National Defence Défense nationale

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RELIABILITY, MAINTAINABILITY AND SUPPORTABILITY OF THE ROYAL CANADIAN AIR FORCE FUTURE FIGHTER CAPABILITY

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JCSP 42

Service Paper

PCEMI 42

Étude militaire

Canada

CANADIAN FORCES COLLEGE – COLLÈGE DES FORCES CANADIENNES
JCSP 42 – PCEMI 42
2015 – 2016

JCSP SERVICE PAPER – PCEMI ÉTUDE MILITAIRE

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Word Count: 2412

Compte de mots: 2412

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AIM

1. A world beating combat aircraft is of little military use if it spends more time on the ground than it does in the air delivering effect. 'Billions of dollars are spent by commercial and military operators every year as a direct consequence of the unreliability, lack of maintainability and poor supportability of the systems they are expected to operate'.[1] The aim of this paper is to propose that to drive down capital and through life costs whilst simultaneously increasing the availability of military capability, reliability, maintainability and supportability (RMS) should be considered as of equal importance to capability when selecting the future fighter aircraft for the Royal Canadian Air Force (RCAF).[2]

INTRODUCTION

2. In the context of military aircraft, reliability is often measured by the Mean Time Between Failure (MTBF) of mission or safety critical components, the greater the MTBF the more reliable the aircraft. Maintainability is often measured by Maintenance Man Hours per Flying Hour (MMH/FH), i.e. how long it takes to fix a fault factored by how often that fault occurs per flying hour. Supportability encompasses the delivery of all necessary components to the front line at the right time to generate a mission capable aircraft. In other words, increased reliability reduces the number of occasions when maintenance is required, improved maintainability reduces the time taken to effect a maintenance activity and optimized supportability ensures that everything required to complete the maintenance activity is available when and where it is needed.[3]

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[1] Dinesh U Kumar, *Reliability Maintenance and Logistic Support: A Life Cycle Approach* (Boston, MA: Kluwer Academic, 2000), 2.

[2] There are a number of different definitions of aircraft availability. For the purpose of this paper an aircraft is considered unavailable if it is not mission capable. An aircraft may be serviceable but if it cannot fulfill its mission it is still considered unavailable.

[3] Dinesh U Kumar, *Reliability Maintenance and Logistic Support*. . ., 2.

3. This paper will begin by proving that the reliability of an aircraft can have a significant impact on the deployed footprint of the force element, in terms of both aircraft numbers and support. It will then demonstrate that improved maintainability can reduce the amount of time an aircraft is on the ground, which in turn increases aircraft availability. Subsequently, this paper will propose that the ability to contract for availability, as an extension to current Performance Based Logistics (PBL) contracting principles, will optimize the supportability of the RCAF's future fighter aircraft. Finally, this paper will conclude that optimized RMS can minimize capital spend and through life costs and should therefore be considered as important as capability when selecting the RCAF's future fighter aircraft.

RELIABILITY

4. Measured by MTBF, unreliable aircraft develop unpredictable faults or predictable faults at an alarmingly short periodicity. To mitigate this they require a significant forward holding of spares and an increased number of personnel to deliver the minimum military output. Conversely, the more reliable the aircraft the less you need assets to guarantee delivery of the effect. In a Defence Research and Development Canada report[4] the future requirement for aircraft in whole numbers is based on a factor of MTBFs equated to a percentage of expected serviceability of the fleet. In the case of the future RCAF fighter aircraft this is estimated at 70%, based on historical data. However, given the improvements in technology it would be reasonable to expect that MTBFs continue to improve in a new design; Table 1 shows how MTBF's have improved since the 1950s.

Table 1 - Improvement of Reliability in Recent Years

	First Flight	MTBF

[4] Defence Research and Development Canada, *Comparative analysis of minimum resource requirements for single and mixed fleets for the national fighter procurement evaluation of options*, http://forces.gc.ca/assets/FORCES_Internet/docs/en/about-reports-pubs/06%2005%20Mixed%20Fleet%20(En)%20-%20final.pdf, accessed 4 February 2016.

Aircraft 1	1958	0.6
Aircraft 2	1974	0.7
Aircraft 3	1977	1.2
Aircraft 4	1994	1.5

Source: Reiss, Detlef, *Amplification of the Benefits of a Reliable and Maintainable Design by Adequate Maintenance and Support Concepts*, DaimlerChrysler Aerospace AG, Oct 1999., Table One 13-2.

5. To put this into context, if the Force Commander's desired military effect requires four aircraft to get airborne:

a. A serviceability rate of 70% will require six mission capable aircraft;

b. A serviceability rate of 80% will require five mission capable aircraft.

For the lower reliability, the necessity to generate an additional aircraft will require more manpower, spares, technical advice and repair, which will incur increased cost in terms of capital spend and through life support.

6. Another example, if Canada's commitment to a NATO operation is six mission capable aircraft:

a. A serviceability rate of 70% will require nine aircraft to deploy.

b. A serviceability rate of 80% will require eight aircraft to deploy.

These figures are again significant as, whilst they don't necessarily affect the aircrew or weapons numbers, they do influence the overall deployment footprint and therefore the cost of any contribution to future operations.

7. The calculations above are simple, however they provide an important indication of the impact of reliability; increased reliability improves serviceability rates, increases aircraft availability and reduces the number of capital assets required to deliver the same military effect. The alternative is more aircraft, increased spares holdings and a large deployed footprint.

MAINTAINABILITY

8. Aircraft that are difficult to maintain spend extended periods of time on the ground awaiting high value spares or specialist technical skills that are not necessarily readily available at the front line; they may require complex, environmentally sensitive testing to clear them for flight. This results in high MMH/FH. Historically, air forces were significantly larger than they are today and employing more resource to complete the task could mitigate the high MMH/FH. In addition, technology was less advanced and therefore easier to manipulate at the operator level. With affordable training and experience the simple fighter aircraft of yesteryear could be hammered, riveted and re-rigged with relative ease. Today, with advances in composite materials and the dominance of software in the control of the aircraft's systems, in order to establish an air force with the capability to manipulate future aircraft in the same way, and therefore mitigate high MMH/FH, would require significant skill growth and a radical change to how engineers and technicians are employed in the military context.

9. The evolution of simplifying maintainability at the front line saw significant advances in the last generation of aircraft with the introduction of the Line Replaceable Item[5]. The concept was that at first line[6] a box could quickly be replaced, the system tested and the aircraft released for flight while the more complex fault rectification inside the box could be completed off-aircraft. A perceived disadvantage of this approach to maintainability was the skill degradation of maintainers at the front line as detailed diagnosis of a fault, to sub component level, was no longer necessary. However, this concept was extremely effective at reducing the time necessary to regenerate an aircraft and endures as a design principle

[5] Referred to as Line Replaceable Unit on some aircraft types
[6] Refers to the level of maintenance: first line is squadron level, second line is more in-depth scheduled maintenance or repair in a bay for off-aircraft components or at an aircraft depth maintenance facility and third line normally refers to return to industry or in a depot.

through the next generation of combat aircraft. Table 2 shows how MMH/FH have improved since the 1950s.

Table 2 - Improvement of Maintainability in Recent Years

	First Flight	MMH/FH
Aircraft 1	1958	57
Aircraft 2	1974	53
Aircraft 3	1977	55
Aircraft 4	1994	24

Source: Reiss, Detlef, *Amplification of the Benefits of a Reliable and Maintainable Design by Adequate Maintenance and Support Concepts*, DaimlerChrysler Aerospace AG, Oct 1999., Table One 13-2.

10. The next step in improving maintainability has been the introduction of in-built health monitoring systems that are combined with integrated logistics systems for automated stock control, fault diagnosis and prediction, and maintenance management. The principle of these systems is similar to the diagnostics run on a modern car: a ruggedized hand held laptop, or similar, plugs into the aircraft at the front line, performs a diagnostic test and tells the maintainer what needs to be replenished or repaired, saving time and further reducing MMH/FH. In a report on *The Effect of Current Military Maintenance Practices and Regulations on the Implementation of Integrated Vehicle Health Management Technology*, published in association with Cranfield University, the authors note:

> Calculating the decrease in maintenance cost and time is crucial to justify the investment on a certain tool. Quantitative methods focus on three main areas: reducing maintenance time using diagnostic tools; deferring jobs until they can be carried out along with other scheduled activities using prognostics; reduce the stock of components and delays by improving logistics.[7]

[7]Manuel Esperon-Miguez, John Philip and Ian K. Jennions, *The Effect of Current Military Maintenance Practices and Regulations on the Implementation of Integrated Vehicle Health Management Technology.* (Cranfield University, 2012), 1.

11. In addition to the diagnostic test the system tracks scheduled maintenance and provides maintenance planners with accurate forecasting for planning preventative maintenance, again saving time and allowing for scheduled maintenance and deferred faults to be rectified when the aircraft is not required for a mission. An example of improved maintainability is F-35, which uses digital tracking for fluids instead of gauges. In addition, Lockheed Martin claim that '. . .flight-control-rigging maintenance now takes 5 min. for the F-35, compared to 8-14 hr. on legacy fighters. . . .'[8] All integrated health monitoring and logistics management systems designed into fourth and fifth generation aircraft are designed to improve maintainability, simultaneously increasing aircraft availability.

SUPPORTABILITY

12. Unsupportable aircraft might be plagued with obsolescence and require a wide range of expensive, difficult to procure specialist tools, training and spares. The unavailability of spares, for example, holds the aircraft on the ground for longer whilst a solution is found; an aircraft held on the ground is an asset wasted. Like reliability and maintainability, supportability has also evolved over time. The introduction of, for example, Performance Based Logistics (PBL) just-in-time spares contracts increased efficiency by reducing forward capital spares holdings and second line repair bays. The challenges to supportability don't go away with technological advances and they are difficult to design out when developing specialist aircraft, such as a combat aircraft. Whilst improved reliability and integrated health monitoring and logistics management systems enhance supportability at the front line, the maintainer still requires the spares, tools, technical data and training to perform the maintenance task.

13. To improve supportability PBL aircraft availability contracts, combined with improved reliability and maintainability have been successfully integrated into the military

[8] http://aviationweek.com/awin/f-35-s-ambitious-new-fleet-management-system accessed 4 February 2016.

support environment. These contracts move up a level compared with just-in-time spares delivery to consider the availability of the aircraft rather than its component parts. The challenge of aircraft level PBL in the military air environment is establishing where the line should be drawn between contracting for capability and maintaining the minimum military footprint necessary for expeditionary operations. There are numerous examples of western militaries opting for capability-based contracts for those aircraft operations that align closest to the civilian aircraft industry, strategic lift for example. However, when it comes to combat aircraft the approach remains conservative with militaries seemingly reluctant to relinquish control of capability delivery to industry.

> One of the main objectives of the Eurofighter program is to cut maintenance and support costs. . . . "You can drive huge efficiencies in support if you align the motivations of the supply chain, making use of its ability to be innovative in support," Raine says. "It lines up very tightly with through-life capability management, helping support the equipment more efficiently and upgrade it as time goes by.". . . ."With mature systems we're taking 30 percent out of support costs. . . .We can make up-front savings by changing how the service is defined. The cost of a weapon system is focused on the support phase rather than the acquisition phase."[9]

14. Another challenge to supportability as a consequence of improved reliability and maintainability is that the next generation fighter technology requires a further reduction in maintenance at the front line. This increases the skill gap between that required to generate an aircraft at first line and that necessary to conduct capability upgrades and depth repair at both the component and aircraft levels. It is therefore increasingly difficult and costly to maintain and retain the engineering skill set necessary to cover the full spectrum of military aircraft engineering for most western air forces. An alternative is to partner with industry, where these skills already reside, and to focus air force maintenance on the generation of first line capability.

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[9] Ian Parker, *Avionics Crown Typhoon Performance: Electronic Systems Make Europe's Latest Fighter a Formidable Opponent*, (Avionics Magazine, Aviation Today, Aug. 2006).

15. Partnering with industry can deliver a number of improvements to the supportability of a modern combat aircraft. The defence industrial base is a vast array of companies, which range from the specialist to generalist. These companies form a network of relationships, commercial and personal, with associated dependencies, and employ people with a lifetime of experience, whether commercial, technical or in project management. Depending on the company's profile, their portfolio typically extends beyond military aircraft and includes research and development from internal and external investment. Establishing a relationship with an industrial partner would offer the RCAF the ability to tap into this network. In addition, if the government establishes the prime contract with a partner they benefit from the companies commercial expertise when letting sub-contracts, further improving supportability of the aircraft.

16. In order to realize the full supportability benefits from contracting with industry it is necessary to pass responsibility, and therefore risk, for output to the company; without doing so it is virtually impossible to incentivize the company beyond the value of the contract. Traditionally, contracts in support of military aviation have typically been cost plus in-service support contracts. For example, a company may be contracted to conduct scheduled maintenance but when emergent work materializes the delivery date for that aircraft will move to the right. This is often as a result of negotiations associated with the quote for the additional repair work and the company has no incentive to take action to solve the scheduling problem. If, on the other hand, the contractor is also locked in to a contract to deliver a certain number of available aircraft they are incentivized to find a solution to the problem, for example delivery of a different aircraft while the issue of the emergent work is resolved. Partnering with Industry for availability based contracting at the aircraft level has the potential to mitigate the impacts of improved reliability and maintainability at the front

line and to realize real savings in through life support costs whilst simultaneously improving aircraft availability.

RELIABILITY, MAINTAINABILITY AND SUPPORTABILITY IN THE CONTEXT OF CAPITAL SPEND

17. The fleet size for the future RCAF fighter aircraft has been reverse engineered from the requirement for thirty-six mission capable aircraft. A 70% serviceability factor has been applied necessitating fifty-two aircraft in the forward available fleet. Further, it has been assumed that 20% of the fleet will be in scheduled maintenance at any one time requiring a further thirteen aircraft to be procured. This has resulted in an approximate overall buy of sixty-five aircraft to generate an average of thirty-six mission capable aircraft.[10] To substantiate these figures, a report conducted by Defence Research and Development Canada, cites http://admpol.mil.ca/newsite/dnatopol-eng.html which estimates that 39–56% of a given RCAF fleet's aircraft are mission ready at any given time.[11]

18. In isolation these figures are meaningless. However, with experience of military aircraft maintenance it would be fair to assume that a significant proportion of the aircraft not available are awaiting manpower, spares, technical advice or repair. In addition, as these figures are historical they will include factors bespoke to aging technology that suffers from fatigue and obsolescence.[12] As the RCAF moves towards a decision on the future fighter aircraft it should consider these figures unacceptable. Indeed, the consortiums that have developed the fighter aircraft that are on the market all placed RMS high on the list of requirements.[13] For example, if the reliability of the new aircraft is designed to exceed 80% then this could reduce the total number of aircraft by up to nine. If there is no requirement for

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[10] Note that these numbers may not be accurate as all sources used to develop this paper have been unclassified.
[11] Defence Research and Development Canada, *Comparative analysis of minimum resource. . .*accessed 4 February 2016.
[12] Dinesh U Kumar, *Reliability Maintenance and Logistic Support*. . ., 4.
[13] https://www.eurofighter.com/the-aircraft; http://www.dassault-aviation.com/wp-content/blogs.dir/1/files/2012/08/Fox_Three_nr_3.pdf; accessed 5 February 2016

scheduled maintenance, as is the design concept for Rafale[14], then this has the potential to reduce the overall aircraft numbers by up to thirteen. In real terms, the benefits of considering RMS as a requirement that is equally important to capability and therefore improving these assumptions will reduce the number of aircraft and the support necessary to deliver RCAF's military effect, both domestically and internationally.

CONCLUSION

19. An aircraft unserviceable on the ground awaiting manpower, spares, technical advice or repair is a capital asset wasted. Without an unlimited budget and an aircraft that is designed and built onshore it is no longer feasible to mitigate the risk of a wasted asset from within the RCAF. Increased reliability reduces the number of occasions when maintenance is required, improved maintainability reduces the time taken to effect a maintenance activity and optimized supportability ensures that everything required to complete the maintenance activity is available when and where it is needed. The requirement to drive down capital and through life costs whilst simultaneously increasing the availability of military capability through RMS should be considered as of equal importance to capability when selecting the future fighter aircraft for the RCAF.

[14] http://www.dassault-aviation.com/wp-content/blogs.dir/1/files/2012/08/Fox_Three_nr_3.pdf accessed 5 February 2016.

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