interrelated so that a user's access to the required information is facilitated to the greatest extent possible by a variety of paths.
- c. The computer controlled display device functions interactively to provide procedural guidance, navigational directions, and supplemental information.⁸

16. IETMs have been separated into five classes as shown in Figure 1 below.⁹ Class 1 IETMs are basically electronic versions of paper-based tech pubs: this class possesses limited navigation tools. Class 2 IETMs provide electronically scrolling documents with navigation (usually through hypertext). Class 3 IETMs are linearly structured documents with significant use of hyperlinks, hypermedia and multimedia. Class 4 IETMs are based on hierarchical structured databases and are defined by three US Military Specifications: MIL-M-87268, MIL-D-87269, and MIL-Q-87270.¹⁰ Class 5 IETMs build on Class 4 by utilising expert systems, artificial intelligence and integrated system diagnostics.

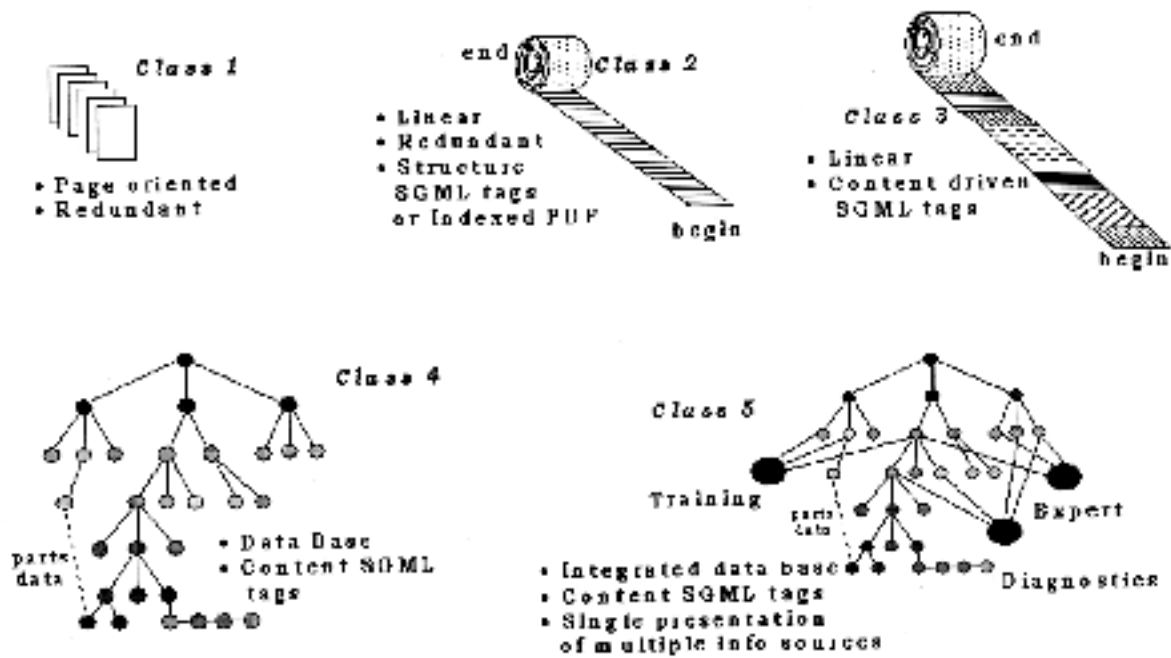


Figure 1: IETM Classes

17. IETMs usually need to be hosted on portable electronic devices (PEDs). Although they can be hosted on desktop computers, this does not enable collocating the electronic information with the maintenance task. Portable electronic devices that have been used or trialed include notebook computers, flat panel displays, personal digital assistants (PDAs), and computer-embedded work vests. Displays have not only included those associated with the PEDs above, but also wrist and head mounted displays. Input devices have included keyboards, touch screens, and voice recognition.

IETMs—MAINTAINER PERSPECTIVE

18. IETMs offer a number of benefits from a maintainer perspective. These benefits are why IETMs are being adopted not only within the military aerospace environment but also within civilian airline and automobile maintenance environments. These benefits are discussed in the following paragraphs.

Benefits

19. **Bulk.** IETM data are significantly less bulky than paper-based tech pubs. For example, the documentation for the F/A-18 consists of 30,000 pages and requires 68 cubic feet of storage space when printed on paper, compared to the 0.04 cubic feet the same information takes up when stored on a CD-ROM.¹¹ Thus, storage and deployment requirements are significantly eased.

20. **Finding and comprehending information.** The main advantage offered by IETMs is that information can be accessed and comprehended faster. Access time is reduced through the use of hyperlinks and having the information contained on one device vice many hardcopy volumes. Comprehension is aided through the ability to present information using a wider variety of means. For example, step-by-step written instructions for removing and replacing a part can be supported by videos of 3D models with voice overlays. Comprehension of wiring diagrams can be improved by highlighting wires of interest with a cursor.

21. The increased ability to access and comprehend maintenance information translates into faster maintenance with fewer errors.¹² Boeing has identified that Class 4 IETMs coupled with an automated maintenance environment have provided a 22 per cent reduction in F/A-18 operational maintenance man-hours and a 73 per cent reduction in false removals at the intermediate maintenance level.¹³ The use of expert systems in Class 5 IETMs has the potential to further increase productivity by restructuring troubleshooting information progressively based on the results of earlier steps.

22. **Version control.** Better control of the revision status is offered by IETMs. A maintainer may only need to insert a new CD-ROM instead of having to remove and replace pages or manuals.¹⁴ Alternatively, automatic updates could be provided via a network.

23. **Different aircraft configurations.** By only providing the maintainer with the information relevant to the configuration being maintained, IETMs can mitigate the risks associated with catering for multiple configurations.

Implications

24. **Cultural impact.** Although IETMs offer a number of benefits to the maintainer, there are a number of implications that need to be considered. Potentially, the key implication is the cultural impact. Maintainers may have spent many years using paper-based tech pubs and may have difficulty adapting to using the new technology. Some maintainers being introduced to Class 1 to 3 publications have used IETMS to find the information but then print the information out to refer to when conducting

the maintenance task. Early 1990s studies of electronic media indicated that up to one third of users complained that it was not as convenient as paper.¹⁵

25. **Hardware requirements.** Although the bulk and cost for the electronic data is minimal, it can be a different case when considering the hardware requirements. How many PEDs are required at each maintenance venue: one for each maintainer? Do these PEDs become just as bulky as hardcopy tech pubs for deployments? Should ruggedised or commercial units be procured: a cost versus reliability trade-off? How will the PEDs be kept charged? How will PEDs be connected into a network if required or desired? If wireless connections are used, then what are the electromagnetic interference issues with ordnance and electronic equipment and what are the security implications?

26. **Display limitations.** There are also limitations associated with the PED displays. Studies have found that reading from a computer screen can be 30 per cent slower than from paper, although the difference can be significantly reduced when advanced anti-aliasing fonts are used. Studies also indicate that smaller screen sizes increased reading and comprehension times. The impact on comprehension times is likely to be worse when viewing complex diagrams or schematics. Reading electronic displays in outdoor conditions can be problematic, especially in harsh sunlight.

27. Trials using head-mounted displays found that the headsets were awkward and keeping the display in the right location for viewing required constant attention. In addition, looking at the display for any length of time became uncomfortable.¹⁶

IETMs—SPONSOR PERSPECTIVE

Benefits

28. **Reduced initial authoring costs.** IETMs not only provide benefits to the maintainer, they also provide benefits to the sponsor or author. A key benefit is a reduction in the initial authoring costs, especially for Class 3 and higher IETMs, by enabling significant re-use of design data including three dimensional (3D) computer-aided design (CAD) drawings, build instructions, and photos of prototypes or initial production items. Further savings are realised by being able to load data once, but then using the data many times throughout the document suite. As an example of the potential savings, Boeing has identified a 7 per cent reduction in initial authoring costs due to Class 4 IETM for F/A-18E/F operational level maintenance tasks.¹⁷

29. **Catering for different configurations.** IETMs can enable the author to identify all the configurations (and different fleets) of the maintained equipment and ensure that configuration differences are correctly catered for. Thus, common maintenance processes do not need to be duplicated for each configuration in an IETM, yet procedural differences due to configuration are readily identifiable. This further reduces the costs of generating technical manuals for multiple fleets and configurations.

30. **Reducing critical path impacts.** By re-using design data and maintaining links to the source material, changes to a design arising from prototyping and first article testing can be incorporated into an IETM much quicker than for a hardcopy technical publication set. This can reduce the probability that the technical manuals will have a significant influence on the critical path of a project.

31. **Reduced distribution costs.** Not only can IETMs reduce the initial authoring costs, they can also reduce the initial and sustainment distribution costs. A single CD-ROM costs significantly less to burn and dispatch than a hardcopy volume, yet that same CD-ROM has the capacity to contain the equivalent of many hardcopy volumes.

32. **Reduced effort to update.** Further cost savings can be realised when generating updates as authors may only need to change the data in one area but the data is then automatically updated in many places. IETMs also improve the ability to locate all affected areas of data, further decreasing the time required to incorporate a change. Expert systems in Class 5 IETMs may even offer the ability to update troubleshooting information automatically based on actual faults found in the field. As an example of the potential savings, Boeing has identified a 36 per cent reduction in sustainment authoring costs due to Class 4 IETM for F/A-18E/F.¹⁸ This reduction in effort reduces the turnaround time for updates.

33. **Reduction in introduction of inconsistencies and errors.** When authoring updates, the risk of creating inconsistencies and introducing errors is likely to be reduced by using IETMs. For Class 4 and higher IETMs, information objects are created once, but used many times in the same product and multiple products.

34. **Reduction in distribution time.** The time taken for updates to be fielded can be significantly reduced through IETMs. Providing updates to maintenance venues via a replacement CD or via a network can result in the amendments being incorporated, and used, without delay. Electronic updates via a network can also enable auditing confirming that maintainers have the current authorised version.

Implications

35. **Publishing software and authoring skills.** Although IETMs offer the sponsor or author a number of benefits, there are a couple of implications. IETM may increase the authoring, graphics, and multimedia skills required. With the broader range of options available for presenting information, authors may need greater education as to which presentation options are most effective for the particular maintenance task being covered. The authors will also need to become familiar with IETMs software programs. Programs that are, at this stage, likely to be proprietary to companies in the business of developing or sustaining tech pubs.

IETMs AND RELATED SYSTEMS

36. The above sections have considered the benefits and implications to maintainers and sponsors when fielding IETMs as a replacement for hardcopy tech pubs. However, IETMs also provide opportunities for integration with other maintenance and logistics systems. These opportunities arise as the maintainers have ready access to PEDs (Personal Electronic Devices) and due to the database/digitised format of IETMs. This section will briefly address four related systems that may benefit from integration or interfacing with IETMs: the logistics, maintenance management, engineering and training systems.

37. **Interface—logistics.** By having an interface into the logistics system available on the IETM PEDs, the maintainers could order replacement parts whilst still at the aircraft rather than having to cease work and walk over to the supply section. The maintainers could also interrogate the logistics system to determine the availability and estimated delivery time for the part, supporting a decision as to whether to carry forward the unserviceability, remove the aircraft from the flying program, or keep working on the aircraft.

38. **Interface—maintenance and engineering management.** Interfacing the IETM PEDs with the maintenance management system could aid maintenance planners by providing current aircraft serviceability status, the assignment of work to maintainers, and the ability for maintainers to certify

maintenance as completed whilst at the aircraft. Additionally, technical information contained on worksheets can be linked to the IETMs such that any updates to an IETM procedure are automatically reflected in updates to the worksheets. Interfacing the IETM PEDs with the engineering management system could improve the timeliness of submitting requests to improve or correct IETM procedures, submitting requests for non-standard repairs, or for submitting defect reports.

39. **Training system.** IETMs can be used as part of the formal technical training package either in the format as used during maintenance or by linking IETMs data into a computer based training package. This can realise savings in developing and maintaining the training package in addition to providing opportunities to decrease formal training and increase automated on-the-job training. Harvey indicates that IETMs can shorten training by 25 to 50 per cent depending on the curriculum whilst simultaneously improving class average scores.¹⁹

40. **Administrative system.** Whilst not so much an interface with IETMs, the use of PEDs provides the opportunity to provide connectivity to the administrative network, the Defence Restricted Network (DRN). Currently, many maintainers at the tradesman and trade supervisor level do not have ready access to the DRN and are not aware of many instructions and information promulgated via the DRN.

41. **Implications.** There is the potential to realise many opportunities by interfacing IETMs and their hosts PEDs with related maintenance and logistics systems, however many of these opportunities heavily rely on the use of wireless connectivity between the PEDs and the other systems. Wireless connectivity raises concerns with respect to security and electromagnetic interference with aircraft systems.

COST/BENEFIT ANALYSIS

42. Having considered in earlier sections what potential benefits and implications IETMs provide to maintainers, sponsors and related engineering and logistics systems, this section will analyse the cost/benefit balance of introducing IETMs to the ADF's aircraft maintenance environment. Three scenarios will be analysed for introducing IETMs:

- a. with the introduction to service of a new aircraft system where the ADF is not the lead customer and the lead customer has specified (or is using) IETMs;
- b. with the introduction to service of a new aircraft system where the ADF is the lead customer; and
- c. replacing hardcopy tech pubs for an aircraft system already in ADF service.

New Aircraft System—ADF not lead customer

43. For the scenario of a new aircraft system where the ADF is not the lead customer, the Joint Strike Fighter (JSF) will be considered. The United States and Lockheed Martin intend to provide IETMs (Class 4 or higher) that are highly integrated with the JSF's engineering, maintenance management, supply, and operational planning systems.²⁰

44. By accepting IETMs, the ADF will realise the following benefits from a sponsor perspective: reduced initial and sustainment authoring costs (especially as the ADF would only pay a small proportion of the non-recurring development costs), improved ability to cater for aircraft configuration variations, reduced distribution costs and time during both initial and sustainment phases, and a reduction in inconsistencies and errors being introduced during the sustainment period. The benefits of integrating with the engineering, maintenance management, supply, and operational planning

systems will also be realised. The cost of the IETMs publishing software and the development of greater authoring skills will have primarily been absorbed by the lead customers.

45. Maintainers will realise the improved ability to find and comprehend information, reduced bulk overheads, and reduced version control overheads. The cultural impact will arguably be lessened as the maintainers will have no previous experience with the new aircraft system and will be more receptive to the new technical publication system (IETMs). The lead customers should have determined the most appropriate PED hardware and should have adequately addressed EMI and security considerations.

46. If the ADF were to reject the IETM technology and specify hardcopy tech pubs, then they would not realise the benefits detailed in the preceding paragraphs. Hardcopy tech pubs cannot be simply generated from the higher IETM classes, indeed the development effort would substantially be starting from scratch. Therefore, the ADF would incur substantial costs to develop and maintain hardcopy publications as amortisation of the non-recurring costs across multiple (and much larger) customers would not occur. The author considers that these increased costs would be significantly more than the costs associated with the PED hardware. This additional development effort may also have critical path impacts for the introduction to service of the new aircraft system.

47. Considering the above paragraphs, it is evident that the ADF should adopt IETMs for new aircraft systems where the ADF is not the lead customer and the lead customer has specified (or is using) IETMs. The ADF will need to ensure that the PED hardware requirements, cultural impact, and security considerations are adequately addressed as part of the transition strategy.

New Aircraft System—ADF lead customer

48. For the second scenario, a new aircraft system where the ADF is the lead customer will be considered. By specifying IETMs, the ADF would likely realise the following benefits from a sponsor perspective: reduced initial and sustainment authoring costs, improved ability to cater for aircraft configuration variations, reduced distribution costs and time during both initial and sustainment phases, and a reduction in inconsistencies and errors being introduced during the sustainment period. If the contractor responsible for developing the IETMs did not have a proven record, then the potential for cost savings would need to be offset against the cost of procuring the IETMs publishing software and the risk that the contractor may not achieve the savings due to inexperience. The potential for cost savings will also need to be offset against the cost of procuring and maintaining the PED hardware.

49. Maintainers will realise the improved ability to find and comprehend information, reduced bulk overheads, and reduced overheads in maintaining the current version. The cultural impact will arguably be lessened as the maintainers will have no previous experience with the new aircraft system and will be more receptive to the new technical publication system (IETMs).

50. The ADF would need to consider the cost and benefits of integrating the IETMs with the engineering, maintenance management, supply, and operational planning systems. The ADF will need to determine the most appropriate PED hardware and address EMI and security considerations.

51. Considering the above paragraphs, there is not a clear argument for specifying IETMs with a new aircraft system where the ADF is the lead customer. The ADF should obtain proposals from potential contractors for IETMs versus hardcopy tech pubs. The ADF should then use these proposals to conduct a more detailed study of the potential cost savings (initial and sustaining), risks, and risk mitigation strategies before deciding whether or not to introduce IETMs. The author intuitively believes that, for a new aircraft system where the ADF is the lead customer, IETMs should be pursued with appropriate risk mitigation strategies employed.

Existing aircraft system with hardcopy publications

52. For the third scenario, an existing aircraft system in ADF service with hardcopy tech pubs will be considered. By pursuing IETMs, the ADF is likely to realise the following benefits from a sponsor perspective: reduced sustainment authoring costs, improved ability to cater for aircraft configuration variations, reduced distribution costs and time during both initial and sustainment phases, and a reduction in inconsistencies and errors being introduced during updates. Actual savings during the sustainment period will depend on the residual life-of-type for the aircraft system and the expected amount of change required to cater for aircraft system modifications, procedural improvement and procedural correction.

53. The ADF, however, will need to fund the initial IETMs development, a significant cost especially where the original design documents and tech pubs have not been digitised. Harvey indicates that the cost of converting legacy data is class \$US10–20 per page for IETM Class 3 and \$US40–100 per page for IETM Class 4.²¹ The cost of initial development may be reduced if other customers also adopt IETMs, however any potential cost reductions will depend on the extent of configuration similarity between the ADF's and the other customer's aircraft.

54. Additional to the cost of developing the IETMs, will be the cost of procuring and maintaining appropriate PED hardware. The ADF will need to determine the most appropriate PED hardware and addressed EMI and security considerations.

55. Maintainers will eventually realise the improved ability to find and comprehend information, reduced bulk overheads, and reduced overheads in maintaining the current version. However, this scenario presents the greatest cultural impact as many maintainers will be familiar with the aircraft systems' existing hardcopy tech pubs. Their productivity is very likely to be reduced rather than increased in the early stages of introducing IETMs. This is likely to engender negative attitudes towards the IETMs that will impact effective implementation and full realisation of the potential benefits.

56. This scenario is unlikely to result in any substantial integration with the existing engineering, maintenance management, supply, and operational planning systems. Thus any benefits in these areas will not be realised.

57. Considering the above paragraphs, the author believes that the potential benefits arising from IETMs are unlikely to offset the costs associated with their introduction for aircraft systems already in ADF service. The ADF should not consider introducing IETMs, except where another (significantly larger) customer has funded IETMs development for an aircraft system of very similar configuration to the ADF's, both the other customer and the ADF have similar upgrade plans for their aircraft systems, and the ADF's aircraft system has a significant life-of-type remaining. Any consideration would need to be supported by a refined costing model.

Conclusion

58. Aircraft maintenance has a significant impact on sustaining the ADF's airpower capability in terms of availability, technical airworthiness, and cost of ownership. Effective maintenance requires competent maintainers with access to appropriate technical tooling, data and processes. Technical publications provide the data and processes.

59. Traditionally, technical publications have been paper-based and have shortcomings that increase maintenance time and maintenance errors. From a maintainer perspective, these shortcomings

are bulk, finding and comprehending information limitations, version control overheads, excessive timeframes for addressing errors and improvements, and complexity in catering for different aircraft configurations. From a sponsor perspective, the shortcomings are the cost and timeliness to initially author and sustain.

60. IETMs have been developed to overcome some of the paper-based technical publication deficiencies that impact on airpower capability. IETMs are technical manuals prepared in digital form and designed for electronic window display to the maintainer. IETMs have been separated into five classes starting at basic digital representations of the paper-based technical publications extending through to hierarchical structured databases with significant use of hyperlinks, hypermedia and multimedia, and incorporating expert systems, artificial intelligence and integrated system diagnostics.

61. IETMs offer a number of benefits from a maintainer perspective including reduced bulk, improved ability to access and comprehend information which translates into faster maintenance with fewer errors, better revision control, and improved catering for multiple configurations. There are however implications that include the cultural impact, requisite hardware requirements, display limitations and connectivity issues relating to electromagnetic interference and security.

62. IETMs also offer a number of benefits from a sponsor perspective including reduced initial and sustainment authoring costs, improved ability to cater for aircraft configuration variations, reduced distribution costs and time, and a reduction in introduced inconsistencies. There are implications with respect to publishing software and authoring skills. IETMs also offer productivity benefits through integration with engineering, maintenance management, logistics, training, and administrative systems.

63. Cost/benefit analysis indicates that IETMs are cost effective and will improve airpower capability for new aircraft systems where the ADF is not the lead customer and the lead customer has specified (or is using) IETMs. For a new aircraft system where the ADF is the lead customer, the cost/benefit balance is not so certain and therefore a more detailed study of the potential cost savings, risks, and risk mitigation strategies would need to be conducted before deciding whether or not to introduce IETMs. The author intuitively believes that IETMs are cost effective subject to the employment of appropriate risk mitigation strategies. For aircraft systems already in ADF service, the cost/benefit analysis indicated that the potential benefits arising from IETMs are unlikely to offset the costs associated with their introduction.

RECOMMENDATIONS

64. This paper recommends that the ADF should:
- a. pursue IETMs for new aircraft systems where the ADF is not the lead customer and the lead customer has specified (or is using) IETMs;
 - b. pursue IETMs for any new aircraft systems where the ADF is the lead customer subject to a more detailed study of the potential cost savings, risks, and risk mitigation strategies; and
 - c. not pursue IETMs for aircraft systems already in ADF service, except where the ADF's aircraft system has a significant life-of-type remaining, another customer has already funded IETMs development, and both the other customer and the ADF have similar upgrade plans.

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