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DOR(MLA) RESEARCH NOTE RN 2002/12

ASSESSING THE IMPACT OF SPARES REDUCTIONS ON CF-18 OPERATIONS

By

JAY ADAMSSON

NOVEMBER 2002

OTTAWA, CANADA

National Defence | Défense nationale

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ASSESSING THE IMPACT OF SPARES REDUCTIONS ON CF-18 OPERATIONS

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JAY ADAMSSON

Recommended by: P.E. DESMIER, DASOR   Approved by: J. EVANS, DOR (MLA)

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OTTAWA, ONTARIO   NOVEMBER 2002

ABSTRACT

In response to an upcoming reduction in the NP budget for the CF-18 fleet, DASOR was asked to assist in quantifying the fleet impact of a reduction in the repair rate of unserviceable parts. It is believed that the reduction in funds will impose a situation where unserviceable parts are not being repaired to save on costs, resulting in aircraft being down due to a shortage of spare parts. In response to this request, the Reduction of Spares Impact Model (RSIM) was created. This model uses actual failure rates and stockpile levels. Varying the repair rate allows a determination of the impact on the fleet size.

It has been found that at a 90% repair rate (the best estimate based on expert knowledge), a significant impact will begin to be felt by the fleet in mid-2003. The ability of the fleet to sustain a long-term deployment will be jeopardized by mid-2004, and the ability to deploy aircraft at all will be jeopardized by mid-2005.

RÉSUMÉ

En prévision de la réduction des fonds d'approvisionnement national alloués à la flotte des CF-18, on a demandé à la DROFA de participer à la quantification des répercussions qu'une révision à la baisse du taux de réparation des pièces inutilisables aurait sur la flotte. On croit que dans un contexte de compressions budgétaires, on ne pourra réparer certaines pièces inutilisables, ce qui se traduira par des aéronefs cloués au sol faute de pièces de rechange. En réponse à cette demande, on a mis au point le Reduction of Spares Impact Model (RSIM), modèle qui mesure les répercussions de la réduction du nombre de pièces de rechange disponibles. Il est possible, à partir des taux de défaillance et des niveaux de réserve actuels, de déterminer les effets de différents taux de réparation sur la taille de la flotte.

L'étude a révélé qu'avec un taux de réparation de 90 p. 100 (l'estimation la plus réaliste selon des spécialistes), des répercussions importantes commenceront à se manifester au milieu de l'année 2003, la capacité de la flotte de soutenir un déploiement à long terme sera compromise d'ici la moitié de l'année 2004 et la possibilité même de déployer un aéronef sera incertaine d'ici le milieu de 2005.

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ASSESSING THE IMPACT OF SPARES REDUCTIONS ON CF-18 AIRCRAFT

1 – Introduction

1. In September 2002, the Director of Aerospace Equipment Program Management (Fighters and Trainers) was directed to reduce the National Procurement (NP) budget allocation for CF-18 support by $50M per year, effective immediately. Since the NP budget was slightly under $200M, this reduction represented slightly more than 25% of the budget. Staff were given a week to assess the expected impact of this reduction on the fleet.

2. One of the significant components of the NP budget involves the repair of aircraft that have been declared unserviceable. When an item is found to be defective within an aircraft, it is removed and replaced, and the defective part is then taken for repair. Often, the part is shipped to maintenance facilities off the wing.

3. With the implementation of the planned reductions in funds, these repair activities will be one of the areas that will be curtailed. For the short term, this will mean relying more heavily on existing stockpiles of spares for the aircraft, in place of paying for the repair of defective parts. The expected result would be a subsequent lowering of stockpiles. When the stockpiles are exhausted, the only way to keep aircraft flying is to cannibalize other aircraft, thereby effectively removing those aircraft from the fleet.

4. An initial estimate, based on experience, was that this reduction would lead to the grounding of up to thirty aircraft over the next two years due to a shortage of spares. However, this estimate was based on the experience of the officers in the headquarters staff, and not through a rigorous analysis. The Director Air Staff Operational Research was asked to assist in quantifying the impact on the operational fleet of a reduction in spare repair activity. In particular, as the rate of repair decreases, how does the rate of cannibalization increase?

5. A model was created that considers the list of CF-18 parts with frequent breakdowns. The mean time between replacement (MTBR) and existing quantity of spares were combined in a Microsoft Excel @Risk model to simulate the spares requirement on a monthly basis until the end of March 2005. The resulting Reduction of Spares Impact Model (RSIM) predicts the loss of aircraft in the CF-18 fleet. When combined with outputs from the Air Force Structure Analysis (ASTRA) model [1], the impact on operational capability can easily be derived.

2 – Spares System Description

6. The RSIM model is based on a simple model of spares management of the CF-18 fleet. When an aircraft becomes unserviceable, the Weapon Replaceable Assembly (WRA) identified as the problem is removed. If another item is available in the supply system, this is placed in the aircraft and the aircraft is returned to service immediately.

7. The WRA removed from the aircraft is taken to a repair facility, where the problem is diagnosed. If some sub-component (called a Shop Replaceable Assembly, or SRA) of the item is found to be at fault, that sub-component is replaced and the WRA is returned to the supply system. If no fault can be identified, the entire item is replaced. The WRA is then sent to further repair facilities (in most cases to a contractor) or discarded.

8. When there are no available spares in the supply system, the only place to obtain working spares is from other aircraft. In cases where a spare is needed, and an aircraft is already unserviceable for other reasons, that aircraft can be robbed, with the intention of replacing the part when more spares become available. Robbing an aircraft is an undesirable procedure for two reasons: First, it removes an aircraft from service for a longer period of time; second, the time for maintenance doubles because now a single breakdown means removing and replacing the part from two aircraft instead of just one.

9. Returning an unserviceable part to a supply depot, and especially to a contractor, is an expensive procedure. It is anticipated that the reduction of budgets will have an impact on this process. The result is that not all the parts removed from aircraft will be repaired. There will instead be a backlog of parts that are unserviceable, but are not even considered for repair. Unless and until further funds are found, this has the same operational impact as discarding an unserviceable part.

3 – Model Description

10. The model simulates the system over a number of months. At the start of the simulation, the number of aircraft and the number of spares are input. Let $A(0)$ be the number of aircraft available at the start of the simulation. If there are k parts to be modelled, let $S_i(0)$ be the quantity of part i in the system at the start of the simulation.

11. The monthly impact is now calculated iteratively. Let m designate a future month. For each month, there is a flying rate assigned to the fleet, denoted by $Y(m)$. In addition, each part has a Mean Time Between Replacement (MTBR), denoted by F_i for the i^{th} spare. Given that there are n_i copies of part i on each aircraft, the expected number of breakdowns across the fleet during the month is given by

$$\frac{Y(m) * n_i}{F_i} \qquad (1)$$

The actual number of breakdowns $B_i(m)$ is determined randomly using a Poisson distribution with mean as given in equation (1).

12. Once the number of breakdowns is determined, the next step is to determine how many are repaired and how many are either discarded (cannot be repaired) or stored for repair at some future point, as a result of budget reductions. Note that for modelling purposes, it does not matter whether a part is discarded or stored for future repair. The net effect is that it is taken out of the supply system and not used again. For each part, let p_i be the probability that the part is repaired and returned to the supply system. Let $R_i(m)$ represent the number of parts repaired and returned to the supply system. The value of $R_i(m)$ is determined randomly using a binomial distribution with $B_i(m)$ events and p_i probability of success.

13. The number of spares available for month *m* can now be calculated as

$$S_i(m) = S_i(m-1) - B_i(m) + R_i(m-1) \qquad (2)$$

This is the sum of the spares available from the previous month, minus the number of breakdowns for the month, plus the number of repairs from the previous month (it is assumed that there is a one-month elapsed time to repair a part and return it to the supply system). Note that this number can become negative once the spares in the system are exhausted and further breakdowns occur.

14. The number of aircraft grounded because of lack of spares can now be calculated. Define

$$S(m) = -\min\left\{0, \frac{S_1(m)}{n_1}, \cdots, \frac{S_k(m)}{n_k}\right\} \qquad (3)$$

This value is the number of aircraft that are rendered unserviceable due to spares shortages. The number of aircraft that are down depends on the smallest of these numbers (i.e.: the most negative number) since it is assumed that once an aircraft goes down, it will in effect become a "parts bin" and will be robbed to keep other aircraft in the fleet serviceable.

15. Finally, the number of aircraft available at the end of each month can be calculated as

$$A(m) = A(m-1) - S(m) \qquad (3)$$

where $A(m-1)$ represents the number of aircraft available from the previous month. This process is then repeated for each month until the desired length of time has been reached.

16. The model has been implemented in a Microsoft Excel spreadsheet using Palisade Corporation's @Risk software. Figure 2 shows a screen shot of the implementation of the model over a one-year period.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	16000		Oct-02	Nov-02	Dec-02	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03
2	0 9	YFR/Mo	1333 333	1333 333	1333 333	1333 333	1333 333	1333 333	1333 333	1333 333	1333 333	1333 333	1333 333	1333 333
3		AC	80	77	77	77	77	77	76	76	75	75	74	74
4		YFR/AC	16 66667	17 31602	17 31602	17 31602	17 31602	17 31602	17 54386	17 54386	17 77778	17 77778	18 01802	18 01802
5														
6	1	**43Z000000**	**Detecting Set AN/AAS-38B System. DETECTING SET AN/AAS-38B**											
7		New Spares	12											
8		Spares	12	11	10	9	8	7	6	5	4	3	2	1
9		MTBR	197 2765											
10		Failures	7	7	7	7	7	7	7	7	7	7	7	7
11		Ramaining	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6
12		Num Robs	0	0	0	0	0	0	1	1	1	1	1	1
13		Parts Per AC	1											
14		Consider Pctg	0 9											
15		Repair Rate	1											
16		Months to Repair	1											
17		AC Down	0	0	0	0	0	0	1	2	3	4	5	6
18														
19														
20	2	**43D0B0000**	**Radar System Airborne APG-65 RECEIVER, EXCITER RADAR R-2089/APG-65**											
21		New Spares	16											
22		Spares	16	15	14	13	12	11	10	9	8	7	6	5
23		MTBR	213 8196											
24		Failures	6	6	6	6	6	6	6	6	6	6	6	6
25		Ramaining	10	9	8	7	6	5	4	3	2	1	0	-1
26		Num Robs	0	0	0	0	0	0	0	0	0	0	0	1
27		Parts Per AC	1											
28		Consider Pctg	0 9											
29		Repair Rate	1											
30		Months to Repair	1											
31		AC Down	0	0	0	0	0	0	0	0	0	0	0	1
32														

Figure 2: Implementation of RSIM model

17. The number of aircraft available each month is given in row 3. For each aircraft part (of which only two are shown in this figure), the first line is the number of spares in the system. If additional spares are coming into the system at a later point, they can be entered into this line as well. The second row is the number of spares left in the system each month. The third line is the MTBR for the part. Next is the number of failures for each month, determined randomly as described earlier. The next row is the remaining number of parts in the supply system. Note that in this example, the number of parts remaining eventually becomes negative, meaning that existing stocks have been exhausted and aircraft must now be robbed to keep the fleet operational. The next row is the number of robs that occurs in the month (which is not used in this implementation, but has been included for later use in determining the added maintenance hours required with these reductions). The number of parts in each aircraft is given in the next row.

18. The next two rows are used to determine the repair rate. The "Consider Pctg" is altered by the user of the spreadsheet and represents the percentage of parts that are removed from the aircraft and stored. The "Repair Rate" is taken from actual historical

values and represents the percentage of parts that historically can be repaired and returned to the system. The multiple of these two rows gives the value of p_i as described earlier. Finally, the months to repair each part and return it to the supply system is included (set to one for this implementation), and finally, the number of aircraft that are down as a result of shortages for these parts is given.

19. The list of parts in the model consists of both WRAs and SRAs. Because of the number of parts, the list was first reduced to those spares most likely to be exhausted. Using the MTBR and existing spares, the probability of exhausting spares was calculated, and those with a greater than 50% probability of being exhausted were used. The MTBR values were obtained from Bombardier [2], while the existing spares data was pulled from the Canadian Forces supply system.

4 – Results

20. The main results are captured in Figure 3 below. This is the result of running the simulation for approximately two and a half years (from Oct 02 to Mar 05). Various repair rates from 80% to 100% were considered. Five hundred iterations of the model were conducted, and the results were compiled to produce expected numbers of aircraft down, as well as best- and worst-case scenarios. Various repair rates from 80% to 100% were considered. As can be seen, a reduced repair rate has little effect by the end of the current fiscal year (Mar 03). After that point, reductions start to have a greater effect. The initial fleet size of 80 aircraft has been reduced by between eight and twenty by Mar 04, and by nine to 35 aircaft by Mar 05.

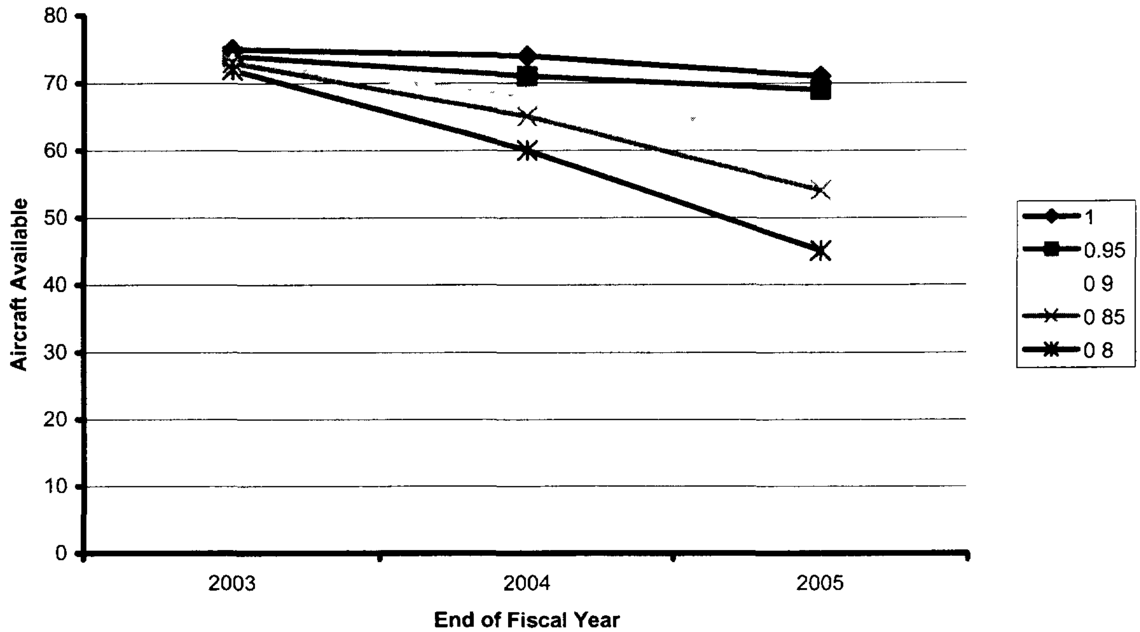

Figure 3: Aircraft Availability For Various Repair Rates (16,000 YFR)

21. Initial estimates place a probable repair rate at 90% given the impending budget restrictions. This corresponds to the centre line on the graph, and a reduction of 18 aircraft by Mar 05. Further study of the @Risk results reveals that on 90% of the runs, the number of aircraft was reduced by between 14 and 23 aircraft. Thus, the best-case scenario is that only 14 aircraft are lost, and the worst-case is that 23 aircraft are lost, giving an effective fleet size of between 57 and 66 aircraft.

22. With a few assumptions, ASTRA can now be used to predict the impact of this loss on fleet capabilities. Assuming a continuation of the current ASA commitment, and a daily availability remaining consistent with current values (not including aircraft not available due to robbing), the numbers of aircraft required to meet commitments can be determined. Maintaining the capability of sustaining a long-term deployment of six aircraft requires a fleet size of at least 66 aircraft. It is expected that this capability would be lost by mid-2004, and no later than March 2005. If a sustained deployment is not considered, a short-term deployment (no more than six months) of twelve aircraft requires 69 aircraft. It is expected that this capability would be lost by Mar 2004, and no later than early 2005. Having the capability to deploy six aircraft on a short-term deployment requires 57 aircraft. This capability should be maintained well into 2005, although even this small deployment will be in jeopardy past that point.

5 – Impact and Recommendations

23. The results obtained using this model were briefed to the Aircraft Management Committee Secretariat. The initial estimate of 30 aircraft removed from the fleet due to spares shortages was shown to be too high, and better estimates were forwarded based on the model results.

24. It was pointed out that the level of analysis of the model remains at a simple level, and does not account for many aspects of the current supply system, nor does it yet consider possible mitigating effects due to better management or changed policies. There is a desire to expand the model to take some of these factors into account.

25. The model, both as it stands currently and with future enhancements, will be used on a regular basis (currently envisioned as being run quarterly) as spares levels change. This will also permit the validation of the model against real-world results, and suggest modifications to improve the model's fidelity.

26. A number of immediate areas of enhancement were identified. Most of these areas are not long term projects, and can be added to the model without major modifications:

a) Improve the relation between WRAs and SRAs in RSIM;

b) Permit the specification of repair rates for each spare instead of using a global rate (the model currently uses a single repair rate, and applies it to all the parts in the system);

c) Model the various levels of diagnostic and repair instead of using a single repair level, including various times for returning the spare to the supply system;

d) Perform calculations by wing instead of for the entire fleet;

e) Allow changes in replacement rates by FY to account for changing budget levels from year to year;

f) Include repair and rob costs;

g) Include analysis to determine an optimal strategy for allocation of resources towards items to repair or commodities to purchase.

27. There are other implications on aircraft availability that have not been modeled with RSIM, but are worth consideration. First, the connection between replacement rates and funding levels has not been established. For RSIM, this is passed over by running

the model for various replacement rates, and making the assumption that the resultant replacement rate will be within the values modelled. This is a critical connection in understanding the impact of reduced budgets that has not been explicitly modelled.

28. Secondly, the increased maintenance time required to perform robs has been mentioned, but was not modelled in RSIM. Note there are two aspects to the impact on Ops that we are having trouble explaining. When we say we cause a number aircraft to be grounded due to parts, this is not to be confused with the serviceability aspect of the operation. The current availability rate depends mostly on three variables: the availability of qualified technicians, the time required to complete repairs, and the availability of spares. Assuming that the number of technicians remains unchanged, there are two variables left to consider. As the rob rate increases, the time required to rob adds to the work associated with the job and lowers the availability rate. As aircraft are removed from service, spare parts availability will not change, or may even become better, since the aircraft can now be robbed, but this is not expected to have a major impact. The main change will be the time required to complete each repair. This increase in time will have a negative effect on availability rates over and above the impacts that have been modelled.

29. Incorporating these changes would also move the model towards a tool that can be used to optimize spares replacement policy. Although there are other tools, both on the open market and within DND that accomplish this task, this tool uses a simulation process, providing "best-case" and "worst-case" boundaries. The other tools available have not been looked at in the course of this project, and should be considered before major effort has been expended on expanding RSIM. In particular, the Omega PS suite of tools by Pennant should be studied. Parts of this tool are already being implemented within the department, and may provide some of the required capabilities.

6 – Conclusion

30. The RSIM simulation gives a first-order approximation of the impact of reduced spare repair rates on the overall numbers of aircraft. Combined with ASTRA outputs, it is possible to estimate the decline in CF-18 capability as the number of unserviceable aircraft increases.

31. Validation of RSIM remains to be completed by comparing predicted aircraft rob rates against actual values over the near future. RSIM can then be enhanced in a number of ways to create a more effective management tool.

32. The actual link between budget levels and repair rates has to be further investigated. At present, this value can only be estimated by subject matter experts, but needs a more rigorous analysis.

33. If a repair rate of 90% is used, it is predicted that between 14 and 23 aircraft will be lost due to parts shortages by Mar 03. The impact on the fleet capability can be determined using ASTRA. It is expected that by mid-2004, the loss of aircraft will jeopardize the force employment and/or force generation requirements to mount either a sustained deployment of six aircraft or a short-term deployment of twelve aircraft. The ability will still be present by Mar 2005 to generate a short-term deployment of six aircraft, although even this will be jeopardized shortly after that point.

34. There are a number of areas of expansion for RSIM, but first, an evaluation of other tools should be initiated. In particular, the Omega PS suite of tools by Pennant should be studied. Parts of this tool are already being implemented within the department, and may provide some of the required capabilities.

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2. E-mail correspondence, Jay Adamsson/Richard Devine, 18 Sep 2002.

UNCLASSIFIED
SECURITY CLASSIFICATION OF FORM
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1 ORIGINATOR (the name and address of the organization preparing the document Organizations for whom the document was prepared e g Establishment Sponsoring a contractor's report, or tasking agency, are entered in Section 8) OPERATIONAL RESEARCH DIVISION DEPARTMENT OF NATIONAL DEFENCE OTTAWA, ONTARIO K1A 0K2	2 SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable) UNCLASSIFIED

3 TITLE (the complete document title as indicated on the title page Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title)

ASSESSING THE IMPACT OF SPARES REDUCTIONS ON CF-18 OPERATIONS

4 AUTHORS (last name, first name, middle initial)

ADAMSSON, JAY

5 DATE OF PUBLICATION (month Year of Publication of document) NOVEMBER 2002	6a NO OF PAGES (total containing information Include Annexes, Appendices, etc) 12	6b NO OF REFS (total cited in document) 2

7 DESCRIPTIVE NOTES (the category of document, e g technical report, technical note or memorandum If appropriate, enter the type of report e g interim, progress, summary, annual or final Give the inclusive dates when a specific reporting period is covered)

RESEARCH NOTE

8 SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development Include the address)

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9a. PROJECT OR GRANT NO (if appropriate, the applicable research and development project or grant number under which the document was written Please specify whether project or grant)	9b CONTRACT NO. (if appropriate, the applicable number under which the document was written)
10a ORIGINATOR's document number (the official document number by which the document is identified by the originating activity This number must be unique to this document) DOR (CAM) RESEARCH NOTE 2002/12	10b OTHER DOCUMENT NOS (Any other numbers which may be assigned this document either by the originator or by the sponsor)

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In response to an upcoming reduction in the NP budget for the CF-18 fleet, DASOR was asked to assist in quantifying the fleet impact of a reduction in the repair rate of unserviceable parts. It is believed that the reduction in funds will impose a situation where unserviceable parts are not being repaired to save on costs, resulting in aircraft being down due to a shortage of spare parts In response to this request, the Reduction of Spares Impact Model (RSIM) was created This model uses actual failure rates and stockpile levels. Varying the repair rate allows a determination of the impact on the fleet size.

It has been found that at a 90% repair rate (the best estimate based on expert knowledge), a significant impact will begin to be felt by the fleet in mid-2003. The ability of the fleet to sustain a long-term deployment will be jeopardized by mid-2004, and the ability to deploy aircraft at all will be jeopardized by mid-2005.

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