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ORD PROJECT REPORT PR9818

CC130 Replacement Study
Part 2: Life Cycle Costing Analysis

by

P. Fournier

DECEMBER 1998

OTTAWA, CANADA

National Defence Défense nationale

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CC130 Replacement Study

Part 2: Life Cycle Costing Analysis

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OTTAWA, CANADA **December 1998**

CC130 Replacement Study

Part 2: Life Cycle Costing Analysis

Abstract

This Project Report documents the Life Cycle Cost (LCC) analysis conducted in support of the Combined Operational Effectiveness and Investment Appraisal for the CC130E Replacement Study. This study was conducted because the CC130E fleet is approaching its Estimated Life Expectancy (ELE) of 2010. To go beyond this date, the CC130E aircraft will require significant refurbishment. Two options are considered in order to maintain the current airlift capability beyond 2010. The first option is the refurbishment of the CC130E aircraft. The second option is the replacement of all CC130E by new C130J "Hercules II" aircraft. This study showed that although there are expected savings of about 20% in Personnel, Operation and Maintenance (P, O&M) costs per flying hour for the C130J, the acquisition cost of a replacement fleet is much higher than the cost to refurbish the CC130Es.

Résumé

Ce rapport documente la Comptabilisation du Coût du Cycle de Vie (CCCV) du matériel effectuée dans le cadre de l'analyse conjointe de l'efficacité opérationnelle et de l'estimation de l'investissement pour le remplacement des CC130E. Cette analyse a été effectuée parce que la flotte des CC130E approche la fin de sa durée de vie estimée prévue pour 2010. Les CC130E devront subir un important programme de révision afin de pouvoir continuer à voler après 2010. Deux options sont examinées afin de maintenir la capacité actuelle de transport aérien des Forces Canadiennes après 2010. La première option est celle de la remise à neuf des CC130E par le programme "Service Life Extension Program" (SLEP). La seconde option à l'étude est le remplacement des CC130E par des C130J "Hercules II". Cette analyse a démontré que même si les coûts en Personnel, Opération et Maintenance (P, O&M) par heure de vol du C130J sont inférieurs de 20% à ceux du CC130E, le coût d'acquisition d'une flotte de remplacement est largement supérieur à celui d'une remise à neuf des CC130E.

Keywords: Business Plan, CC130, Economic Life Analysis, Estimated Life Expectancy, Hercules aircraft, Life Cycle Cost.

EXECUTIVE SUMMARY

The Canadian Forces CC130E Hercules fleet is approaching its Estimated Life Expectancy (ELE) of 2010. To go beyond this date, a significant aircraft refurbishment must occur. An alternative to refurbishment is the procurement of new aircraft. The Directorate of Aerospace Requirements (DAR) and the Directorate of Aerospace Equipment Project Management (Transport and Helicopter) (DAEPM(TH)) launched a CC130 Replacement Study under project number A2529 "Hercules Replacement Project". Part one of this study is the Operational Effectiveness Comparison. It was conducted by I. Julien of the Central Operational Research Team (CORT) and is documented in reference [2]. The Directorate of Air Staff Operational Research (DASOR) was tasked to conduct Part two of this study, the Investment Appraisal, for which a Life Cycle Costing (LCC) analysis was conducted to compare the financial implications of both options.

The two parts of this LCC analysis are the Structural Life Analysis (SLA) and the Economic Life Analysis (ELA). The purpose of the SLA is to forecast how far into the future the fleet of CC130E aircraft is capable of flying. The SLA was conducted by simulating the usage of the fleet of aircraft over the course of the life cycle. The simulation assumes that the CC130E can fly until they reach 40,000 hours on their Centre Wing Box, at which point the aircraft are retired from service.

One of the options to maintain the current airlift capability beyond 2010 is to refurbish the fleet of CC130E aircraft through the Service Life Extension Program (SLEP) before they reach the end of their life. The other option is to replace the CC130Es with a new transport aircraft. The C130J was chosen as the candidate replacement for the purpose of this study because it is currently in production and current aircraft data is available. Two replacement options are examined: replace 19 CC130Es with 19 C130Js or replace 19 CC130Es with 16 C130Js.

The CC130 Structural Life Analysis Model (CC130 SLAM) was run with two Yearly Flying Rate (YFR) limits of 20,000 hours and 30,000 hours, for all the options examined, for a 52 year time frame that goes from 1998 to 2050. Simulation results show that if the YFR is 20,000 hours, a SLEP or a replacement program

must start in 2010. Under these conditions, the SLEP option extends the CC130E fleet life until FY2038/39. Replacement of 19 CC130Es with 19 C130Js ensures the current airlift capability until at least FY2050/51, and replacement with 16 C130Js also ensures the current airlift capability until at least FY2050/51. The simulation model was not run beyond 2050.

If the YFR is 30,000 hours, the SLEP or the replacement program has to start in 2005. In that case, the SLEP option extends the life of the CC130E until FY2026/27. Replacement of 19 CC130Es with 19 C130Js ensures the current airlift capability until FY2041/42, and replacement with 16 C130Js ensures the current airlift capability until FY2039/40. The following table summarizes the results of the SLA. These results show that no matter which life extension option is selected, the airlift capability will extend far into the future.

FIRST YEAR OF RETIREMENT FOR SLEP OR A REPLACEMENT FLEET.

Option	YFR=20,000 hours	YFR=30,000 hours
SLEP 19 CC130E	FY2038/39	FY2026/27
19 C130J	After FY2050/51	FY2041/42
16 C130Js	After FY2050/51	FY2039/40

The second part of the LCC analysis deals with the economic aspects of the options considered. An economic model was developed to estimate the total cost of each option. The costs are broken down into Personnel, Operations and Maintenance (P, O&M), and Capital Investment. The P, O&M costs for the SLEP CC130E are estimated from the Weapon System Support Plan (WSSP). P, O&M Costs for the C130J are based on Lockheed Martin's estimates. The P, O&M Costs are cumulated over the Life Cycle of the aircraft.

The LCC analysis showed that the C130J has a lower P, O&M cost per flying hour than the CC130E, for both YFR rates. The P, O&M Cost per Flying Hour of each option is shown in the table below. Over the course of the life cycle, the expected savings in P, O&M cost per flying hour for the C130J range from 19.1% to 23.4%, depending on the YFR. Details of the Cost Breakdown Structure for the P, O&M showed that the expected savings for the C130J are in Spares, Maintenance

Personnel, Aircrew, and Fuel. Contacts with other countries who purchased the C130J indicate that they expect the C130J to require costly software support. At present, all the CC130E aircraft are periodically sent to the Progressive Structural Inspection (PSI) program. If the CF replace the CC130Es, there will be savings in PSI costs because the C130J will start the PSI program 13 to 15 years after acquisition if YFR=20,000 hours, and 10 to 12 years after acquisition if YFR=30,000 hours.

P, O&M COST PER FLYING HOUR FOR EACH OPTION

YFR	SLEP 19 CC130E	19 C130J	16 C130Js
20,000 hours	$7,832	$6,045	$5,997
		22.8% savings	23.4% savings
30,000 hours	$6,035	$4,735	$4,884
		21.6% savings	19.1% savings

The two tables below summarize the cumulative P, O&M Costs and the Capital Investment Costs for the duration of the Life Cycle, for YFR=20,000 hours and YFR=30,00 hours, respectively. The values are rounded off to the nearest million dollars. When the Total Life Cycle Cost (P, O&M plus Capital Investment) is calculated, the SLEP option has a much lower cost than the replacement option. The high acquisition cost of the C130J has a detrimental impact on its Total Life Cycle Cost, even after a substantial residual value for the C130J has been taken into account.

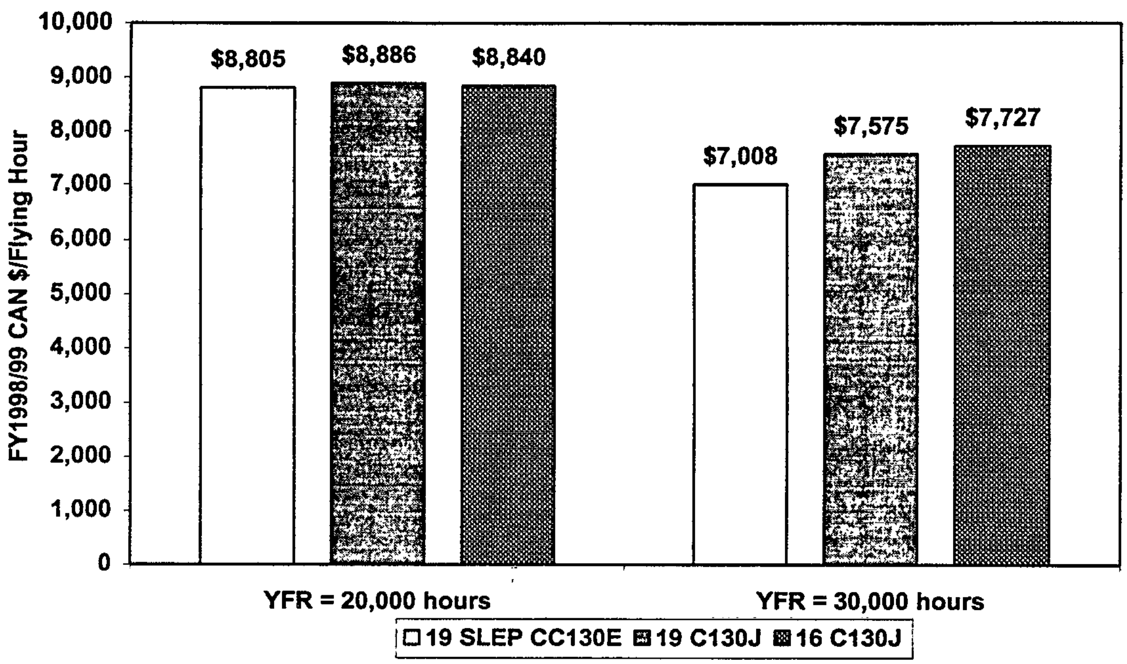
CUMULATIVE P, O&M COSTS AND CAPITAL INVESTMENT COSTS YFR=20,000 HOURS (ROUNDED OFF VALUES)

Cost Factor	SLEP 19 CC130E	19 C130J	16 C130J
P, O&M	$2,004 M	$1,653 M	$1,599 M
Capital Investment	$370 M	$1,628 M	$1,386 M
Total Cost	$2,373 M	$3,281 M	$2,985 M

CUMULATIVE P, O&M COSTS AND CAPITAL INVESTMENT COSTS YFR=30,000 HOURS (ROUNDED OFF VALUES)

Cost Factor	SLEP 19 CC130E	19 C130J	16 C130J
P, O&M	$2,329 M	$1,936 M	$1,818 M
Capital Investment	$370 M	$1,655 M	$1,413 M
Total Cost	$2,699 M	$3,591 M	$3,230 M

A Normalized Total Cost per Flying Hour was developed to express the cost of the three options in terms of aircraft life in flying hours. Aircraft life is 20,000 hours for the SLEP CC130E and 40,000 hours for the C130J. This indicator avoids making use of a residual value and allows comparison of two aircraft with different life over a normalized base. The Figure below shows this normalized indicator for YFR=20,000 hours and YFR=30,000 hours. The differences in Normalized Total Cost per Flying Hour for the three options are marginal if the YFR is 20,000 hours. If YFR=30,000 hours, the Normalized Total Cost per Flying Hour shows a small advantage for the SLEP.



Normalized Total Cost per Flying Hour.

The three options considered in this study are all capable of ensuring the current airlift capability well beyond 2010. Results from the LCC analysis show that the P, O&M Cost per Flying Hour of the C130J is 19.1% to 23.4% lower than the P, O&M Cost per Flying Hour of the refurbished CC130Es. The LCC analysis also shows that the refurbishment of the CC130Es has a significantly lower total cost than the replacement by new C130J aircraft because of the acquisition cost of new aircraft.

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CC130 REPLACEMENT STUDY
PART 2: LIFE CYCLE COSTING ANALYSIS

INTRODUCTION

1. The Canadian Forces (CF) CC130E Hercules fleet is approaching its Estimated Life Expectancy (ELE) of 2010. To ensure the current airlift capability beyond this date, a significant aircraft refurbishment must occur. An alternative to refurbishment is the procurement of new aircraft. The Directorate of Air Staff Operations Research (DASOR) was tasked by the Directorate of Aerospace Requirements (DAR) and by the Directorate of Aerospace Equipment Program Management (Transport and Helicopters) (DAEPM(TH)) to conduct a Life Cycle Costing (LCC) analysis to compare the financial implications of both options. This LCC analysis was conducted in support of Project A2529 "Hercules Replacement Project". It is the second part of the Combined Operational Effectiveness and Investment Appraisal for the CC130E Replacement Study. The results of this analysis were briefed and the briefing was published in [1]. Part one of the CC130 Replacement Study is the Operational Effectiveness Comparison and it is published in [2] and [3].

2. The first part of this LCC analysis is the Structural Life Analysis (SLA). The SLA examines the impact on the CC130 fleet of the ageing of the 19 CC130E aircraft. The SLA also examines the impact on fleet size and fleet life of the introduction of refurbished CC130Es and the introduction of new C130Js. The second part of this analysis is the Economic Life Analysis (ELA), in which the financial implications of refurbishing the CC130Es are compared with the financial implications of replacing them with new C130Js.

CC130 UPGRADE PROGRAMS AND CURRENT STATUS

3. The CF acquired its first CC130 aircraft in the mid 1960's, and since then acquired other CC130s at different periods. The CF now operate a fleet of 32 CC130 aircraft. Table I shows the cumulative flying hours on the CC130 aircraft as of December 1997 [4]. Cumulative airframe flying hours on the CC130 fleet are

distributed over a wide range, reflecting different acquisition periods since the 1960's. The oldest aircraft has accumulated over 40,000 airframe hours up to the end of 1997 while the newest aircraft had not reached 500 airframe hours. Table I also shows that the CC130 fleet comprises different aircraft models, that can be separated in three groups: the CC130Es, the CC130H73s and the CC130H84s (CC130H73&H84s), and the CC130H90(T)s and the CC130H90-30s (CC130H90s).

TABLE I

CUMULATIVE FLYING HOURS FOR THE CC130 FLEET, 5 DECEMBER 1997

Tail No	Model	Base	Airframe Hrs	Centre Wing Hours	Outer Wing Hours	No landings
130305	E	Trenton	36924	24320.0	10309.2	13068
130306	E	Greenwood	37957	25871.0	11348.0	16204
130307	E	Trenton	38069	25883.0	12242.7	13544
130308	E	Trenton	39002	28254.0	11560.2	16661
130310	E	Greenwood	37128	25912.0	12665.3	13187
130311	E	Trenton	36597	26018.0	12745.8	14471
130313	E	Greenwood	38702	26523.0	12901.5	14028
130314	E	Greenwood	38915	28762.0	13159.8	16319
130315	E	Trenton	40545	29860.0	13026.8	17537
130316	E	Trenton	38049	26669.0	11697.1	14723
130317	E	Trenton	38230	29446.0	12431.2	16487
130319	E	Trenton	37300	26258.0	11446.2	13361
130320	E	Trenton	39038	27865.0	13553.2	15554
130323	E	Trenton	38542	29667.0	15788.7	15627
130324	E	Trenton	36784	27613.0	12528.0	16328
130325	E	Trenton	36850	29599.0	11822.6	17776
130326	E	Trenton	36840	28985.0	11904.7	16826
130327	E	Trenton	35849	27842.0	12171.7	16075
130328	E	Trenton	37060	29175.0	15118.7	15808
130332	H73	Winnipeg	24190	24190.0	24190.0	13604
130333	H73	Winnipeg	24198	24198.0	24198.0	13650
130334	H84	Trenton	12074	12074.0	12074.0	8445
130335	H84	Trenton	11826	11826.0	11826.0	8139
130336	H73	Trenton	15818	15818.0	15818.0	8829
130337	H73	Trenton	15638	15638.0	15638.0	8593
130338	T (H90)	Winnipeg	5070	5070.0	5070.0	3069
130339	T (H90)	Winnipeg	2754	2754.0	2754.0	1926
130340	T (H90)	Winnipeg	5433	5433.0	5433.0	3184
130341	T (H90)	Winnipeg	5674	5674.0	5674.0	3117
130342	T (H90)	Winnipeg	4657	4657.0	4657.0	3000
130343	H90-30	Trenton	252	252.0	252.0	409
130344	H90-30	Trenton	155	155.0	155.0	235

4. The oldest aircraft in the fleet are the 19 CC130E models and they are the subject of the present analysis. These aircraft underwent several upgrade programs since their acquisition in the mid 1960's. Among those upgrade programs, the structural modifications are the most important. The centre wing boxes on all CC130E were replaced by H model centre wing boxes in 1973 and 1974. Following

the Centre Wing Replacement Program (CWRP), it became necessary to improve the outer wings on all CC130E aircraft. An Outer Wing Improvement Program (OWIP) was conducted on all CC130E aircraft between 1974 and 1977 to bring the E model outer wings to the same configuration as the H model outer wings. Also, a Fuselage Improvement Program (FIP) was conducted from 1973 to 1978 to improve fatigue prone areas and to add improved design features and materials. Finally, in 1984, the outer wings were replaced when it was found that the outer wing improvement program conducted 10 years earlier did not extend the component's life sufficiently ([5], [6]). All these structural improvement programs brought the structural configuration of the CC130E aircraft much closer to the structural configuration of the CC130H model. Table I shows differences in airframe, centre wing and outer wing hours for the CC130E aircraft, reflecting the installation of the centre wings and the outer wings at different times.

5. In addition to the structural upgrades made to the CC130E fleet, a large number of minor upgrade and modification programs were conducted in order to keep up with technology and improve the overall capability of the aircraft. These small projects were carried out as part of the normal Repair and Overhaul Program conducted at the third line of maintenance by SPAR Aerospace in Edmonton.

6. From the beginning of 1998 until the end of 2000, all CC130s will undergo a major Avionics Upgrade Program (AUP) which consists of the installation of a computerized avionics suite and a flight management system in the cockpit. Each aircraft receiving the AUP is grounded for three months. It is believed that in order to keep up with technology, a follow-on AUP will be required around 2015. This follow-on AUP will not be as extensive as the first AUP.

7. The replacement of the T56-7B engines by T56-15 engines started in 1998. This engine upgrade program applies to the CC130E aircraft only, and aims at bringing them to the same engine configuration as the CC130H aircraft. The program calls for two aircraft fitted with the new engines each year, until completion of the program in 2007. The new engines are installed on the aircraft during one of the aircraft's scheduled inspections. For that reason, the engine upgrade does not generate additional downtime for the aircraft.

8. As indicated in the introduction, the CC130E aircraft are approaching the estimated limit of their service life, currently established at 40,000 hours on the centre wing. This limit of 40,000 centre wing hours is not a hard limit. Rather, it means that the engineers in charge of the airworthiness of the CC130 fleet are confident, following thorough inspections of the centre wing box on all CC130E aircraft, that they can fly until they have accumulated 40,000 hours on their centre wing box [7]. A thorough structural inspection of the centre wing box on two selected aircraft during the winter of 1998 showed that the centre wings of both aircraft are in a much better condition than what was expected. However, current knowledge cannot predict whether the CC130E will be able to fly beyond the assumed limit of 40,000 centre wing hours. It is also possible that future structural inspections reveal that other aircraft components might limit aircraft life sooner than the centre wing. For the purpose of this analysis, it is assumed that a CC130 aircraft is retired from service upon reaching 40,000 centre wing hours.

CC130 AIRCRAFT ATTRITION

9. The actual crash attrition of CC130 aircraft since their entry in service with the CF is depicted in Figure 1. The projected crash attrition is also indicated for the period 1960 to 2050. As seen in Figure 1, the first two crashes followed the attrition model closely. These first two crashes were followed by a period of 13 years without any losses. The actual losses caught up with the predicted losses in the 1980's. In 1985, two aircraft were lost in a single accident when they collided during an airshow practice. The two crashes in the early 1990's brought the actual losses curve above the line for the predicted losses.

10. The predicted losses are modelled as a RAND learning curve [8]. This prediction is based on the actual flying hours from 1960 to 1997, and on the two YFR used in the present analysis for the period 1998 to 2050. The attrition model predicts that by 2050, the CF will probably lose four more aircraft if the YFR is 20,000 hours and seven more aircraft if the YFR is 30,000 hours.

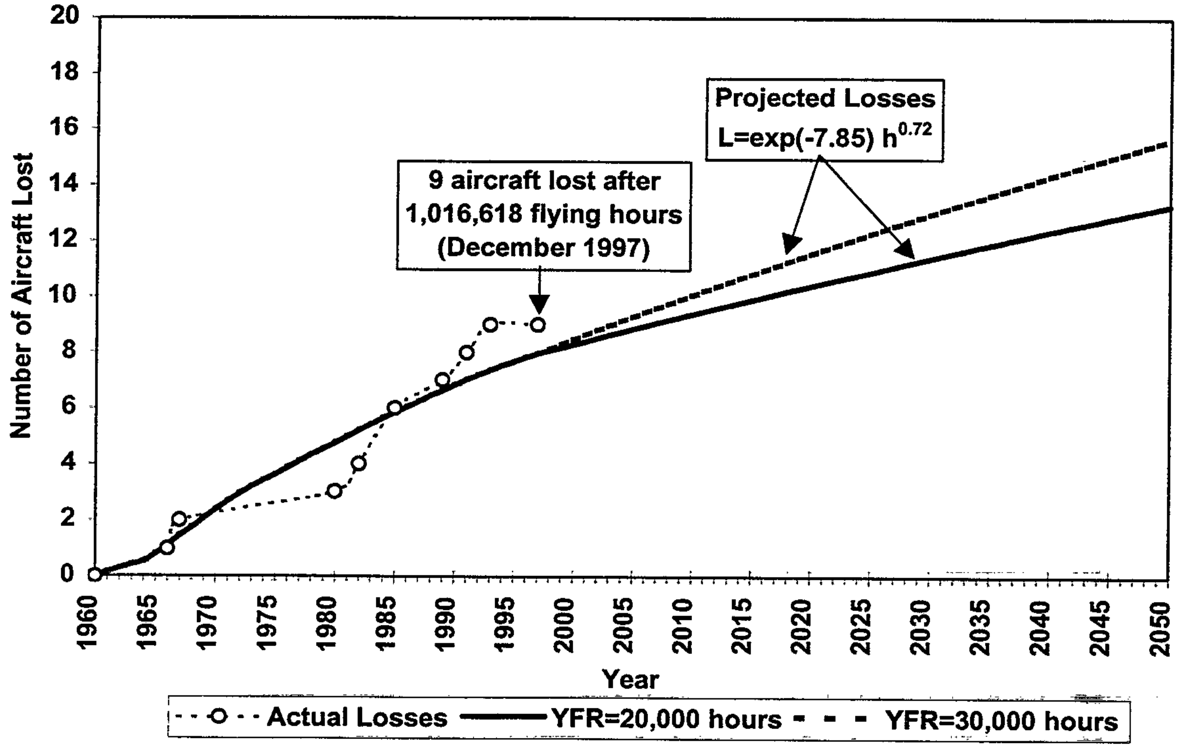

Figure 1: Actual and predicted CC130 aircraft losses.

CC130 STRUCTURAL LIFE ANALYSIS MODEL (CC130 SLAM)

11. There are two elements to this Life Cycle Costing (LCC) analysis. The first is the Structural Life Analysis (SLA). The aim of the SLA is to examine with a stochastic model the impact on fleet size of the ageing of the CC130E, and the impact of refurbishing or replacing those aircraft with new ones. The second part of an LCC analysis is the Economic Life Analysis (ELA). The aim of the ELA is to examine the financial implications of refurbishing or replacing the CC130Es [9].

12. The stochastic model used for the SLA is an updated version of the CC130 Structural Life Analysis Model (CC130 SLAM) [10]. CC130 SLAM is a Monte-Carlo model programmed in Fortran that simulates CC130 fleet usage over a user-defined time frame. It was originally developed in 1993 for a previous CC130 ELE study. It was updated with fleet flying hours data as of December 1997 and was modified to simulate the impact on the CC130 fleet of the AUP, the Follow on AUP, the SLEP of the CC130Es, and the introduction of new C130Js to replace the CC130Es.

13. The time frame in the simulation was set from 1998 to 2050. This very long time frame was chosen in order to capture the larger part of the life of a replacement fleet of C130Js under a YFR of 20,000 hours.

14. CC130 SLAM simulates the life of the entire fleet of 32 CC130 aircraft. Different flying rates apply to the aircraft depending on what base they are attached to. The CC130 are distributed on three bases as follows: four CC130Es in Greenwood; 15 CC130Es and six CC130Hs in Trenton; and seven CC130Hs in Winnipeg. In the simulation model, Greenwood and Trenton aircraft are grouped together as if they were on a single base because in the real world, CC130E aircraft are rotated between Greenwood and Trenton and airframe hours even out over the years. In CC130 SLAM, the total YFR is divided between the following bases: 82% to the Greenwood/Trenton bases, and 18% to the Winnipeg base. The breakdown of the YFR between the bases is known from historical data. Each Base YFR is divided between the number of aircraft at the base, giving mean annual aircraft flying hours. CC130 SLAM uses the mean annual aircraft flying hours as the value around which individual aircraft flying hours are normally distributed. When the number of aircraft on a base declines due to retirement from service or crash attrition, the mean annual aircraft flying hours increases. When it reaches 1200 hours per aircraft per year, it stays constant at this value, and the Base YFR is reduced as the number of aircraft on the base further declines.

15. CC130 SLAM simulates the usage of the entire fleet of 32 CC130 aircraft. It includes an attrition model based on a RAND learning curve [8]. Flying hours are randomly attributed to each aircraft, and the model keeps track of airframe hours, centre wing hours, outer wing hours, and aircraft age. The downtime generated by the AUP, the follow-on AUP and the refurbishment program for the CC130Es is implemented in the model. The simulation model outputs the number of aircraft in each sub fleet (CC130E, CC130H73&H84, CC130H90), and the number of hours flown by each sub fleet, for each year of each iteration. This simulation output is used to calculate annual average values for the number of aircraft in each sub fleet and the number of flying hours for each sub fleet. These average values are used in the economic model to estimate future Operations and Maintenance (O&M) costs.

STRUCTURAL LIFE ANALYSIS

16. The purpose of the SLA is to estimate how far into the future the fleet of CC130E will fly based on usage rate and aircraft retirement assumptions. It is also used to examine the impact on the CC130 fleet of retaining the CC130Es or replacing them with new C130Js. Four scenarios were examined with the SLA: Status Quo, SLEP 19 CC130Es, Acquire 19 C130Js, and Acquire 16 C130Js. Fleet life depends on the flying rate, hence all four options were simulated for two YFR limits of 20,000 hours and 30,000 hours.

The "Status Quo" option: description and results

17. The "Status Quo" option was used for the sole purpose of forecasting in what year the CC130E aircraft will start to retire, based on the assumption that their life is limited to 40,000 centre wing hours. In this scenario, no actions are taken to extend the life of the CC130Es beyond their assumed limit of 40,000 centre wing hours. The only upgrade programs the aircraft go to are the T56-15 engine upgrade and the AUP. As explained in section **CC130 upgrade programs and current status**, the AUP generates three months of downtime per aircraft. This downtime is implemented in the simulation.

18. Figure 2 shows the average number of CC130Es in the fleet based on their assumed structural life limit of 40,000 centre wing hours. It shows that the CC130E fleet starts retiring in FY2007/08 if the YFR is 30,000 hours, and in FY2012/13 if the YFR is 20,000 hours. Losses prior to FY2007/08 or FY2012/13 are based on crash attrition only. This chart also shows that on average, two aircraft are withdrawn from service annually if YFR is 20,000 hours. The average retirement rate is four aircraft per year if the YFR is 30,000 hours.

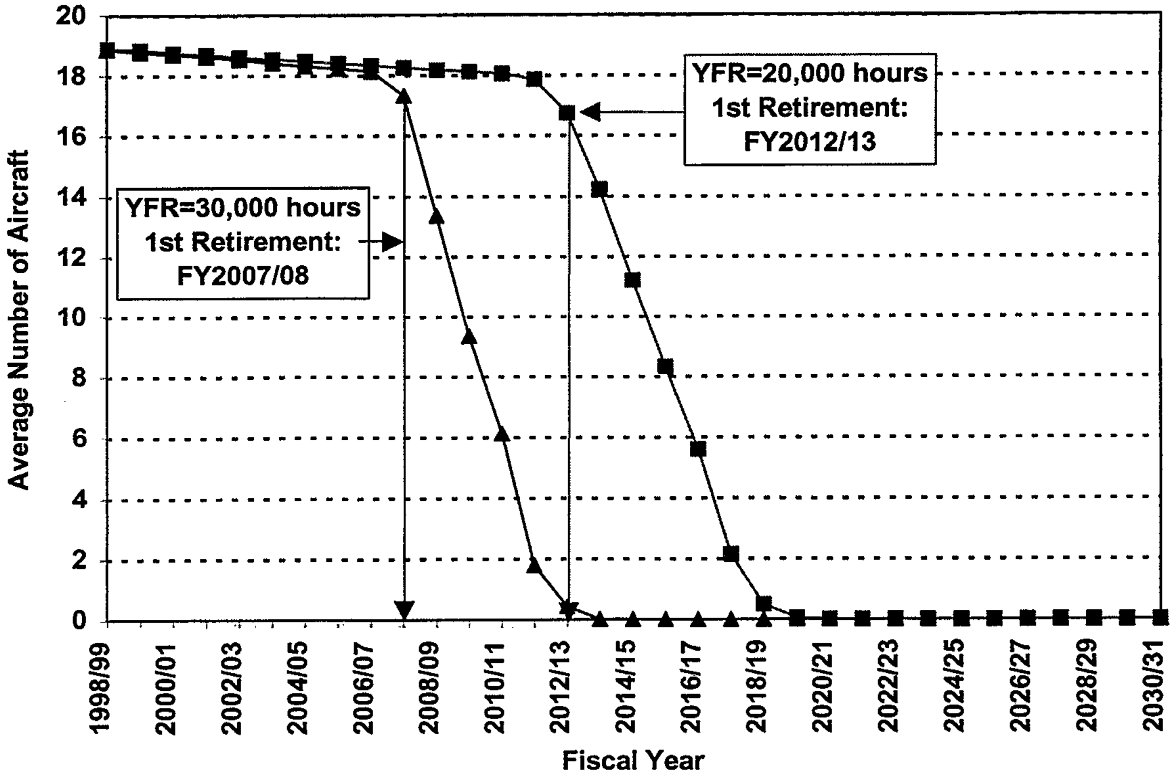

Figure 2: Average number of CC130E in the fleet, "Status Quo" option.

19. It is also interesting to examine the most probable year of retirement of each individual aircraft by plotting the aircraft tail number against the average year in which this aircraft retired in the simulation. Figure 3 shows such a chart for the "Status Quo" option at a YFR of 20,000 hours. It shows that a progressive refurbishment of the CC130E or a replacement by C130J must take place before FY2013/14 in order to maintain a continuing airlift capability beyond 2010. Figure 3 shows that all CC130Es retire within 7 years, between FY2012/13 and FY2018/19 inclusive.

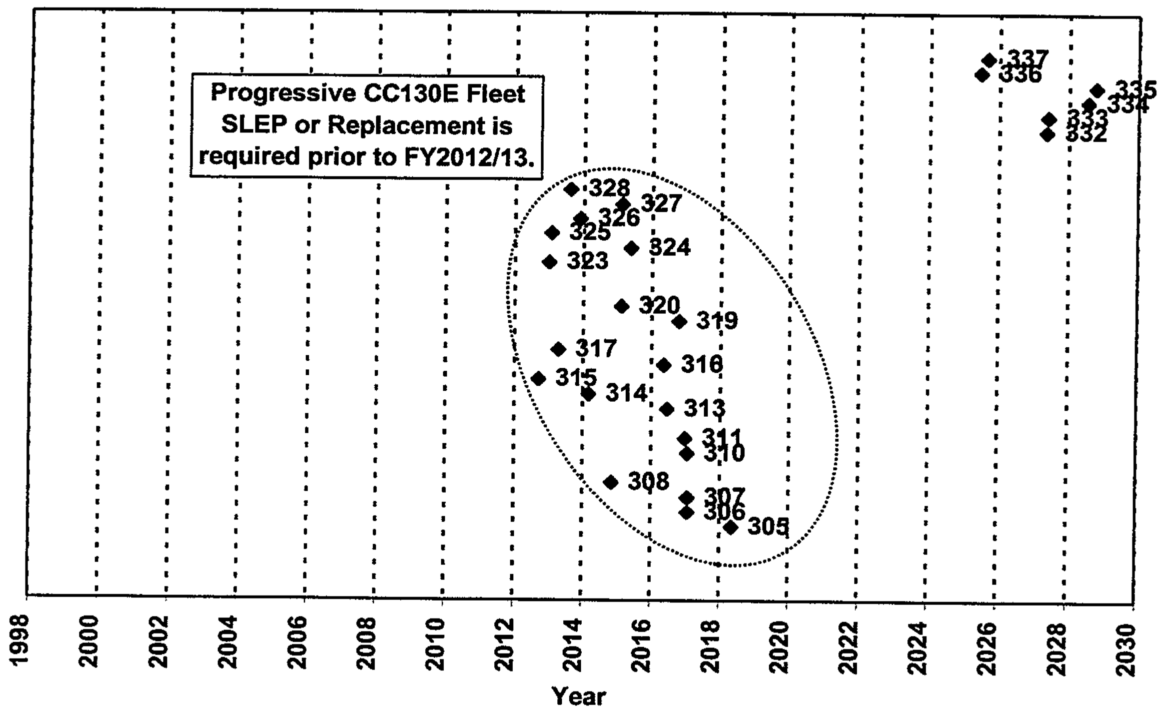

Figure 3: Most probable year of retirement, "Status Quo" option, YFR=20,000 hours.

20. Figure 4 shows a plot of the aircraft tail number against the most probable year of retirement, for a YFR of 30,000 hours. Comparing with Figure 3, the cluster of aircraft tail numbers moves 5 years ahead, and all CC130E aircraft retire within 6 years, between FY2007/08 and FY2012/13 inclusive. In this case, a progressive refurbishment of the CC130E or their replacement by C130J is required prior to FY2007/08, in order to maintain the CC130 fleet airlift capability.

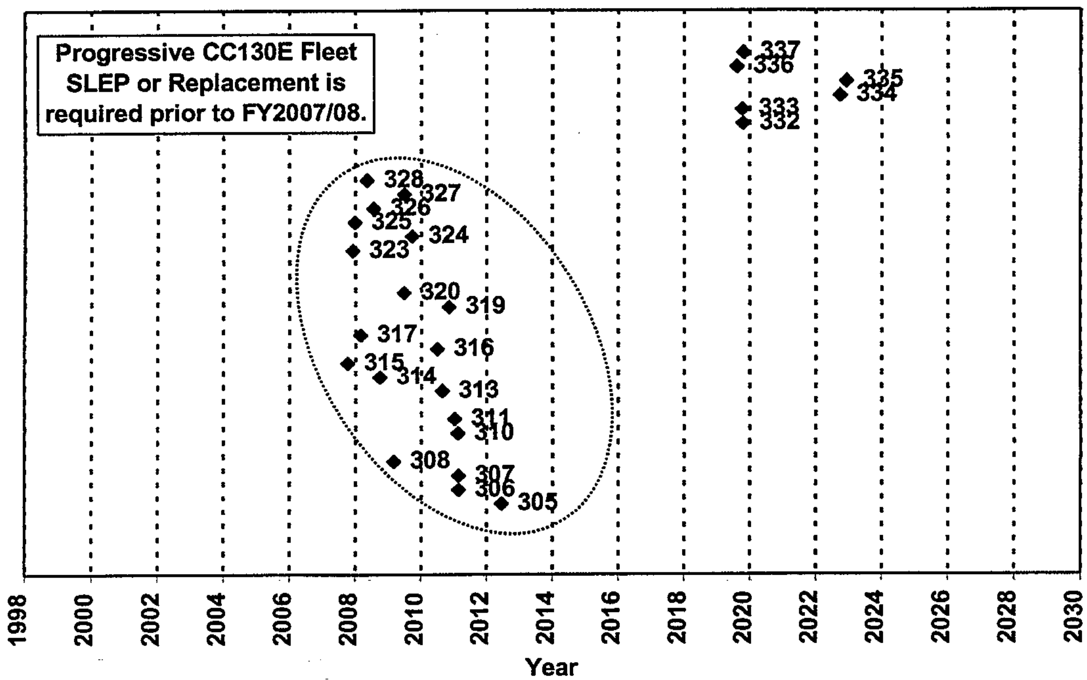

Figure 4: Most probable year of retirement, "Status Quo" option, YFR=30,000 hours.

CC130 fleet options

21. Three options are considered to provide the current airlift capability beyond 2010. The first option is to retain the CC130Es and refurbish them. The two other options are a replacement of the CC130E by new C130J: a one-for-one replacement in which the CF acquire 19 C130Js, and a less-than-one-for-one replacement in which the CF acquire 16 C130Js. Each of these options is described in detail in the following paragraphs.

22. **The "SLEP 19 CC130E" option: retain the CC130Es.** Retaining the CC130Es requires sending those aircraft to a program known as the "Service Life Extension Program" (SLEP). Several aircraft components are repaired or upgraded in the SLEP. The critical component is the centre wing box. In the worst case, the centre wing boxes will have to be replaced. If they are in a better condition, a centre wing improvement program will be sufficient to ensure the airworthiness of the aircraft past the 40,000 centre wing hours mark. Both centre wing programs extend the life of the aircraft to 60,000 centre wing hours. In-depth structural inspections of the centre wing boxes on all CC130Es will determine what kind of program is

required to extend aircraft life beyond the current assumed limit of 40,000 centre wing hours.

23. Another major item in the SLEP is the rewiring of the aircraft. The majority of the CC130E electrical system wiring, associated hardware and Radio Frequency (RF) cables are original equipment that have deteriorated over the past 25 years, due to normal wear, exposure to environmental extremes, and contamination [11]. These components generate significant aircraft downtime, and replacing them would improve aircraft serviceability. Finally, miscellaneous aircraft systems will also be upgraded or repaired as part of the SLEP.

24. Results from the "Status Quo" option show that the SLEP must start in FY2010/11 if the YFR is 20,000 hours, and in FY2005/06 if the YFR is 30,000 hours, in order that all CC130Es are refurbished before any of them reach 40,000 centre wing hours. Four aircraft would be sent to the SLEP every year. The aircraft with the most hours on their centre wing would go to the SLEP first.

25. The aircraft going to the SLEP also receive the T56-15 engines and the AUP. These upgrades follow the same calendar as in the "Status Quo" option, and the AUP generates three months of downtime per aircraft. The refurbished CC130Es will eventually need to receive a follow-on AUP in order to keep up with technology. In the CC130 SLAM, this follow-on AUP occurs between 2015 and 2018, at a rate of 12 aircraft per year, and generates three months of downtime per aircraft.

26. **The "Acquire 19 C130Js" option.** In this scenario, all the CC130Es are progressively retired from service before they reach 40,000 centre wing hours and replaced by 19 new C130Js. The aircraft with the most centre wing hours are replaced first. It is assumed that each new aircraft has a life of 40,000 hours, but there is yet no data to support this assumption because the C130J was never put to the test. The 40,000 centre wing hours life of the C130J is based on CF experience with previous CC130 models.

27. Results from the "Status Quo" option show that in order to replace all CC130Es before any of them reach 40,000 centre wing hours, the replacement

must start in FY2010/11 if the YFR is 20,000 hours, and in FY2005/06 if the YFR is 30,000 hours. The replacement scenario was programmed such that the CC130Es receive the AUP and the T56-15 engines according to the same schedule as in the "Status Quo" and the "SLEP 19 CC130Es" options. It is understood that in the real world, should the replacement option be selected, the T56-15 engine upgrade will not be completed on all CC130E aircraft in order to save money.

28. **The "Acquire 16 C130Js" scenario.** The Reliability and Maintainability (R&M), Operational Capability and Performance comparison showed that 16 C130Js are capable of providing the same airlift capability as 19 CC130Es [2]. For this reason, the replacement of all CC130Es with 16 C130Js is examined. All the other aspects of the scenario (upgrade programs for the CC130E, dates for replacement, etc.) are the same as in the "Acquire 19 C130Js" option.

29. Both replacement scenarios assume that the C130J will not require any upgrade programs over the course of its life. It is understood that this assumption is probably too optimistic, but since the C130J is just entering service, there is just too much uncertainty on what the upgrades to the C130J might be, when they would be required and how much they would cost. For that reason, it was decided not to include mid-life and upgrade programs for the C130J in the model.

CC130 SLAM results for YFR = 20,000 hours

30. Figure 5 shows simulation results for YFR = 20,000 hours and the three fleet options. The value plotted is the average number of aircraft at the end of each Fiscal Year, from FY1998/99 to FY2050/51. The refurbishment and the replacement start in FY2010/11.

31. Figure 5 shows that with a YFR of 20,000 hours, all three options procure the current airlift capability far beyond 2010. The life of the refurbished CC130E fleet is extended until FY2038/2039, at which time the aircraft progressively reach their new life limit of 60,000 centre wing hours. By this time, most of the aircraft are over 70 years old. The fuselages have accumulated in the vicinity of 70,000 hours. Despite all the modifications, improvements and upgrade programs that will

be carried out to keep the CC130E aircraft airworthy into the far future, the CF will not continue supporting these aircraft after they reach the end of their extended life and they will have to be replaced. In addition to reliability and maintainability problems inherent in 70-year old airframes, it is highly probable that supportability issues will prevent any further use of the CC130Es.

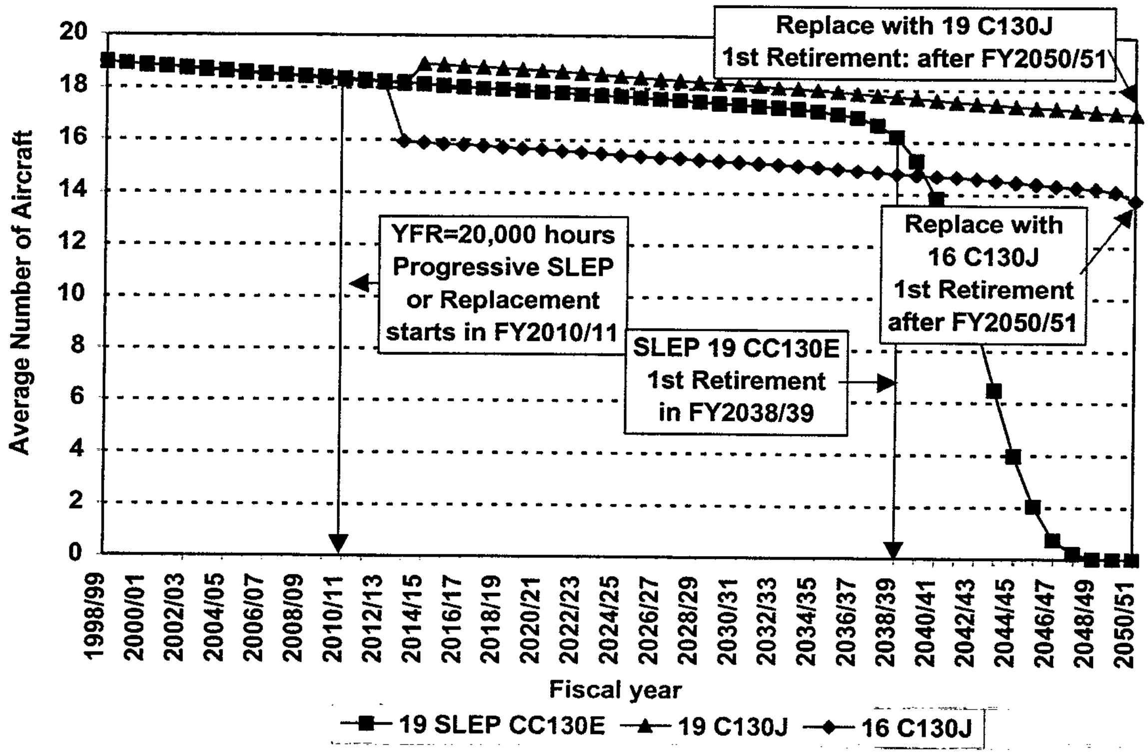

Figure 5: CC130 SLAM results for YFR = 20,000 hours.

32. There are three distinct phases for the replacement options. The first phase goes from FY1998/99 to FY2010/11, during which the CC130Es continue to fly. They are sent to the AUP between FY1998/99 and FY2000/01, and are fitted with T56-15 engines from FY1998/99 to FY2007/08. The second phase is the introduction of C130J to replace the CC130Es. This phase goes from FY2010/11 to FY2013/14 if 16 C130Js are acquired, and from FY2010/11 to FY2014/15 if 19 C130Js are acquired. The drop to 16 aircraft on the line with the diamond marker, in FY2013/14, indicates the retirement of the last CC130Es and the beginning of the operation with a replacement fleet of 16 C130Js.

33. The downward trend between FY1998/99 and the year of the first retirement seen on the three plots in Figure 5 show the impact of crash attrition. All three plots show that on average, two aircraft are lost to crashes over the simulated time frame. The jump to 19 aircraft on the line with the triangle marker in FY2014/15 shows that the acquisition of 19 C130Js compensate for crash attrition among the CC130Es.

34. Figure 5 shows that either replacement fleet has a longer life than the fleet of refurbished CC130Es. The chart shows that none of the 19 C130Js and none of the 16 C130Js reach the 40,000 centre wing hours limit at the end of FY2050/51. Since the C130Js are introduced into the CF fleet in FY2010/11, this translates into an airframe life of at least 40 years.

35. The present analysis assumes that the maintenance concept for the C130J is the same as the actual maintenance concept for the CC130Es and CC130Hs. This means that the C130J aircraft will be subject to the Progressive Structural Inspection (PSI) program. The PSI is a periodic inspection that starts when the aircraft has accumulated 10,000 airframe hours. A Hercules aircraft goes to the PSI every 3,600 flying hours. A PSI generates three months of downtime, but has a minor impact on C130J aircraft availability, as was demonstrated in [2].

36. Figure 6 shows the number of C130J aircraft that have accumulated 10,000 airframe hours or more if YFR=20,000 hours, for both replacement options. Both lines in Figure 6 are never equal to the total number of aircraft acquired because of crash attrition. Figure 6 shows that aircraft in the "Acquire 16 C130Js" option progressively reach 10,000 airframe hours in FY2023/24, and that all of them reach that milestone in FY2028/29. Aircraft in the "Acquire 19 C130Js" option progressively reach 10,000 airframe hours in FY2024/25, and all of them reach that milestone in FY2031/32. Aircraft in the "Acquire 16 C130Js" option reach 10,000 airframe hours earlier because they fly more hours per year than the aircraft in the "Acquire 19 C130Js" option.

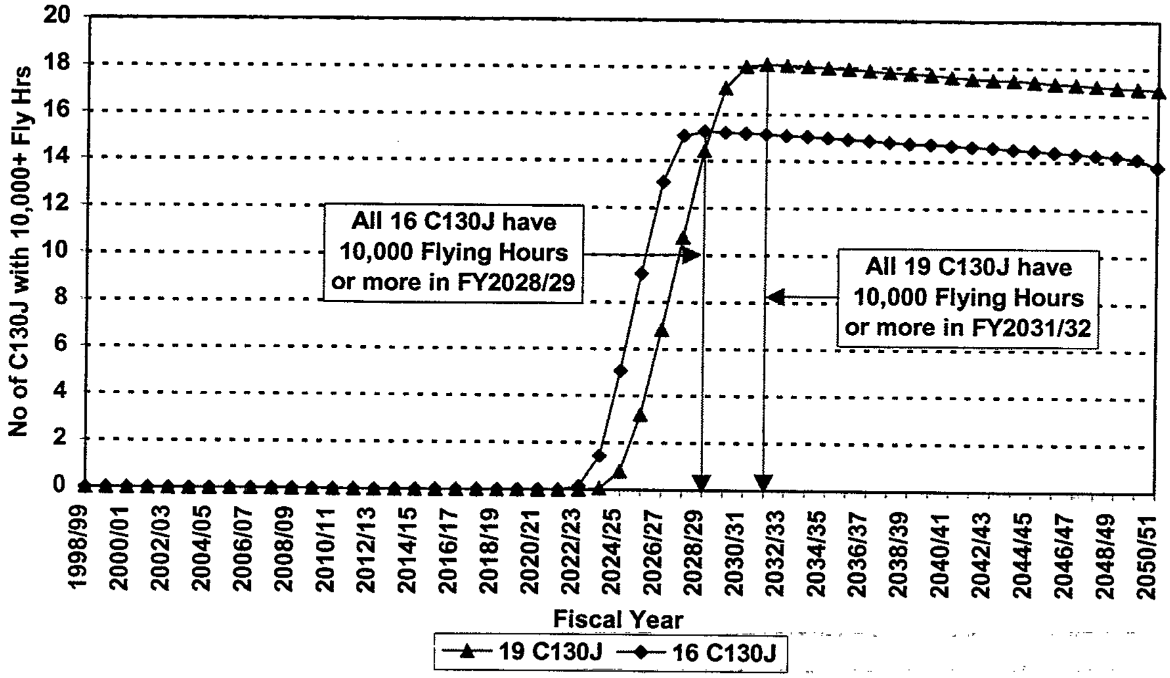

Figure 6: Number of C130J at or above 10,000 airframe hours; YFR=20,000 hours.

CC130 SLAM results for YFR=30,000 hours

37. Figure 7 shows simulation results for YFR=30,000 hours. The value plotted is the average number of aircraft at the end of each Fiscal Year, from FY1998/99 to FY 2050/51. The refurbishment and the replacement start in FY2005/06.

38. Figure 7 shows that if YFR=30,000 hours, all three options have a shorter life than if YFR=20,000 hours. The life of the refurbished CC130E fleet is extended until FY2026/2027, at which time the aircraft progressively reach their new life limit of 60,000 centre wing hours. At this point in time, the CC130Es start to be retired from service for the same reasons as with YFR=20,000 hours, and a replacement program will be required. Figure 7 shows that aircraft in the fleet of 16 C130Js start to retire in FY2039/40. Those in the fleet of 19 C130Js start to retire in FY2041/42.

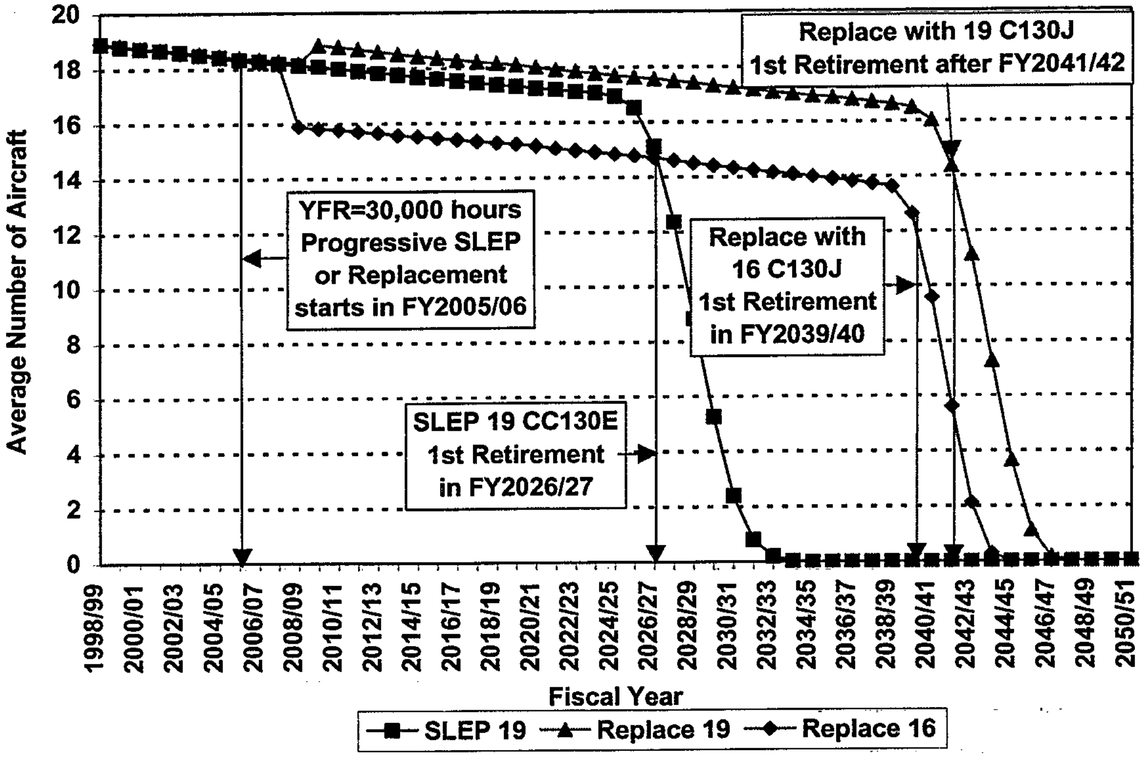

Figure 7: CC130 SLAM results for YFR = 30,000 hours.

39. As with YFR = 20,000 hours, there are three distinct phases for the two replacement options. The first phase goes from FY1998/99 to FY2005/06, during which the CC130Es continue to fly. They receive the AUP between FY1998/99 and FY2000/01, and receive T56-15 engines starting in 1998 at a rate of 2 aircraft per year. The second phase is the introduction of C130J to replace the CC130Es. This phase goes from FY2005/06 to FY2008/09 if 16 C130Js are acquired, and from FY2005/06 to FY2009/10 if 19 C130Js are acquired. The drop to 16 aircraft on the line with the diamond marker, in FY2008/09, indicates the retirement of the last CC130Es and the beginning of the operation with a replacement fleet of 16 C130Js.

40. Figure 8 shows the number of C130J aircraft with 10,000 airframe hours or more, if YFR = 30,000 hours. As in Figure 6, both lines in Figure 8 are never equal to the maximum number of aircraft in the fleet they represent because of crash attrition. Figure 8 shows that aircraft in the "Acquire 16 C130Js" option progressively reach 10,000 airframe hours in FY2014/15, and that all of them reach that milestone in FY2018/19. Aircraft in the "Acquire 19 C130Js" option start to

reach 10,000 airframe hours in FY2015/16, and all of them reach that milestone in FY2020/21. Again, aircraft in the "Acquire 16 C130Js" option reach 10,000 airframe hours earlier because they fly more hours per year than the aircraft in the "Acquire 19 C130Js" option. Both lines in Figure 8 also show that aircraft start to retire in FY2039/40 for the "Acquire 16 C130Js" option and in FY2041/42 for the "Acquire 19 C130Js" option.

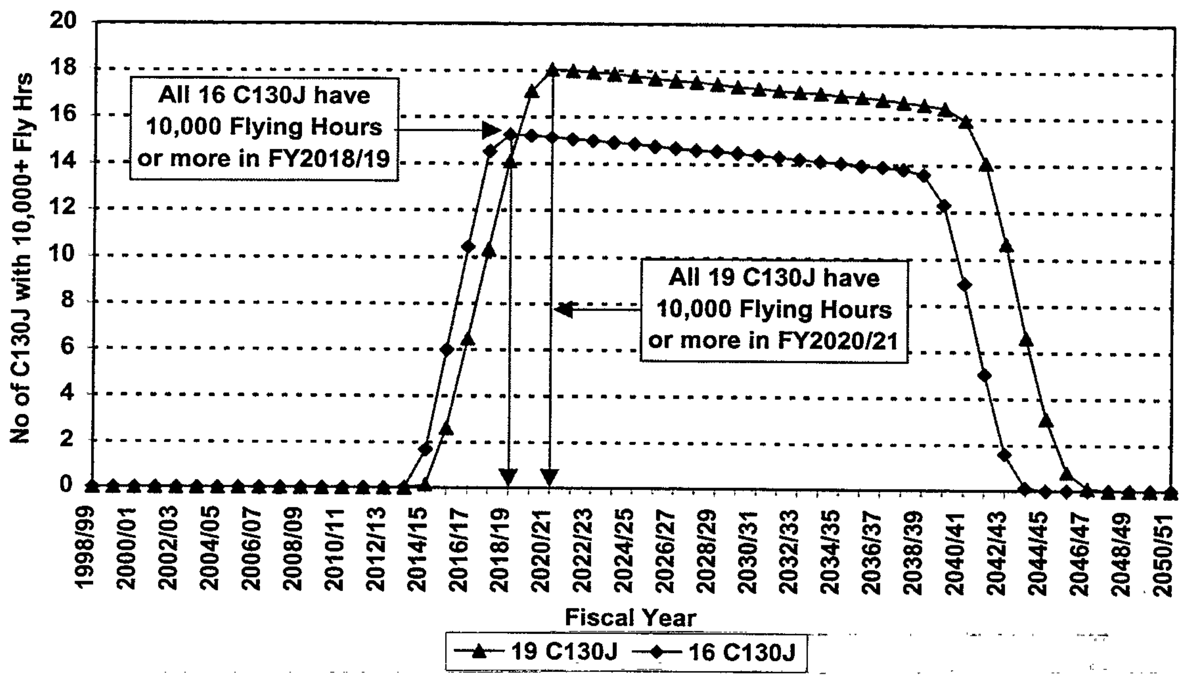

Figure 8: Number of C130J going to PSI; YFR=30,000 hours.

Observations from the Structural Life Analysis

41. **Year of retirement (Fleet Life).** Table II shows a summary of the SLA results. The SLA shows that with either YFR, retaining or replacing the CC130Es can provide airlift capability far beyond 2010. The SLA also shows differences in fleet life between the options that were examined. The fleet life differences are consistent for both YFR limits.

TABLE II

FIRST YEAR OF RETIREMENT

Option	YFR=20,000 hours	YFR=30,000 hours
Status Quo	FY2012/13	FY2007/08
SLEP 19 CC130E	FY2038/39	FY2026/27
Replace with 19 C130J	After FY2050/51	FY2041/42
Replace with 16 C130Js	After FY2050/51	FY2039/40

42. What the SLA does not show however is the risk associated with each option. Currently, the CC130Es are in very good condition thanks to an aggressive maintenance program. In fact, it appears that they are among the best maintained military Hercules. However, it is difficult to predict with certainty how the condition of these aircraft will evolve.

43. **Cumulative flying hours.** Table III shows aircraft cumulative flying hours for each option. The cumulative flying hours are calculated over the life cycle. The reader should refer to the section **Life Cycle Time Frame** for a discussion of the length of the life cycle. The differences in cumulative flying hours for a given YFR are caused by the random allocation of flying hours by the simulation model. Simulation results showed that the "Acquire 16 C130Js" option is not capable of maintaining a YFR of 30,000 hours for the whole course of the life cycle because of the retiring CC130H73&H84s and CC130H90s. Annex A discusses the flying hours results in more details.

TABLE III

CUMULATIVE FLYING HOURS DURING THE LIFE CYCLE

YFR	SLEP 19 CC130E	19 C130J	16 C130J
20,000 hours	256,048.3	273,828.1	267,477.1
30,000 hours	386,348.5	409,255.2	372,164.6

ECONOMIC LIFE ANALYSIS

44. The second part of a Life Cycle Costing analysis is the Economic Life Analysis (ELA). The ELA examines the financial implications of the three options studied in the SLA: refurbishing the CC130Es with the SLEP program, acquire 19 C130Js, and acquire 16 C130Js. These three options are examined for a YFR of 20,000 hours and a YFR of 30,000 hours because some Personnel, Operations and Maintenance (P, O&M) costs are variable and depend on the flying rate.

45. The CC130 Economic Life Analysis (CC130 ELA) model was developed to support the ELA. It is implemented in an Excel spreadsheet and is used to estimate P, O&M costs over the life cycle of the aircraft and to estimate Capital Investment costs incurred by each option. All costs in the CC130 ELA model are in constant FY1998/99 Canadian dollars.

46. The P, O&M cost structure is derived from the Weapon System Support Plan (WSSP) [12]. The P, O&M cost structure also includes fuel costs calculated from fuel price and from engine fuel burn, and personnel costs estimated from unit establishment. The WSSP is central to the economic model, and is explained in Annex B.

47. The WSSP is compiled for the fleet of 32 CC130 aircraft. Since the present analysis is concerned with the ELA of the 19 CC130E aircraft, total costs in the WSSP must be apportioned to reflect the consumption of WSSP funds by the CC130Es. All the cost items in the WSSP, except Spares and R&O, can be apportioned in direct proportion to the number of CC130E in the Hercules fleet. That is, to obtain the share of WSSP funds consumed by the 19 CC130Es, each cost is multiplied by 19/32 ([13],[14]).

48. The case of Spares and Repair and Overhaul (R&O) is a little more complicated. The consumption of these funds by the CC130E aircraft is not only related to the number of CC130E aircraft in the fleet and their share of the total flying hours, but depends also on their Reliability and Maintainability (R&M) characteristics. R&M parameters show that an older aircraft consumes more Spares

and R&O resources and more Maintenance Man-Hours than a new aircraft [15]. A cost apportionment method based on maintenance parameters was used in the CC130 ELA model to apportion Spares and R&O Costs between the three CC130 sub-fleets.

49. Costs figures in the WSSP are in Budget Year (BY) dollars. For an economic analysis to make sense, it is necessary to convert BY dollars to Constant Year (CY) dollars. In the present analysis, the reference year for constant dollars is FY1998/99. The inflation rates relevant to the WSSP [16] are taken from the DND Economic Model (DND EM) [17].

Cost Breakdown Structure for Personnel, Operations and Maintenance

50. Table IV shows the Cost Breakdown Structure (CBS) used to develop the CC130 ELA model, and the value of each cost factor. These costs apply only to the CC130E and the C130J. Spares, R&O, and Fuel Costs are modelled as costs per flying hour, and are the only costs in the CC130 ELA model that are in direct proportion to the hours flown. Software Support, Aircrew and Maintenance Personnel Costs are modelled as costs per year and are not affected by the number of hours flown. Fixed Costs include engineering services, projects, foreign military sales, publications, cooperative logistics, ammunitions and miscellaneous costs, and they are not affected by the hours flown.

TABLE IV

CC130E AND C130J P, O&M COSTS

Cost Item	19 CC130Es option	19 C130Js option	16 C130Js option
Spares	$443/FHr	$248/FHr	$248/FHr
R&O	$1073/FHr	$1016/FHr	$1016/FHr
Fuel Burn	2600 litres/FHr	2059 litres/FHr	2059 litres/FHr
Software Support	$312 K per Year	$2.85 M per Year	$2.4 M per Year
Fixed Costs	$17.8 M per year	$17.8 M per year	$17.8 M per Year
Aircrew	$14.6 M per Year	$9.5 M per Year	$8.1 M per Year
Maintenance Personnel	$32.0 M per Year	$21.0 M per Year	$21.0 M per Year

51. All the cost factors for the CC130E in Table IV are based on an average value of costs in the WSSP for FY1993/94 to FY1998/99, calculated in Constant FY1998/99 dollars. The Spares and the R&O costs for the C130J were provided by Lockheed Martin Aeronautical Systems (LMAS) [18]. Fuel Burn is based on test bench data provided by Allison [19].

52. Annual Spares Cost per Flying Hour ($SPARES_E$) and Annual R&O Cost per Flying Hour ($R\&O_E$) for the CC130E are calculated with equations (1) and (2), respectively. In these equations, AvgSPARES is the 6-year average annual spares cost, AvgR&O is the 6-year average annual R&O cost, AvgHrs is the 6-year average number of flying hours, and MTBLD is the 6-year average of the Mean Time Between Logistic Demand. The subscripts E, H7, and H9 refer to the CC130E, the CC130H73&H84, and the CC130H90&H90-30, respectively. This method of cost apportionment was developed in [20], and it reflects the higher usage of spares and R&O funds by older aircraft.

$$SPARES_E = AvgSPARES \times \left[\frac{AvgHrs_E}{AvgHrs_E + \left(AvgHrs_{H7} \times \frac{MTBLD_E}{MTBLD_{H7}} \right) + \left(AvgHrs_{H9} \times \frac{MTBLD_E}{MTBLD_{H9}} \right)} \right] \quad (1)$$

$$R\&O_E = AvgR\&O \times \left[\frac{AvgHrs_E}{AvgHrs_E + \left(AvgHrs_{H7} \times \frac{MTBLD_E}{MTBLD_{H7}} \right) + \left(AvgHrs_{H9} \times \frac{MTBLD_E}{MTBLD_{H9}} \right)} \right] \quad (2)$$

53. Total annual spares cost for the CC130E is calculated with equation (3). Here, $\frac{\text{Flying Hours}_E}{\text{Year}}$ is the sum of all CC130E flying hours per year, calculated in CC130 SLAM and imported in the CC130 ELA model, and $SPARES_E$ is the annual spares cost per flying hour calculated in equation (1). Total annual R&O costs for the CC130Es are calculated in the same manner.

$$\frac{\text{SPARES Cost}_E}{\text{Year}} = SPARES_E \times \frac{\text{Flying Hours}_E}{\text{Year}} \quad (3)$$

54. As previously discussed, fuel costs are calculated from fuel price and from engine fuel burn. Fuel costs are calculated in CC130 SLAM to capture the impact of the T56-15 engine upgrade on the CC130E fleet fuel costs. Fuel costs are then imported in the CC130 ELA model. The T56-15 engine upgrade for the CC130Es is done progressively, at a rate of two aircraft per year. The effect of this engine upgrade is to progressively reduce the total fuel consumption of the CC130E fleet, thereby reducing the total fuel cost for this fleet. CC130 SLAM calculates total fuel cost per year with equation (4).

$$\frac{\text{Fuel Cost}}{\text{Year}} = \frac{\text{Fuel Burn}}{\text{Flying Hour}} \times \frac{\text{Flying Hours}}{\text{Year}} \times \text{Fuel Price} \qquad (4)$$

55. Software support costs shown in Table IV are the CC130Es' share of the total software support cost for the CC130 fleet. Software support costs apply to all the CC130Es after they received the AUP. Software support costs for the CC130Es pay for software configuration management, updates, changes in aircraft configuration, certification requirements, installation of additional equipment, etc. [21]. Contacts with other countries who are in the process of acquiring a fleet of C130J indicated that they expect this aircraft to require costly software support. Software support costs for the C130Js shown in Table IV are a rough estimate provided by the AUP aircraft software support managers, based on the advice from foreign C130J customers.

56. Aircrew and Maintenance Personnel costs for the CC130E are estimated with a military personnel costing model developed by the author. This model uses unit establishment broken down by Military Occupational Code (MOC) and rank [22] and Regular Force personnel costs from the Cost Factors Manual [23] to estimate annual Aircrew and Maintenance Personnel costs for each unit. Aircrew and Maintenance Personnel costs are shown in Table IV and represent the costs for 19 CC130Es.

57. The C130J is advertized as a 3 crew member aircraft, and has provisions to accommodate a fourth crew member should it be required. Aircrew costs for the C130J are estimated as follows. All Air Navigator and Flight Engineer positions are deleted from the military personnel cost model, and are replaced by Mission

Specialists. The number of Mission Specialist positions in each squadron is set to half the number of Air Navigator positions in unit establishment. The rank distribution for Mission Specialists is the same as the Air Navigators. An annual cost for Mission Specialists is calculated and is added to the annual cost for Pilots and Loadmasters. This gives a total annual aircrew cost for the C130J if all CC130 are replaced by C130J. This cost is divided by the number of aircraft to obtain an aircrew cost per aircraft per year for a C130J. It is not the intention of the CF to replace all its CC130 by C130J. For that reason, the aircrew cost per aircraft per year for a C130J is multiplied by the number of C130J in each replacement option to obtain the total annual aircrew cost for the C130J shown in Table IV.

58. The CC130 ELA model assumes that fewer aircrews are required by a fleet of 16 C130J and therefore that aircrew costs for 16 C130Js are lower than for 19 C130Js. It is still uncertain whether 16 C130Js will require fewer aircrews than 19 C130Js, given that the YFR stays the same for both replacement options. However, even if future analysis determines that 16 C130Js will require the same number of crews as 19 C130Js, it is not going to change the conclusion of the present analysis since it makes only a difference of $29.4 M over the life cycle.

59. Lockheed claims that the C130J is significantly less maintenance intensive than the CC130E and CC130H because it makes extensive use of computerized built-in testing, has a computerized avionics suite, and has improved engines and propellers that are easier to maintain. For these reasons, this new aircraft is expected to require less maintenance personnel. A superficial examination of the C130J new systems and a comparison of common systems between the C130J and the CC130E estimated the costs in maintenance personnel to support the CC130J at two thirds of the costs in maintenance personnel to support the CC130E [24]. However, should the CF decide to acquire C130Js, a more in-depth examination of maintenance personnel requirements will have to be conducted, and this is likely to result in different Maintenance Personnel costs than those estimated in the present analysis. The present analysis assumes that Maintenance Personnel Costs are the same if YFR=20,000 hours and if YFR=30,000 hours. It is expected

that the CF will not open additional positions for maintenance personnel if the YFR is 30,000 hours. More productivity will be required from maintenance personnel.

Capital Investment Programs

60. In addition to P, O&M costs, Capital Investment costs are also included in the CC130 ELA model. Retention of the CC130E in the CF Hercules fleet will require investment in upgrades and refurbishment. Capital Investment programs for the CC130E retention are listed in Table V [13]. The LCC analysis assumes a worst case scenario and uses a cost of $12 M per aircraft for the SLEP. Based on this price tag, the total cost to retain the 19 CC130Es beyond 2010 is estimated to be $370 M, when the other upgrade programs are included. The first AUP is not included in the CC130 ELA model because it is already paid for.

TABLE V

CAPITAL INVESTMENT PROGRAMS FOR CC130E RETENTION

Item	Cost per aircraft	Cost for 19 CC130E
T56-15 Engine Upgrade	$2.45 M	$47.0 M
Follow-on AUP	$5.0 M	$95.0 M
SLEP	$12.0 M	$228.0 M
Total	$19.45 M	$370.0 M

61. The cost of the SLEP depends heavily on what kind of program will be required by the centre wing of the aircraft. The costliest option is a centre wing replacement. The least expensive option is a centre wing improvement. Detailed structural inspections of the centre wing on all CC130E will determine what program will be required. It is expected that this information will be available in December 1998. Table VI shows the details of the SLEP for the CC130E. The costs shown in Table VI are estimates only, and are subject to change once the actual requirements are known.

TABLE VI

DETAILS OF THE CONTENTS OF THE SLEP; COSTS PER AIRCRAFT

Item	Centre Wing Replacement	Centre Wing Improvement
Centre Wing	$6.0 M	$1.5 M
Fuselage	$1.5 M	$1.5 M
Rewiring	$1.5 M	$1.5 M
Overhead	$1.9 M	$1.9 M
Sub Total	$10.9 M	$6.4 M
Contingency (10%)	$1.1 M	$0.6 M
Total	$12.0 M	$7.0 M

62. Capital Investment costs incurred by the acquisition of C130Js are shown in Table VII. The cost structure shown in this table is typical of an acquisition program in the CF [25]. Where indicated, the cost of the items in the acquisition plan shown in Table VII is calculated as a percentage of the total cost to acquire a given number of aircraft. These costs are based on a basic aircraft price of $79.05 M CAN. This price is valid for 1998. According to this cost structure, the acquisition of 19 C130Js requires a capital investment of $2.2 B, while acquisition of 16 C130Js requires an investment of $1.8 B.

TABLE VII

DETAILED COSTS FOR THE ACQUISITION OF C130J AIRCRAFT

Cost Item	% of Cost	19 C130Js	16 C130Js
Aircraft	N/A	$1,502 M	$1,265 M
Modifications	4.0%	$60 M	$51 M
Project Support (PMO+PWGSC)	N/A	$10 M	$10 M
Infrastructure	2.5%	$38 M	$32 M
Contractor Support	3.5%	$53 M	$44 M
Training	5.0%	$75 M	$63 M
Spares	15.0%	$225 M	$190 M
Sub Total	N/A	$1,962 M	$1,654 M
Contingency	10.0%	$196 M	$165 M
Total	N/A	$2,159 M	$1,820 M

Life Cycle Time Frame

63. The CC130Es are currently in service in the CF, and the SLA showed that if they are refurbished, they will remain in service until the mid 2020's if YFR=30,000 hours, and until the late 2030's if YFR=20,000 hours. If the CF decides to replace the CC130Es with C130Js, the latter will progressively enter service in 2005 and remain in service until the 2040's if YFR=30,000 hours. If YFR=20,000 hours, the C130 J will progressively enter service in 2010 and remain in service at least until 2050.

64. The length of the life cycle was selected based on the estimated duration of a fleet of refurbished CC130E if the YFR is 30,000 hours (see Figure 7). In that specific case, the time frame goes from 2010 to 2030 inclusive, which gives a 21-year life cycle. The Cumulative P, O&M Costs of each option are calculated over the 21-year periods shown in Figure 9. In the case of the replacement option, the 21-year life cycle excludes the phasing-in period during which C130J are introduced and CC130E are retired. It was found in the course of the analysis that including the phasing-in period in the life cycle causes distortions in P, O&M costs, because of the declining number of CC130E aircraft and the growing number of C130J aircraft, and the transfer of costs from the old aircraft to the new aircraft. The staggered time frames between the SLEP and the Replacement in Figure 9 allow the comparison of the estimated P, O&M costs for 19 CC130Es with the P, O&M costs for 19 C130Js and the P, O&M Costs for 16 C130Js.

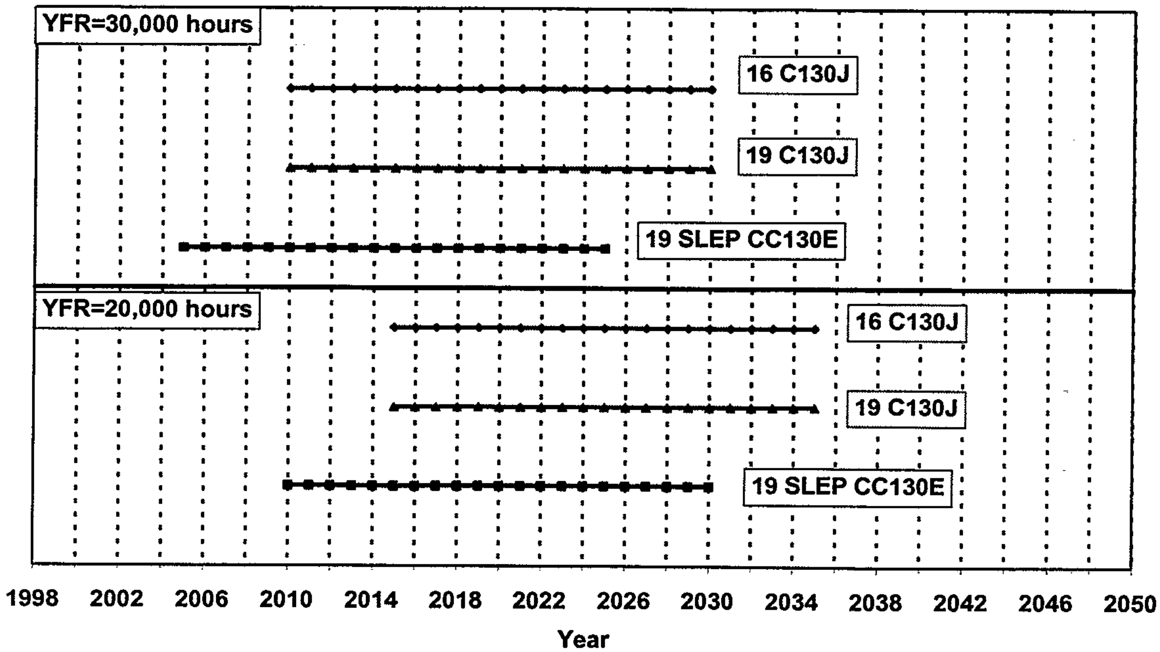

Figure 9: Life Cycle Time Frames.

Residual Value

65. A 21-year life cycle that starts in 2010 if YFR=30,000 hours and in 2015 if YFR=20,000 hours encompasses about 2/3 of the life for either fleet of C130J, as Figures 5 and 7 indicate. One way to account for remaining C130J aircraft life at the end of the life cycle is to calculate a residual value

66. The residual value model used in the present analysis is based on aircraft age only, and is similar to Lockheed's residual value model [18]. Figure 10 shows the linear depreciation model used to calculate C130J residual value. The model assumes a linear loss rate of 3.8% per year from 0 to 15 years of age, and a linear loss rate of 1.8% per year from 16 to 30 years of age. A linear depreciation rate is a close enough approximation for the purpose of the present analysis.

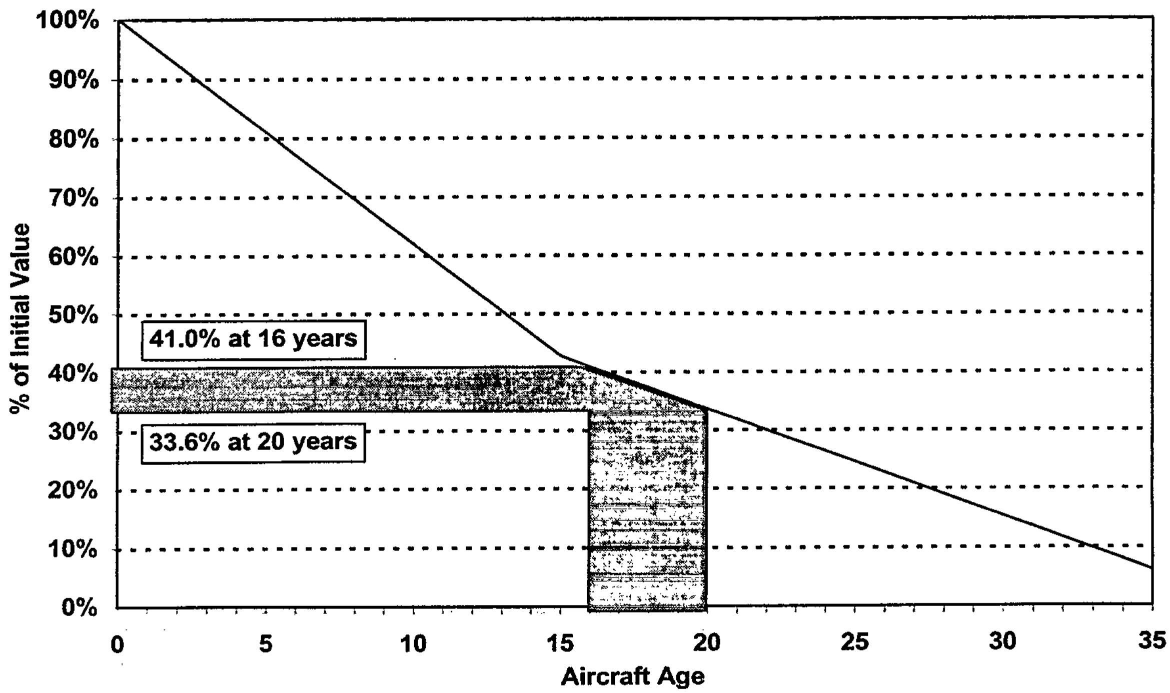

Figure 10: Residual value of C130J aircraft as a function of aircraft age.

67. The residual value of either replacement fleet depends on the distribution of aircraft age. The acquisition program is spread over five years for the 19 C130Js, and 4 years for the 16 C130Js, phasing at 4 aircraft per year. Consequently, at the end of the 21-year life cycle, the aircraft are distributed in different age groups and have different residual values. Table VIII shows how the aircraft are distributed among the different age groups, and show their residual values. The values in Table VIII are based on a basic aircraft price of $79.05 M CAN for the C130J. This price includes a $1 M US ($1.5 M CAN) discount off the 1998 catalogue price of $53.7 M US ($80.55 M CAN) per aircraft.

68. In this analysis, the residual value is corrected for crash attrition as follows. Figure 5 shows that between 2015 and 2035, one C130J is lost to crash attrition for both replacement options. The corrected residual value for YFR = 20,000 hours is calculated based on the assumption that the lost aircraft is one of the first aircraft acquired and is 20 years old. The rationale behind this assumption is that the older aircraft have been flying for a longer time and are therefore more exposed to risk.

Similarly, Figure 7 shows that two C130J are lost to crash attrition between 2010 and 2030. The residual value corrected for attrition is shown in Table IX.

TABLE VIII

C130J RESIDUAL VALUE AS A FUNCTION OF AIRCRAFT AGE

(NOT CORRECTED FOR CRASH ATTRITION)

No A/C	A/C Age	ResVal (%)	ResVal per A/C	Tot ResVal	16 C130Js	19 C130Js
4	20	33.6%	$26.6 M	$106.3 M		
4	19	35.5%	$28.0 M	$112.1 M		
4	18	37.3%	$29.5 M	$117.9 M		
4	17	39.1%	$30.9 M	$123.7 M	$461 M	
3	16	41.0%	$32.4 M	$97.2 M		$558 M

TABLE IX

C130J RESIDUAL VALUE AS A FUNCTION OF AIRCRAFT AGE

(CORRECTED FOR ATTRITION)

YFR	Predicted Losses	16 C130J	19 C130J
20,000 hours	1	$434 M	$531 M
30,000 hours	2	$410 M	$504 M

CC130 ELA model results

69. The Measures of Effectiveness (MOEs) for the ELA are the Cumulative P, O&M Cost over the Life Cycle, the P, O&M Cost per Flying Hour, the Capital Cost, the Total Life Cycle Cost, the Total Life Cycle Cost per Aircraft, the Total Life Cycle Cost per Flying Hour, and the Normalized Total Cost per Flying Hour. Each of these MOEs is calculated for both YFR limits.

70. Figure 11 shows the cumulative P, O&M costs over a 21-year Life Cycle for 19 refurbished CC130Es, 19 new C130Js, and 16 new C130Js. The C130J has a clear advantage over the CC130E. If YFR=20,000 hours, it is expected that the CF will save $351 M over 21 years by operating a fleet of 19 C130Js instead of a fleet of 19 SLEP CC130Es. The savings are estimated at $405 M over 21 years with a

fleet of 16 C130Js. The savings are more substantial, ranging from $393 M over 21 years for 19 C130Js to $511 M over 21 years for 16 C130Js, if the YFR is 30,000 hours.

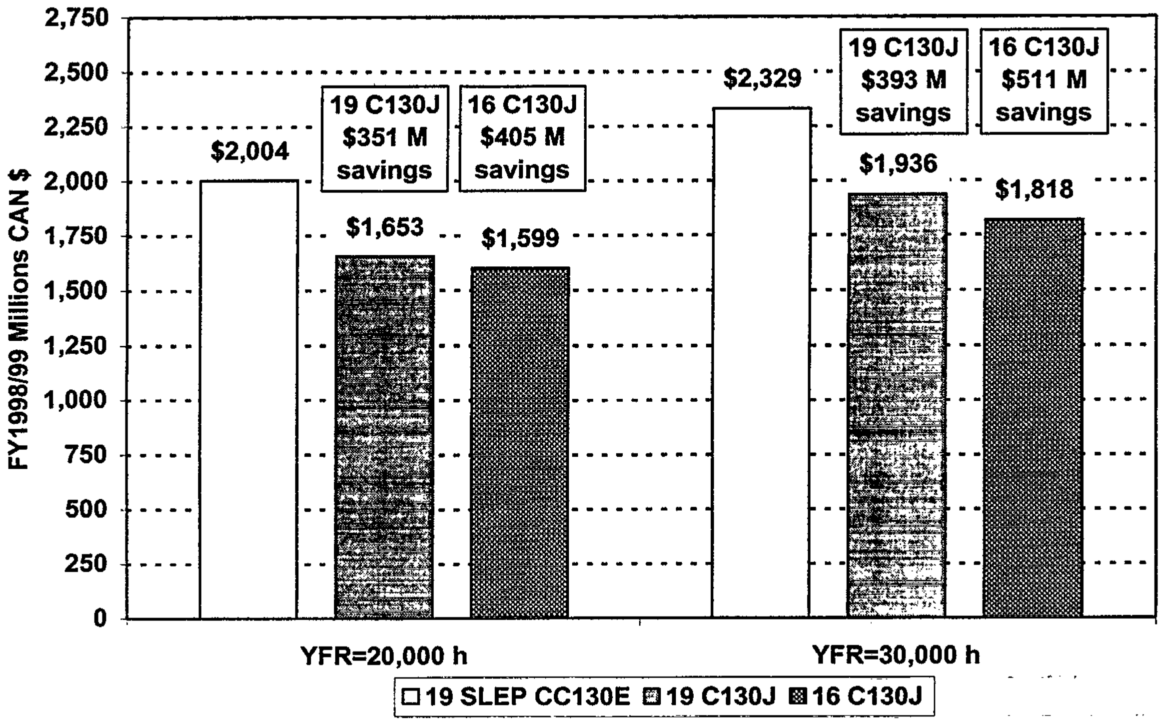

Figure 11: Total P, O&M costs for SLEP CC130E vs C130J.

71. Figure 12 shows a breakdown of the Cumulative P, O&M Costs for a YFR of 20,000 hours, over a 21-year life cycle. The estimated savings shown in Figure 11 are incurred by the lower costs of the C130J in Spares, Maintenance Personnel, Aircrew, and Fuel. Only marginal savings are expected in R&O costs for a fleet of 16 C130Js.

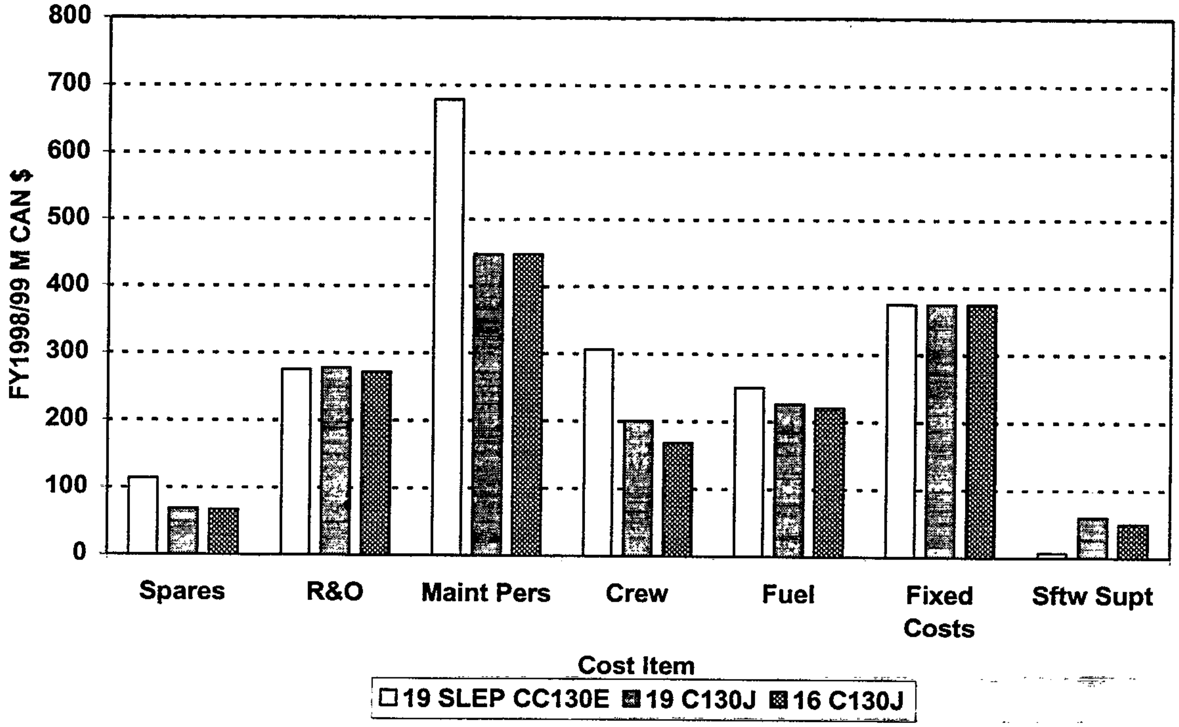

Figure 12: Detailed P, O&M costs for the three options, YFR=20,000 hours.

72. Figure 13 shows the Estimated P, O&M Cost per Flying Hour for the two YFR limits. The P, O&M Cost per Flying Hour is calculated as follows. The Total Annual P, O&M Cost is calculated in the CC130 ELA model for each year of the life cycle. CC130 SLAM outputs the Total Flying Hours per Year. The Annual P, O&M Cost per Flying Hour is calculated by dividing the Total Annual P, O&M Cost by the Total Flying Hours per Year. The P, O&M Cost per Flying Hour shown in Figure 13 is a 21-year average of the Annual P, O&M Cost per Flying Hour.

73. The chart in Figure 13 highlights the lower P, O&M Cost per Flying Hour of a fleet of C130J aircraft compared to a fleet of SLEP CC130E aircraft. The potential savings in P, O&M Cost per Flying Hour relative to the 19 SLEP CC130Es are estimated to be 22.8% for 19 C130Js and to 23.4% for 16 C130Js if the YFR is 20,000 hours. The potential savings in P, O&M Cost per Flying Hour are estimated to be 21.6% for 19 C130Js and to 19.1% for 16 C130Js if the YFR is 30,000 hours. The SLEP program is not expected to affect the P, O&M Costs of the refurbished CC130Es.

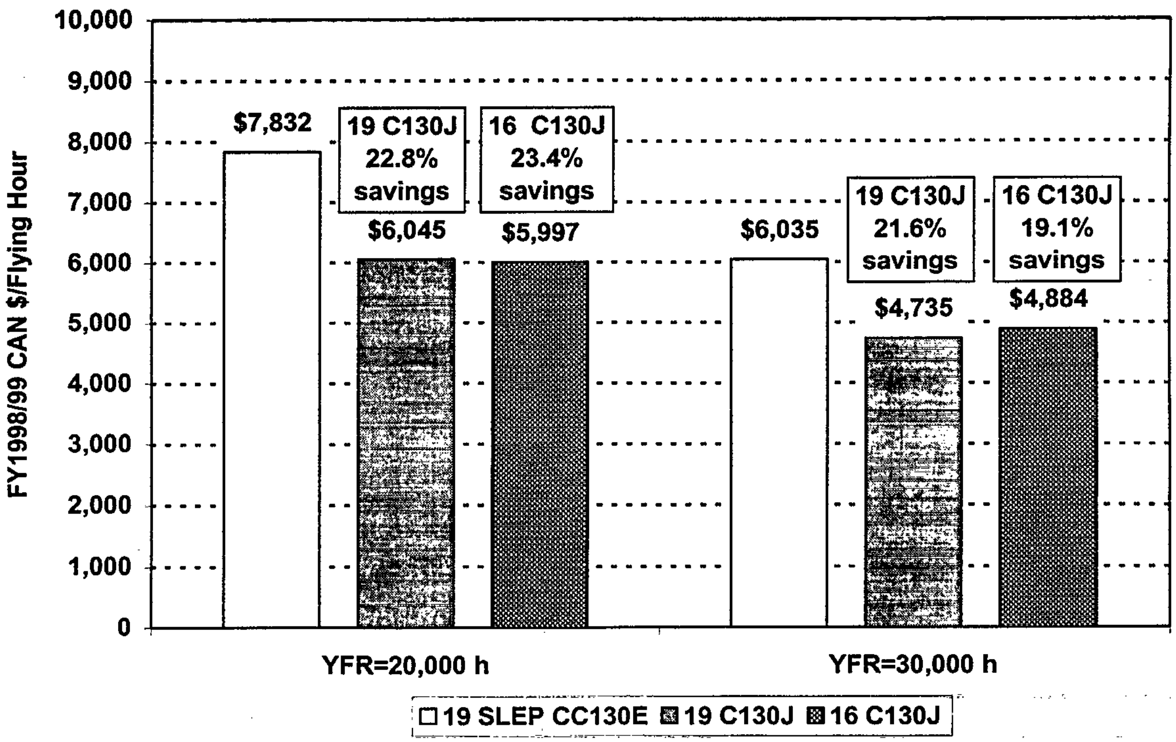

Figure 13: Estimated P, O&M Cost per Flying Hour, 21-year life cycle.

74. Capital Investment Costs for the three options are compared in Figure 14. Capital Investment Costs are independent from the flying rate. Figure 14 clearly shows that refurbishing the CC130Es with the SLEP comes at a much lower price than the replacement by new C130J aircraft. As explained in the section **Capital Investment Programs**, the retention of the 19 CC130E aircraft requires an investment of $370 M, while their replacement by 19 C130Js requires an investment of $2,159 M, and their replacement by 16 C130Js requires an investment of $1,820 M. The left hand side of Figure 14 does not reflect the fact that at the end of the 21-year life cycle, the refurbished CC130Es reached the end of their service life, while the C130Js are about 2/3 of the way through their service life. Even when accounting for the substantial residual values calculated in Table IX, the acquisition of 19 C130Js is $1,258 M more expensive than refurbishing 19 CC130Es if YFR = 20,000 hours. The acquisition of 16 C130Js is $1,016 M more expensive than refurbishing 19 CC130Es if YFR = 20,000 hours. If YFR = 30,000 hours, the acquisition of 19 C130J is $1,285 M more expensive, and the acquisition of 16 C130J is $1,043 M more expensive.

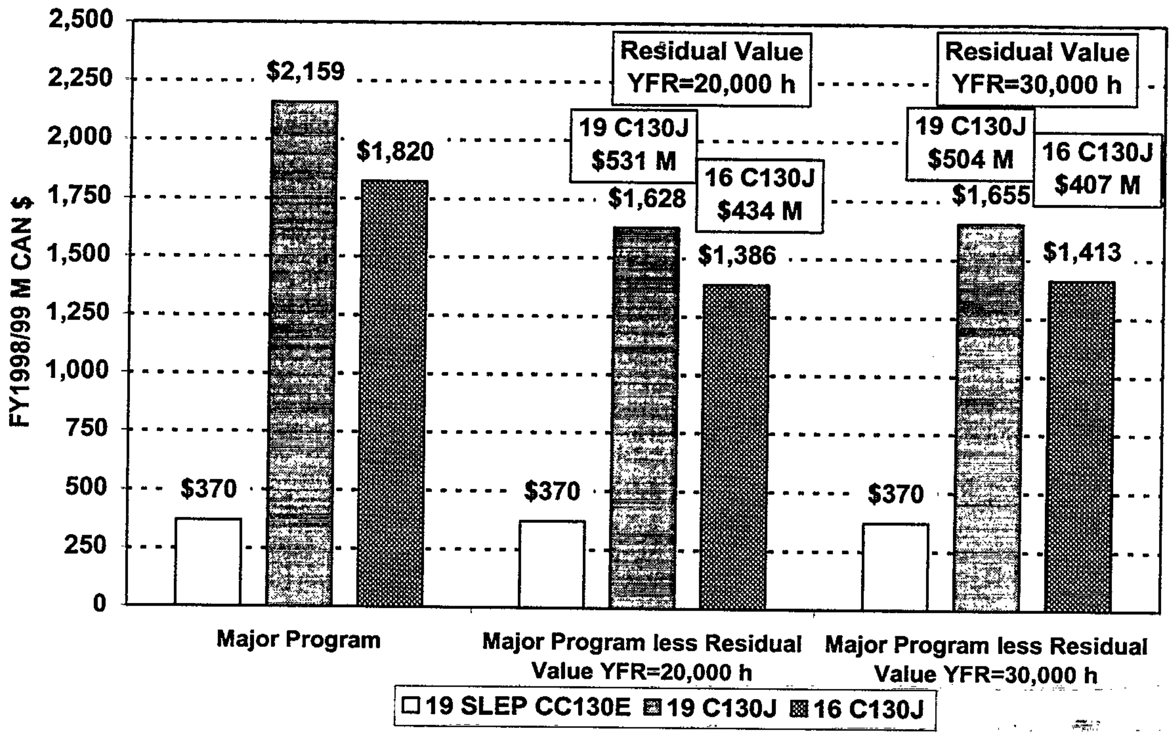

Figure 14: Capital Investment Costs for the three options.

75. Figure 15 shows the Total Life Cycle Cost for a YFR of 20,000 hours. Total Life Cycle Cost is the sum of Cumulative P, O&M Costs and Capital Investment Costs. When the residual value corrected for attrition is subtracted from Total Life Cycle Cost, the acquisition of 19 C130Js is $908 M more expensive than refurbishing 19 CC130Es, and the acquisition of 16 C130Js is $611 M more expensive than refurbishing 19 CC130Es.

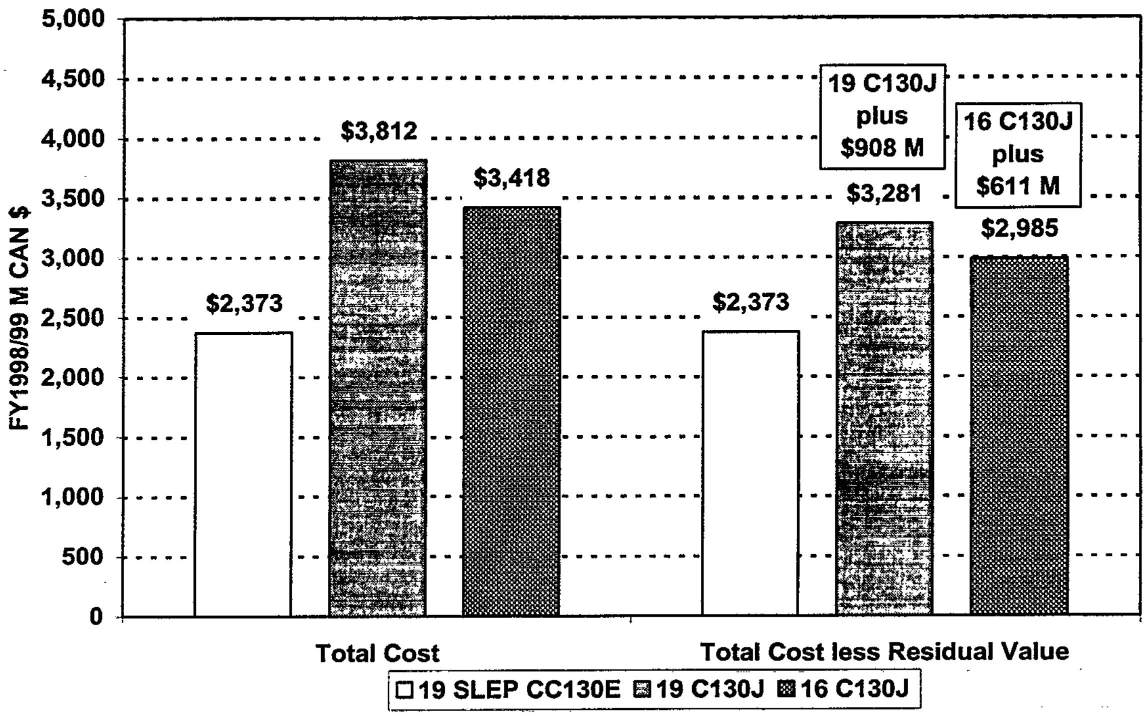

Figure 15: Total Life Cycle Cost, YFR=20,000 hours, M CAN$.

76. Figure 16 shows the Total Life Cycle Cost for a YFR of 30,000 hours. In this case, when accounting for a residual value corrected for attrition at the end of the life cycle, the replacement by 19 C130Js is $892 M more expensive, while the replacement by 16 C130Js is $531 M more expensive.

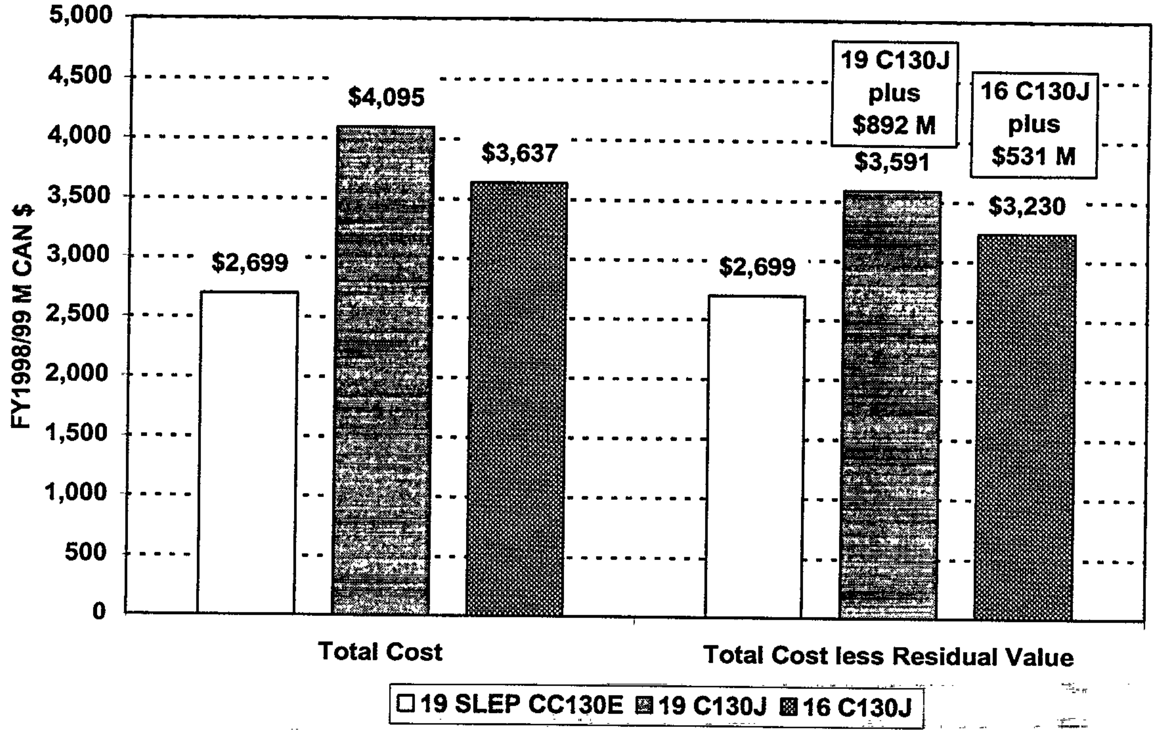

Figure 16: Total Life Cycle Costs, YFR=30,000 hours, M CAN $.

77. The Average Total Life Cycle Cost per Flying Hour if YFR=20,000 hours is shown in Figure 17. It is calculated by dividing the Total Life Cycle Cost by the cumulative number of flying hours over the life cycle shown in Table III. Figure 17 clearly shows that even with residual value corrected for attrition subtracted at the end of the life cycle, both replacement options are more expensive than refurbishing the CC130Es. Replacement with 19 C130Js is 29.3% more expensive, and replacement with 16 C130Js is 20.4% more expensive.

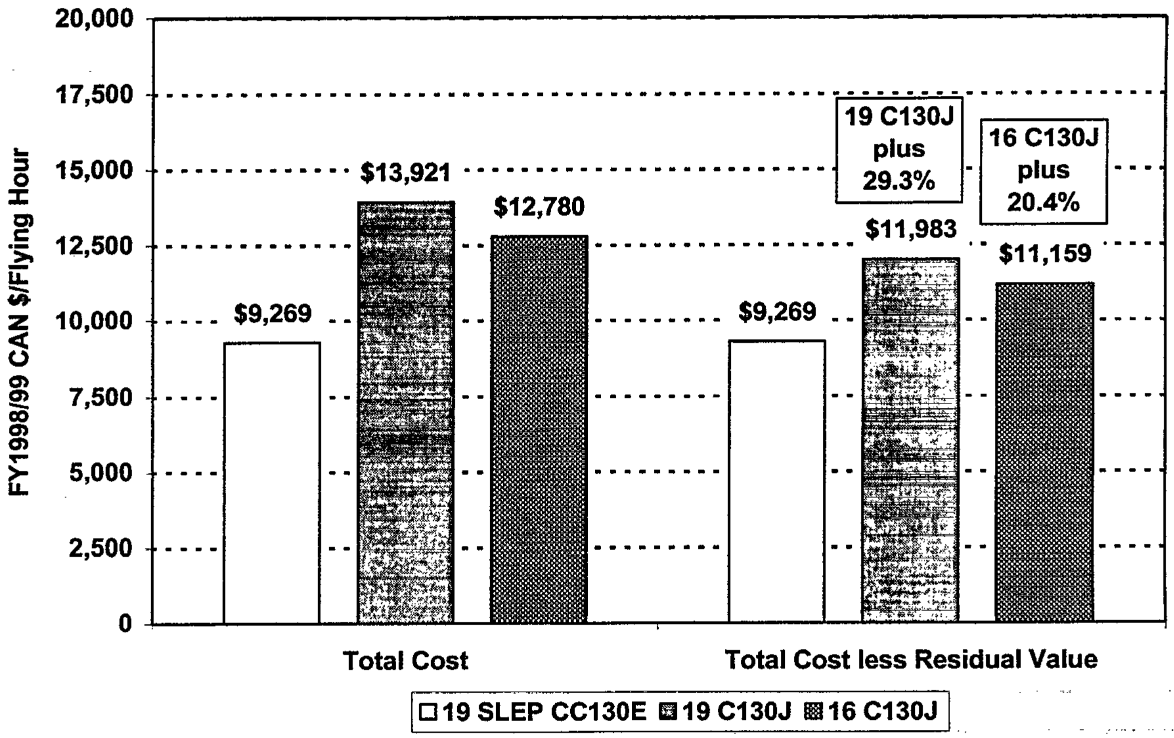

Figure 17: Total Life Cycle Cost per Flying Hour, YFR=20,000 hours.

78. Figure 18 shows the Average Total Life Cycle Cost per Flying Hour calculated for YFR=30,000 hours. Total Life Cycle Cost per Flying Hour corrected for attrition is 25.6% more expensive for 19 C130Js, and 24.3% more expensive for 16 C130Js.

79. Figure 19 shows the Total Life Cycle Cost per Aircraft for YFR=20,000 hours. It is calculated by dividing the Total Life Cycle Cost by the number of aircraft involved in each option. When the residual value corrected for attrition at the end of the life cycle is subtracted, the cost for each of the 19 replacement C130Js is $48 M higher than the cost per SLEP CC130E. Similarly, the cost for each of the 16 replacement C130Js is $62 M higher than the cost per SLEP CC130E.

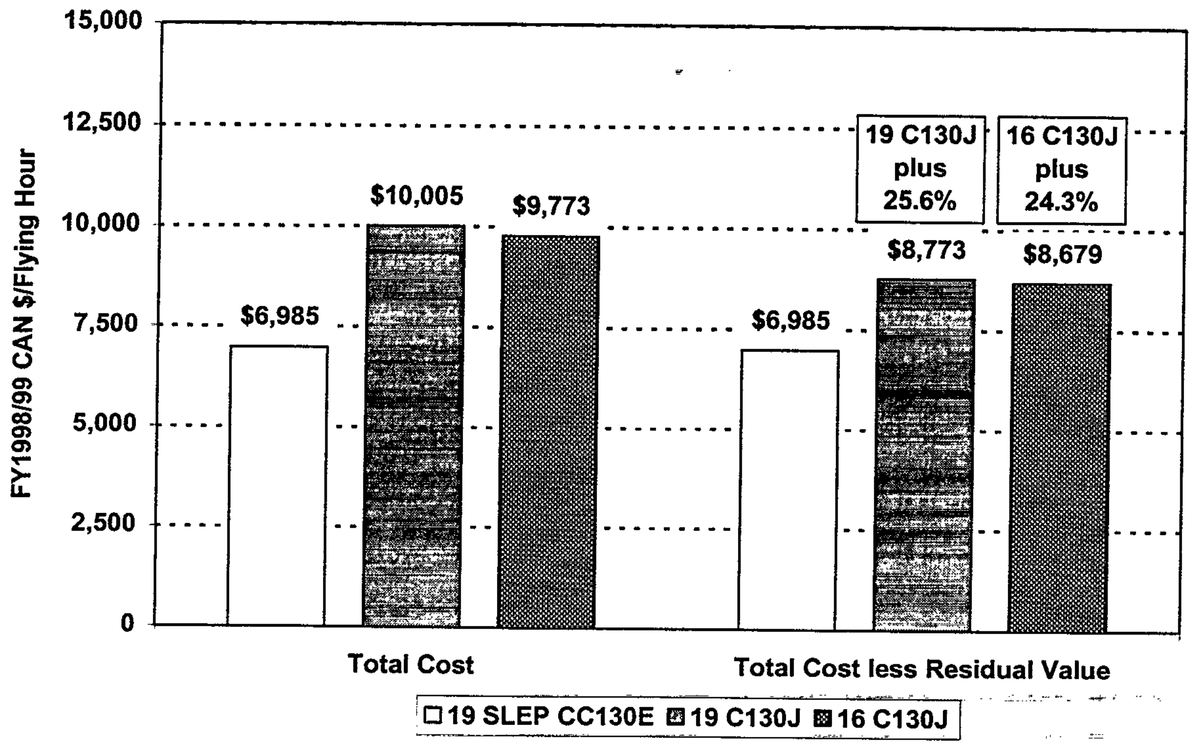

Figure 18: Total Life Cycle Cost per Flying Hour, YFR = 30,000 hours.

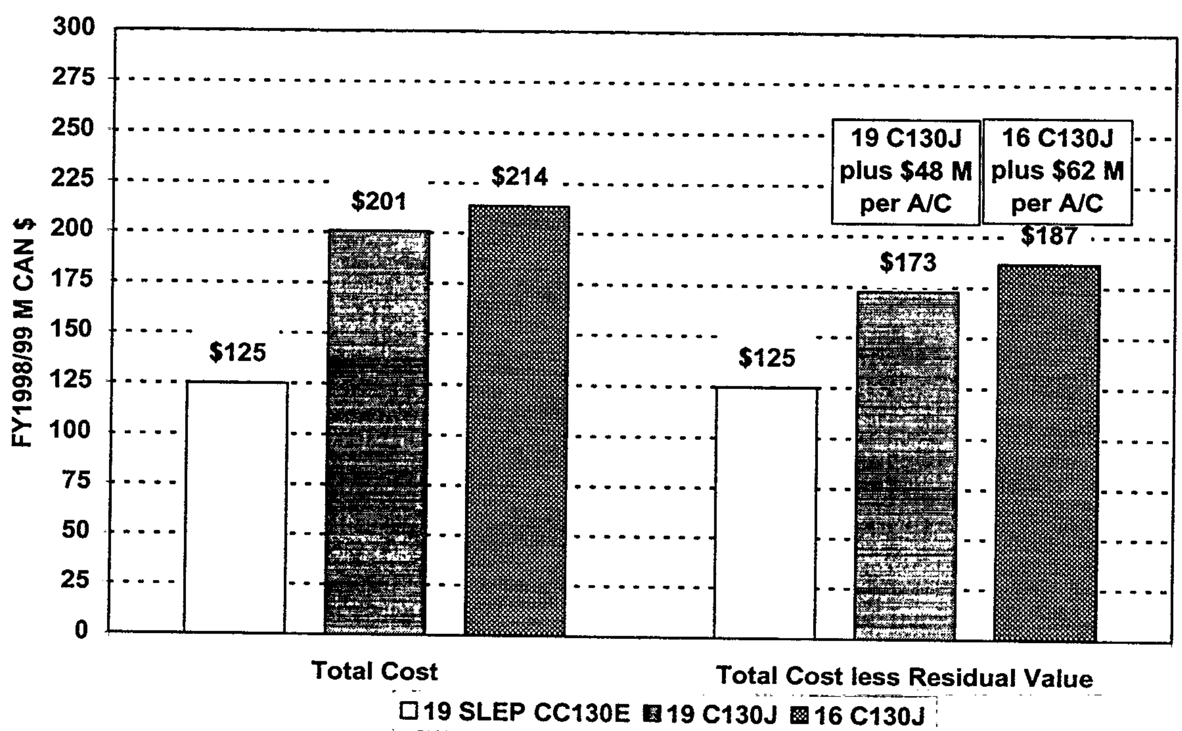

Figure 19: Total Life Cycle Cost per Aircraft, YFR = 20,000 hours.

80. Figure 20 shows the same indicator for YFR=30,000 hours. Again, both replacement options are more expensive than refurbishing the CC130E. When the residual value corrected for attrition at the end of the life cycle is subtracted, the cost for each of the 19 replacement C130Js is $47 M higher than the cost per SLEP CC130E. Similarly, the cost for each of the 16 replacement C130Js is $60 M higher than the cost per SLEP CC130E.

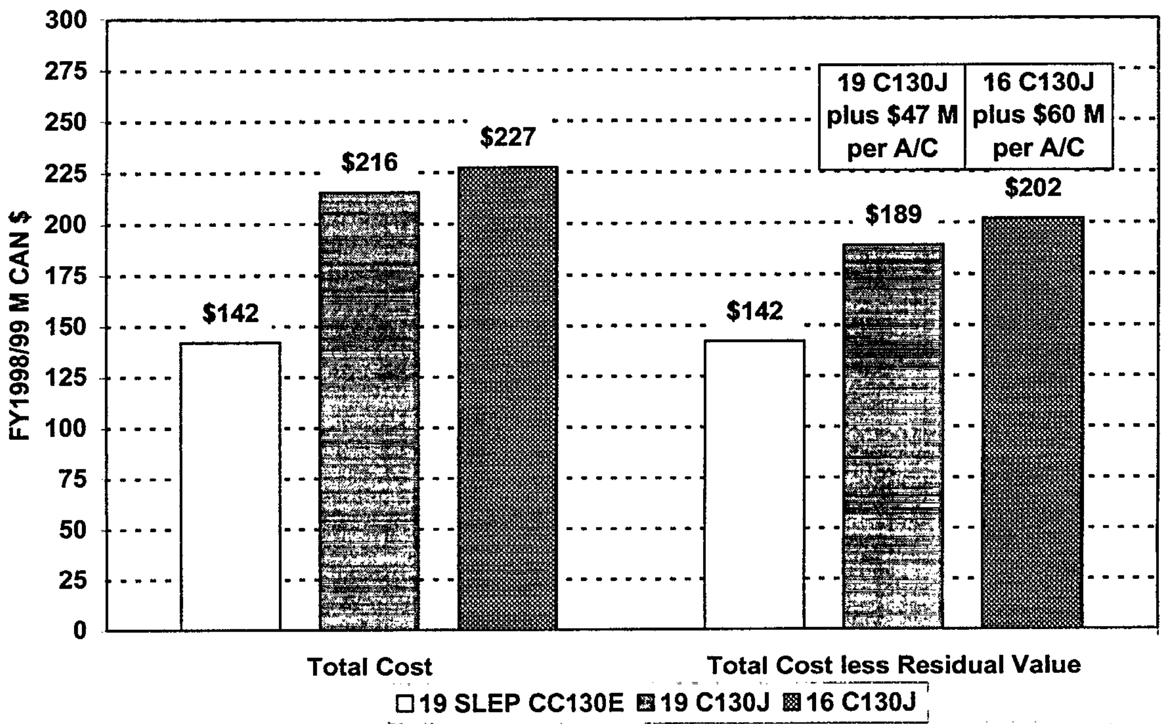

Figure 20: Total Life Cycle Cost per Aircraft, YFR=30,000 hours.

81. The Normalized Total Cost per Flying Hour was developed to compare each option in terms of aircraft life in flying hours. This indicator avoids using residual value, about which there is much uncertainty, to compare on a normalized basis options with different life duration. The Normalized Total Cost per Flying Hour is calculated with equation (5).

$$\text{NCostFHr} = \frac{(\text{P, O \& MCost/FHr} \times \text{A/C Life}) + \text{Capital Investment}}{\text{A/C Life}} \qquad (5)$$

82. The P, O&M Cost per Flying Hour in equation (5) is estimated from simulation data and is shown in Figure 13. Capital Investment Costs are known from the SLEP and the acquisition costs described in the section **Capital Investment Programs**, and are found in Tables V and VII. Aircraft Life in equation (5) is the product of the number of aircraft in each option and the life in flying hours of each individual aircraft in each option. A SLEP adds 20,000 hours to the life of each aircraft. Based on past experience with previous CC130 models, it is reasonable to assume that a new C130J has 40,000 hours of life, although the C130J has never been put to the test. Aircraft life in equation (5) is 380,000 hours for the SLEP of 19 CC130Es, 760,000 hours for 19 C130Js, and 640,000 hours for 16 C130Js. The data to calculate the Normalized Total Cost per Flying Hour is summarized in Table X.

TABLE X

PARAMETERS FOR NORMALIZED TOTAL COST PER FLYING HOUR

Program	SLEP 19 CC130E	Acquire 19 C130J	Acquire 16 C130Js
P, O&MCost/FHR YFR=20,000 hours	$7,832/FHr	$6,045/FHr	$5,997/FHr
P, O&MCost/FHR YFR=30,000 hours	$6,035/FHr	$4,735/FHr	$4,884/FHr
Capital Investment	$370 M	$2,159 M	$1,820 M
Aircraft Life	380,000 hours	760,000 hours	640,000 hours

83. Figure 21 shows the Normalized Total Cost per Flying Hour for YFR=20,000 hours and YFR=30,000 hours. If YFR=20,000 hours, differences in Normalized Total Cost per Flying Hour between the three options are marginal. If YFR=30,000 hours, the Normalized Total Cost per Flying Hour shows a small advantage for the SLEP option. The Normalized Total Cost per Flying Hour for the C130J is driven by the acquisition costs and the aircraft life in flying hours. A variation of the costs in the acquisition plan or in the SLEP, or a significantly different aircraft life in flying hours for each new airframe, could all affect the Normalized Total Cost per Flying Hour and tip the balance in favour of one option or the other.

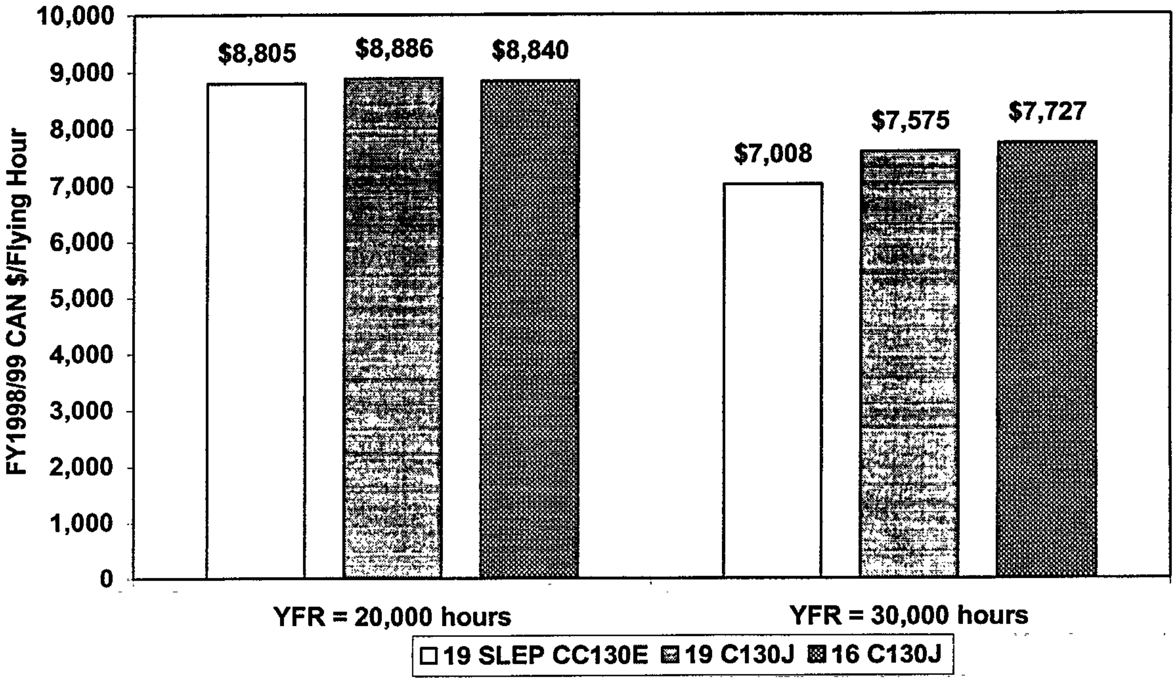

Figure 21: Normalized Total Cost per Flying Hour.

84. Two types of sensitivity analysis were done with the Normalized Total Cost per Flying Hour. The first one examined the effects of varying the basic aircraft price of the C130J. The second examined the effect of varying aircraft life in flying hours for the C130J. In all cases, the Normalized Total Cost per Flying Hour for the CC130E was kept constant and was used as a reference. The results of the sensitivity analysis are in Annex C.

UNEXAMINED ISSUES

85. This analysis examined only a few aspects of the LCC analysis of the CC130Es. Many aspects were not examined, although they play an important role in selecting the best option for the CF. These aspects are: maintenance creep; optimum fleet mix; costs variation; inflation; risk analysis; future supportability issues; technological gap; aircrew concept of operation for the C130J; C130J concept of maintenance; manpower requirements for aircrew and maintenance personnel if the CF operates a mixed fleet of C130J and two types of C130H; cost of maintaining and operating a mixed fleet of C130J and two types of CC130H; etc.

Some effort should be directed towards analyzing some of the aspects listed in this paragraph.

Maintenance Creep

86. Maintenance Creep is defined as the increase in P, O&M cost due to the increasing maintenance burden of an ageing aircraft. In dealing with representatives from the Market Analysis Division of LMAS, the most controversial issue in making the case for aircraft replacement was Maintenance Creep.

87. In their LCC modelling, LMAS Market Analysis Division apply a Maintenance Creep Factor to <u>all</u> P, O&M costs [26]. For the CC130E, the Maintenance Creep factor is 5% per year before the SLEP and 3.5% per year after the SLEP. The Maintenance Creep factor for the C130J is 1% per year, and is applied after 10 years of operation. Hence, according to the LMAS LCC model, as a C130 ages, not only does it become costlier in spare parts and R&O, but it also becomes costlier in fuel, software support, aircrew, and maintenance personnel. It is the opinion of the author that such an undiscriminating application of a Maintenance Creep Factor is a highly questionable assumption, and that its effects on Life Cycle Costs must be interpreted with a great deal of caution.

88. After several discussions with LMAS representatives [26] and with CF aerospace engineers, it was decided not to include maintenance creep in the present analysis for the following reasons. Cost variations in CC130 P, O&M found in the WSSP are caused by budget cut backs, "catch up" after cut backs, contents of support contracts, inventory requirements, and the like. Hence, cost variations in the WSSP are driven by factors that are not related to aircraft ageing. A more direct measurement of the effects of aircraft ageing is found in the maintenance parameters. The R&M analysis for the replacement of the CC130E [2] examined some maintenance parameters for the CC130Es for the last five years. This analysis showed that the CC130Es' maintenance performance is in a steady state, with only minor variations from year to year.

89. An analysis of the CC130Es' maintenance parameters over the life of these aircraft would give a more accurate picture of the effect of aircraft ageing. Such an analysis was done for the CC130H73&H84s by AMDU in 1994 [15]. It indicated that aircraft maintenance performance decreased slowly after entering service, until it reached a steady state and the aircraft stopped deteriorating. The data used in the AMDU study did not show when the steady state ends and aircraft maintenance performance deterioration resumes. Maintenance data is available since day one for CC130 aircraft. It appears possible to extract this data and analyze CC130E maintenance performance to determine if there is a long term trend in their maintenance performance. That could help in assessing the risk of the refurbishment option.

90. The CC130 ELA model was run with a maintenance creep factor for the CC130E and the C130J in order to examine its impact on Life Cycle Costs. In these model runs, the maintenance creep factor for the CC130E was set to 5% per year before the SLEP and 3.5% per year after the SLEP. The maintenance creep factor for the C130J was set to 1% per year 10 years after acquisition. The maintenance creep factor affects only Spares and R&O costs. Results of the CC130 ELA model with a maintenance creep factor were affected in such a manner that replacement of the CC130Es with C130Js would make economic sense. However, as long as the actual maintenance creep factor, if any, is not measured from the CC130E maintenance parameters, CC130 ELA model results with a maintenance creep factor cannot be considered valid, and should not be used to support a replacement decision.

CONCLUSION

91. The Structural Life Analysis showed that the three options are all capable to ensure the current airlift capability beyond 2010. More specifically, the refurbishment of the CC130Es ensures the current airlift capability until the late 2030's if the YFR is 20,000 hours, and until the mid 2020's if the YFR is 30,000 hours. The replacement with C130Js ensures the current airlift capability until 2050 if the YFR is 20,000 hours, and until 2040 if the YFR is 30,000 hours.

92. The ELA showed that depending on C130J fleet size and on the YFR, the P, O&M Cost per Flying hour for the C130J are 19.1% to 23.4% lower than the P, O&M Cost per Flying Hour for the refurbished CC130E. The potential savings in P, O&M for the C130J are in Spares, Maintenance Personnel, Aircrew and Fuel costs. Upgrade programs such as the T56-15 engine, the follow-on AUP, and the SLEP can be avoided if it is decided to replace CC130Es with technologically more up-to-date C130Js.

93. The ELA has shown that even with lower P, O&M costs, higher residual value and no upgrade programs, Total Life Cycle Cost for both replacement options is more expensive because of the high cost of the C130J acquisition program.

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A DISCUSSION OF THE FLYING HOURS IN THE SIMULATION

1. In this Annex, the labels"CC130H7" and "CC130H9" in the chart legends refer to the CC130H74&H84s and to the CC130H90s, respectively. The drop in Total Flying Hours observed between 2015 and 2018 on all the following charts shows the impact of the Follow-on-AUP. The marker is removed from the plot of a given aircraft type when there are no aircraft of this type left in the fleet.

2. Figure A-1 shows the total annual flying hours by aircraft type for the "SLEP 19 CC130E" option, if YFR=20,000 hours. This chart shows that as the CC130H73&H84s start retiring in FY2028/29, the remaining aircraft pick up the flying hours. Beyond FY2041/42, the Total Flying Hours cannot be within 10% of the planned YFR, and the Total Flying Hours start to decline because of the decreasing number of aircraft in the fleet.

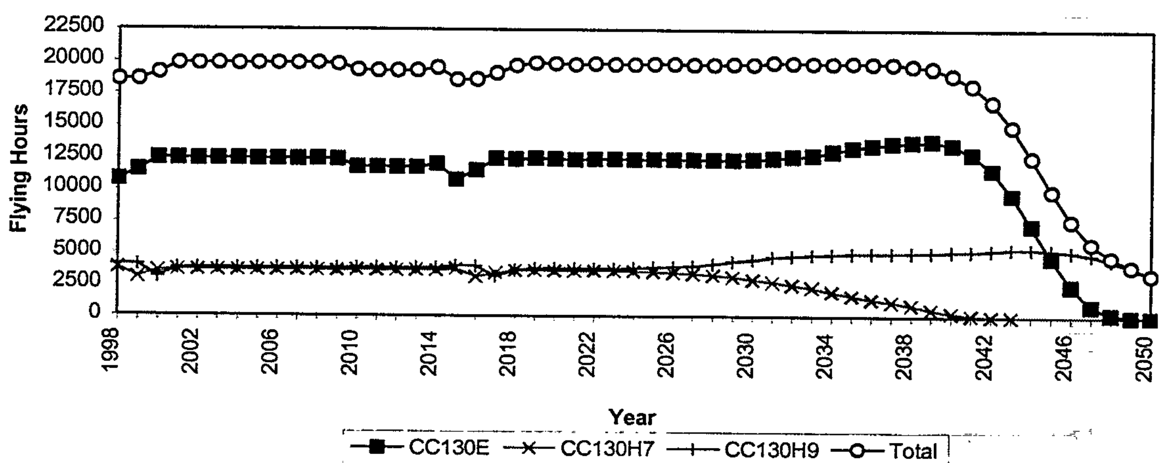

Figure A-1: Flying hours by aircraft type, "SLEP 19 CC130E" option, YFR=20,000 hours.

3. Figure A-2 shows the total annual flying hours by aircraft type for the "Acquire 19 C130Js" option. In that case, the Total Flying Hours are within 10% of the planned YFR until FY2050/51. However, the workload of the 19 C130J is significantly increased once all the CC130H73&H84s are retired in FY2033/34 and the CC130H90s start to retire after FY2046/47.

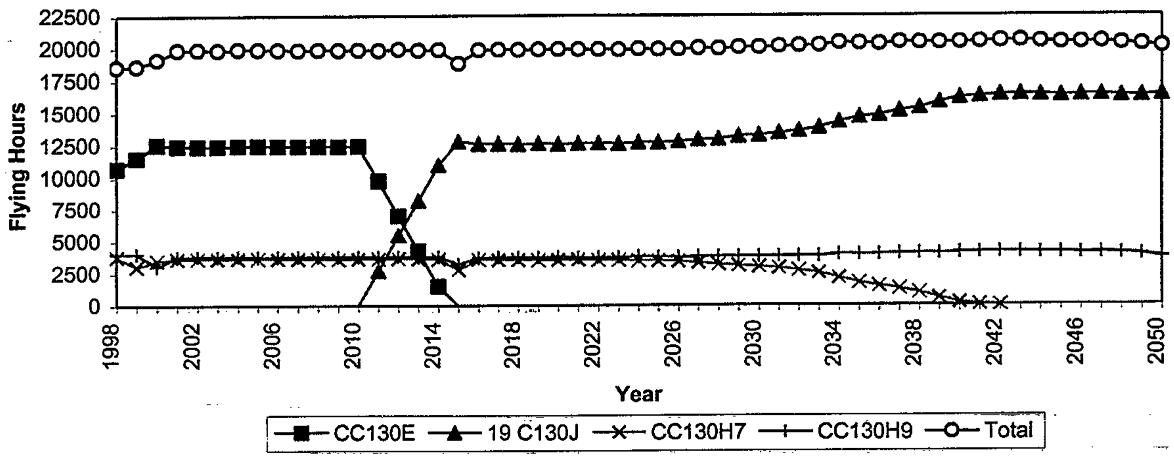

Figure A-2: Flying hours by aircraft type, "Acquire 19 C130Js" option, YFR=20,000 hours.

4. Figure A-3 shows the total annual flying hours by aircraft type for the "Acquire 16 C130Js" option if YFR=20,000 hours. Again, the Total Flying Hours are within 10% of the planned YFR for the entire simulated time frame. As with the other replacement option, the workload of the 16 C130J is significantly increased once the CC130H73&H84s are retired in FY2035/36 and the CC130H90s start to retire in FY2046/47.

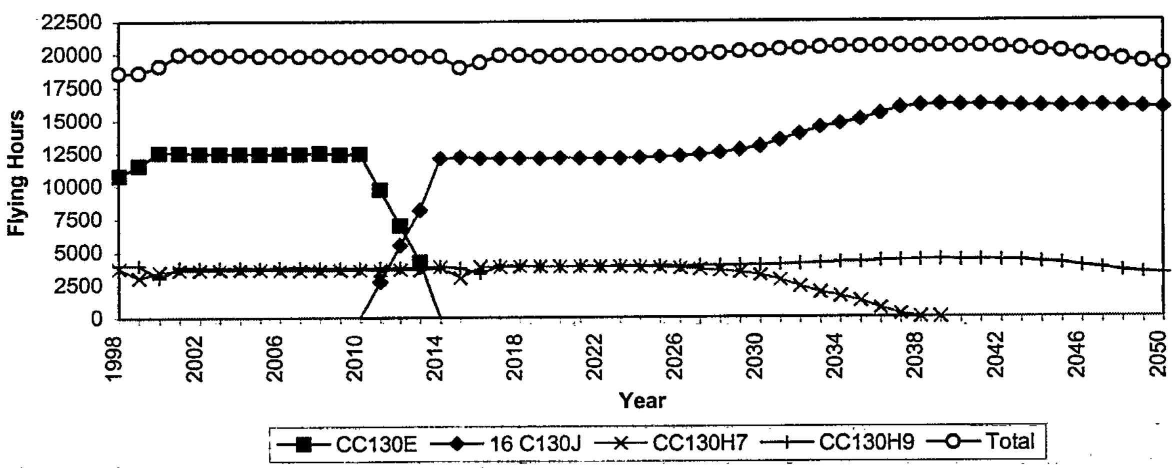

Figure A-3: Flying hours by aircraft type, "Acquire 16 C130Js" option, YFR=20,000 hours.

5. Figure A-4 shows the total annual flying hours by aircraft type for the "SLEP 19 CC130E" option if YFR=30,000 hours. In that case, the Total Flying Hours are within 10% of the planned YFR until FY2025/26. Beyond that date, the Total Flying

Hours decreases rapidly because of the high number of aircraft that reach the end of their life expectancy. Figure A-4 shows that the Total Flying Hours stay within 10% of the planned YFR for the whole duration of the Life Cycle Time Frame of this option, which goes from 2005 to 2025 inclusive.

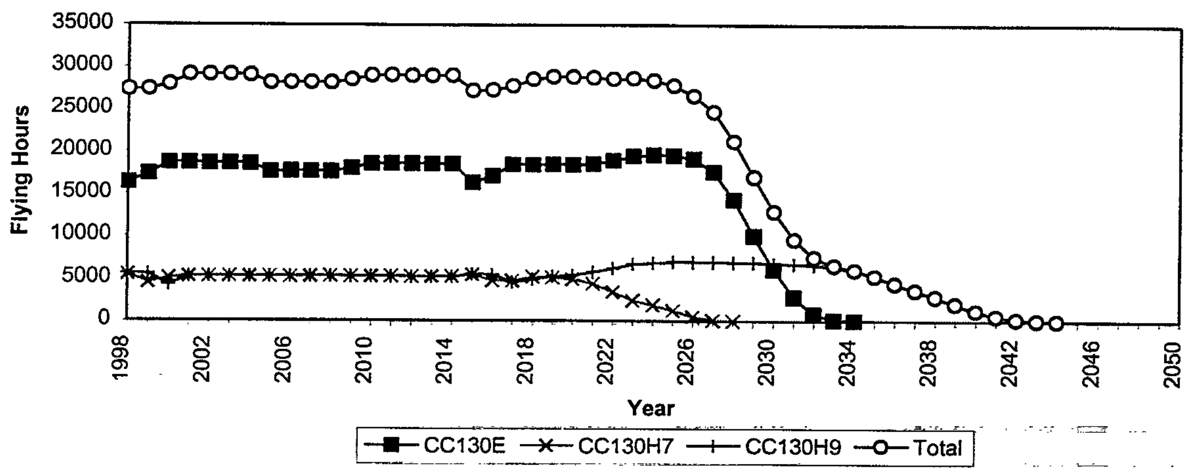

Figure A-4: Flying hours by aircraft type, "SLEP 19 CC130E" option, YFR=30,000 hours.

6. Figure A-5 shows the total annual flying hours by aircraft type for the "Acquire 19 C130Js" option if YFR=30,000 hours. The chart shows that the aircraft fly within 10% of the planned YFR for the duration of the Life Cycle which goes from 2010 to 2030 inclusive. The Total Flying Hours is within 10% of the planned YFR until FY2033/34. There are no CC130H73&H84s available to fly past FY2028/29, and the CC130H90s fly their share of the YFR until the mid 2030's before they start retiring.

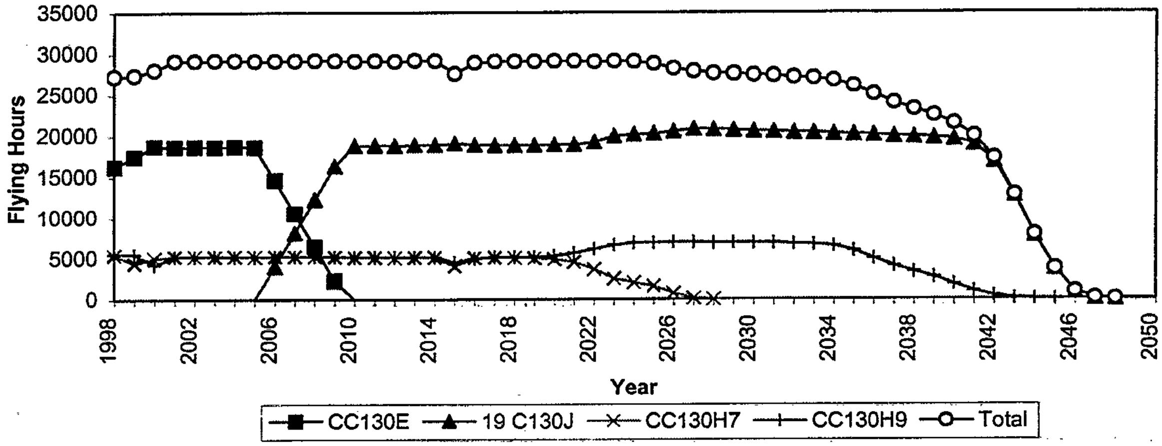

Figure A-5: Flying hours by aircraft type, "Acquire 19 C130Js" option, YFR=30,000 hours.

7. Figure A-6 shows the total annual flying hours by aircraft type for the "Acquire 16 C130Js" option if YFR=30,000 hours. The chart shows that the aircraft fly within 10% of the planned YFR until FY2021/22. Since the Life Cycle Time Frame for this option goes from 2010 to 2030 inclusive, Figure A-6 shows that the planned YFR cannot be sustained for the full length of the Life Cycle Time Frame with the "Acquire 16 C130Js" option because of the other aircraft types who start retiring. There are no CC130H73&H84s available to fly past FY2025/26, and the CC130H90s flying hours start decreasing in the mid 2030's, when they start retiring.

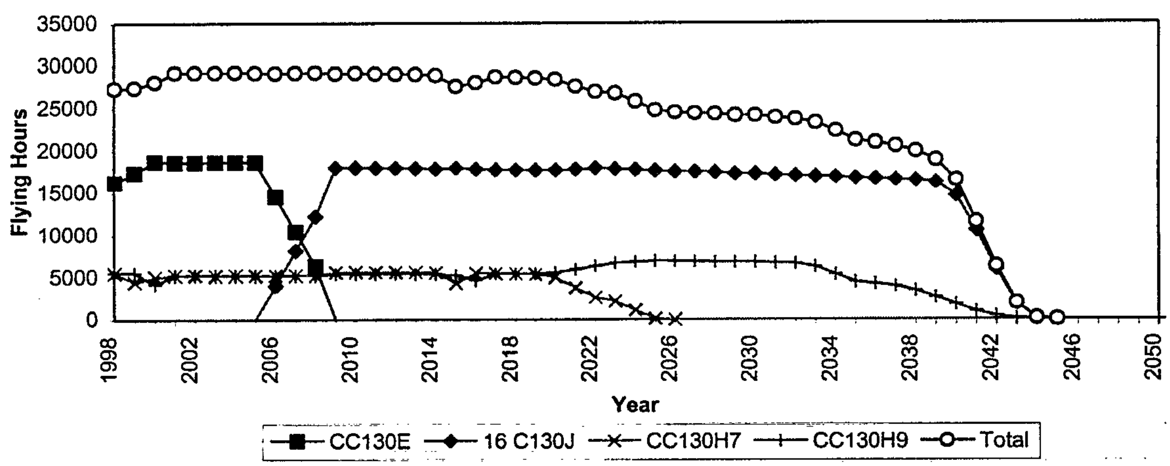

Figure A-6: Flying hours for each sub-fleet, "Acquire 16 C130Js" option, YFR=30,000 hours.

8. This examination of Total Flying Hours by Aircraft Type shows that if YFR=20,000 hours, all three options can sustain the planned YFR until at least FY2040/41. If YFR=30,000 hours, the aircraft cumulate flying hours at a faster rate and are driven to retirement earlier, thereby increasing the workload of the remaining aircraft. This in turn leads to faster ageing of the remaining aircraft. Because of this, a 30,000 hours YFR cannot be sustained for a long time. This is especially true with the "Acquire 16 C130Js" option.

NATIONAL PROCUREMENT AND THE WEAPON SYSTEM SUPPORT PLAN

1. The National Procurement account is a sub-element of DND's Personnel, Operations and Maintenance (P, O&M) account. National Procurement (NP) consists of a number of contracts raised to support the in-service maintenance and repair of DND equipment (eg., aircraft fleets, armoured vehicle, naval vessels, etc.). The Weapon System Support Plan (WSSP) was developed in the early 1990's in order to track National Procurement (NP) expenditures in the support of weapon systems. The WSSP is compiled from hundreds of support contracts. The WSSP for the CC130 fleet has the following cost items:

a) **Repair and Overhaul (R&O)**: includes equipment repair, overhaul and depot level inspection and repair (DLIR) conducted at contractor facilities.

b) **Spares**: includes contracts for replacement spare parts for non-repairable equipment as well as accountable advanced spares (AAS) in support of R&O lines.

c) **Engineering Services (Eng Svcs)**: includes contracted engineering support, where the personnel providing the support are located at contractor's facilities.

d) **Projects**: includes projects to modify, update or replace old, obsolete and/or unsupportable equipment. The contracted portion of these projects is funded under the NP account.

e) **Foreign Military Sales (FMS)**: include several arrangements for the procurement of spares, engineering services and technical data from the U.S. military and industry through cost-sharing arrangements with the U.S. armed forces.

f) **Publications (Pubs)**: includes publication management support (PMS) contracts.

g) **Co-operative Logistics (COLOG)**: Co-operative Logisitcs arrangements with the U.S. for the purchase of spare parts.

h) **Ammunition (Ammo)**: includes contracts for the replenishment of stocks of ammunition, cartridge actuated devices (CADs) and pyrotechnic actuated devices (PADs), flares for Search and Rescue (SAR), etc.

i) **Assigned from DAEPM(C), DTA**: NP resources controlled and managed by DAEPM(C) and DTA which can be directly assigned to the CC130 fleet

j) **Indirect/Allocated from DAEPM(C), DTA, AETE**: reflects the fleet's allocation of those residual NP resources that are controlled and managed by DAEPM(C), DTA and AETE but which have not been assigned directly to fleets.

SENSITIVITY ANALYSIS WITH THE NORMALIZED TOTAL COST PER FLYING HOUR

1. This annex contains the results of the sensitivity analysis run on the Normalized Total Cost per Flying Hour. The impact of varying basic C130J aircraft price is examined first, for YFR = 20,000 hours and YFR = 30,000 hours. Then, the impact of varying aircraft life in flying hours is examined for both YFR limits. The Normalized Total Cost per Flying Hour is calculated with equation (C-1).

$$\text{NCostFHr} = \frac{(\text{P, O \& MCost/FHr} \times \text{A/C Life}) + \text{Capital Investment}}{\text{A/C Life}} \qquad \text{(C-1)}$$

2. This Annex refers to the notions of breakeven aircraft price and breakeven aircraft life for the C130J. The breakeven aircraft price is defined as the C130J's sales price for which the Normalized Total Cost per Flying Hour of the C130J is the same as the Normalized Total Cost per Flying Hour for the refurbished CC130E. The breakeven aircraft life is defined as the C130J's aircraft life in flying hours for which the Normalized Total Cost per Flying Hour of the C130J is the same as the Normalized Total Cost per Flying Hour for the refurbished CC130E. Also, all calculations assume a $1 M US ($1.5 M CAN) discount on the 1998 C130J catalogue price.

3. Figure B-1 shows the effect on the Normalized Total Cost per Flying Hour of varying basic aircraft price while keeping aircraft life and P, O&M Cost per Flying Hour constant, for YFR = 20,000 hours. The breakeven basic aircraft price for 19 C130Js is $45 M US ($67.5 M CAN) per aircraft. This is $7.7 M US ($11.55 M CAN) below the 1998 catalogue price of $52.7 M US. The breakeven basic aircraft price for 16 C130Js is $45.5 M US ($68.25 M CAN) per aircraft for 16 C130Js; this is $7.2 M US ($10.8 M CAN) below the 1998 catalogue price. The model for Normalized Total Cost per Flying Hour assumes an exchange rate of $1 US = $1.5 CAN. This is the exchange rate of July 1998. Although this exchange rate is a historic high, it was used in this analysis to project future costs because it is impossible to know how long the present economic situation will prevail.

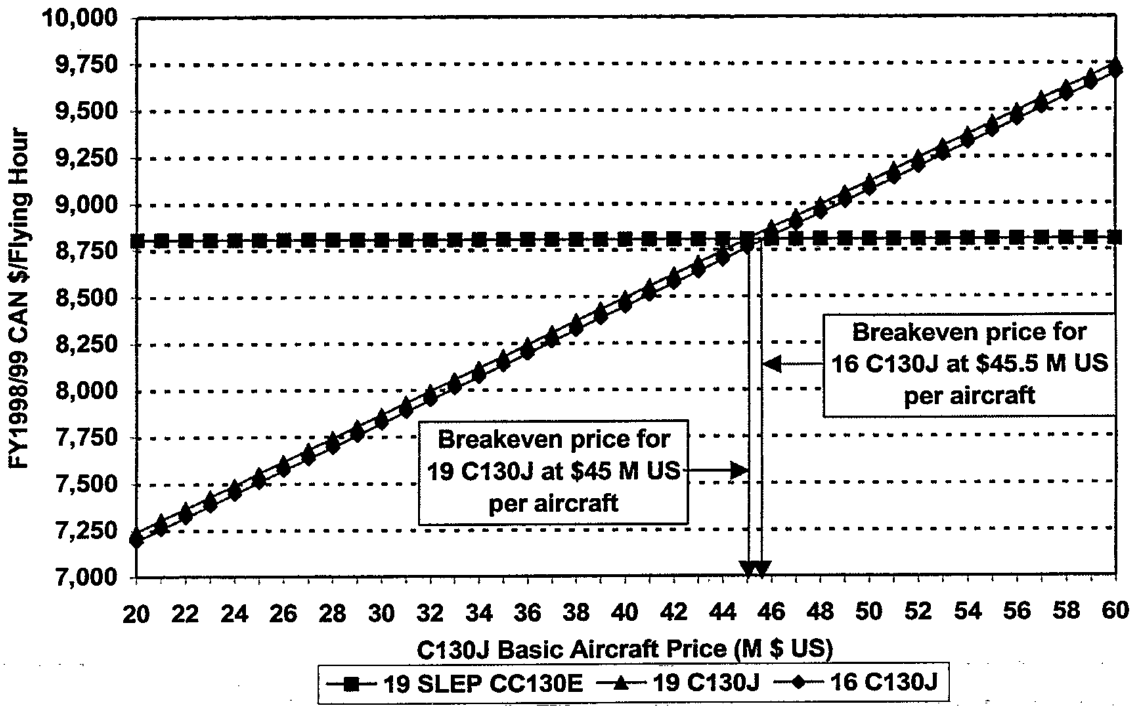

Figure C-1: Normalized Total Cost per Flying Hour as a function of Basic C130J aircraft price, YFR = 20,000 hours.

4. Figure B-2 shows the same type of sensitivity analysis as in Figure B-1, for YFR = 30,000 hours. In this case, the breakeven basic aircraft price for 19 C130Js is $37.1 M US ($55.65 M CAN) per aircraft. This is $15.6 M US ($23.4 M CAN) below the 1998 catalogue price of $52.7 M US. The breakeven basic aircraft price for 16 C130Js is $34.8 M US ($52.2 M CAN) per aircraft for 16 C130Js; this is $17.9 M US ($26.9 M CAN) below the 1998 catalogue price.

5. In both Figure B-1 and Figure B-2, the Normalized Total Cost per Flying Hour is calculated in FY1998/99 CAN $. The conversion of basic aircraft price from FY1998/99 US $ to FY1998/99 CAN $ is built into equation (C-1). A significant change in the exchange rate would also affect the breakeven aircraft price. As an example, an exchange rate of $1 US = $1.25 CAN would affect the C130J's Normalized Total Cost per Flying Hour to the extent that the current sales price of $52.7 M US would be slightly below the breakeven basic aircarft price.

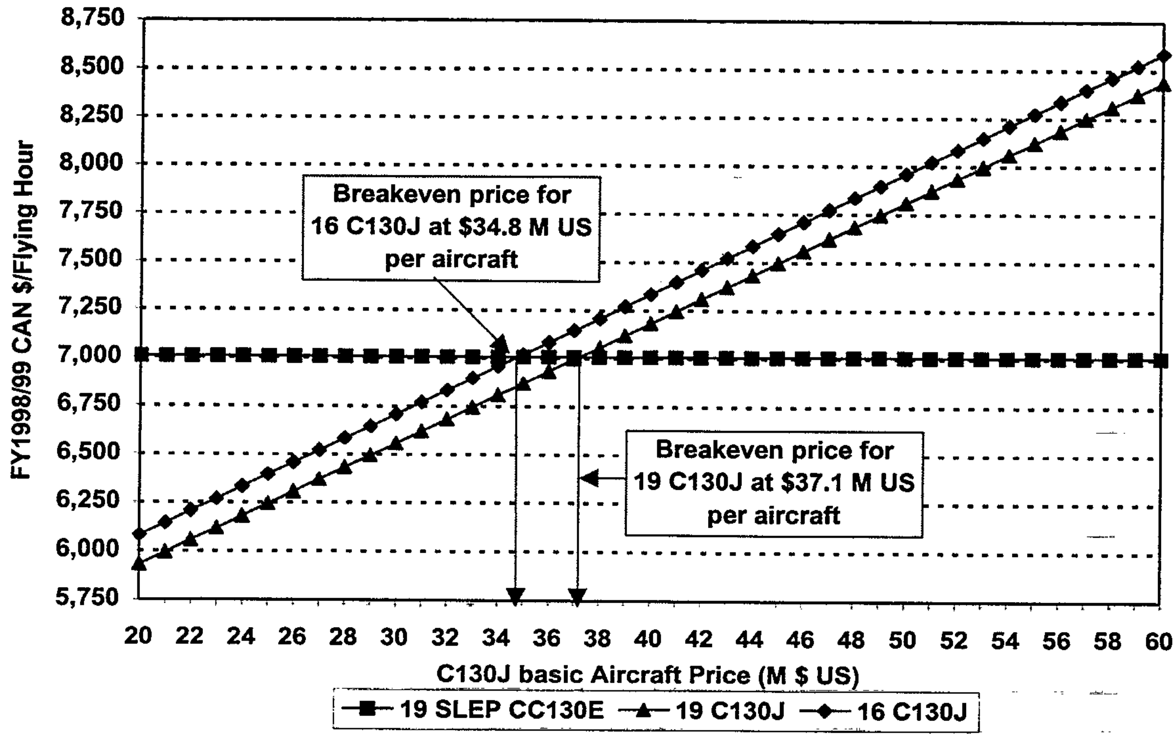

Figure C-2: Normalized Total Cost per Flying Hour as a function of C130J basic aircraft price, YFR = 30,000 hours.

6. Figure B-3 shows the effect on the Normalized Total Cost per Flying Hour of varying aircraft life in flying hours while keeping P, O&M Cost per Flying Hour and Capital Investment constant, for YFR = 20,000 hours. Figure B-3 shows that breakeven aircraft life is 40,500 hours per aircraft for 16 C130Js, and 41,000 hours for 19 C130Js. These are only 500 hours and 1,000 hours, respectively, above the current assumption of 40,000 hours for C130J aircraft life.

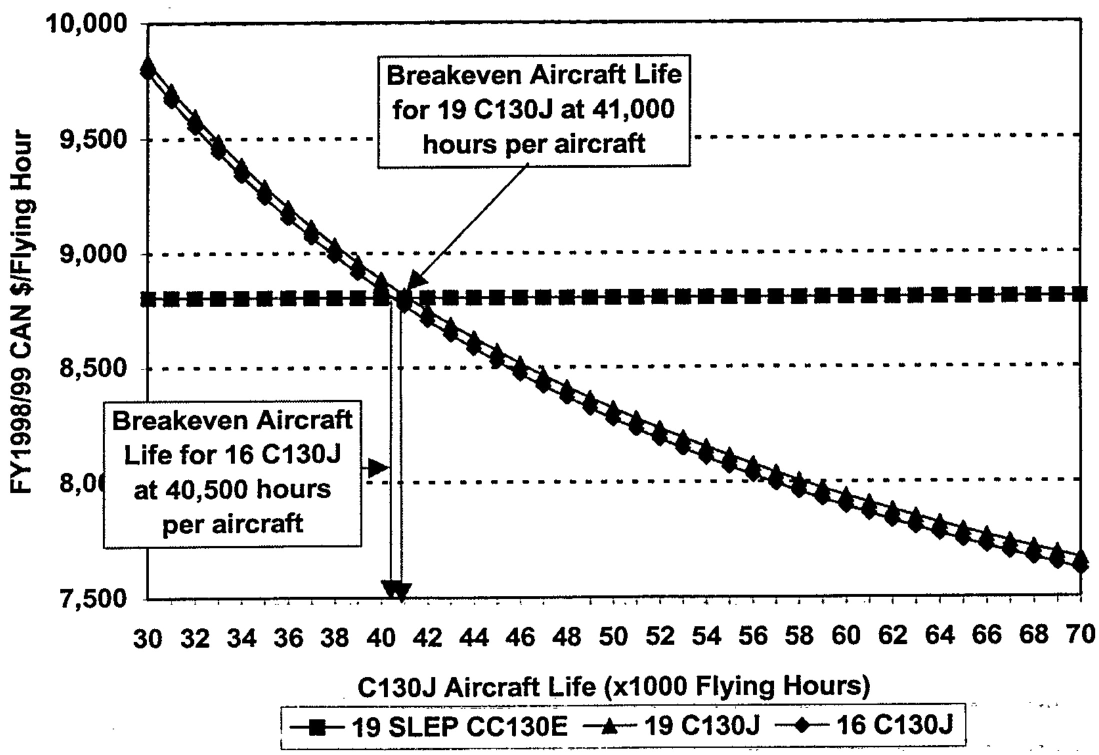

Figure C-3: Normalized Total Cost per Flying Hour as a function of C130J aircraft life, YFR = 20,000 hours.

7. Figure B-4 shows the same type of sensitivity analysis as Figure B-3, for YFR = 30,000 hours. In this case, the breakeven aircraft life is 50,000 hours per aircraft for 19 C130Js, and 53,500 hours per aircraft for 16 C130Js. Both these are substantially higher than the current assumption of 40,000 hours per aircraft used in this study.

8. The sensitivity analysis on the Normalized Total Cost per Flying Hour shows that the current basic aircraft sales price and the current aircraft life in flying hours are close to breakeven if YFR = 20,000 hours. This was already seen in Figure 21 of the main text. If YFR = 30,000 hours, basic aircraft price has to be lowered significantly, or aircraft life has to be considerably higher, for the Normalized Total Cost per Flying Hour of the C130Js to compare favourably with the Normalized Total Cost per Flying Hour of the SLEP CC130Es.

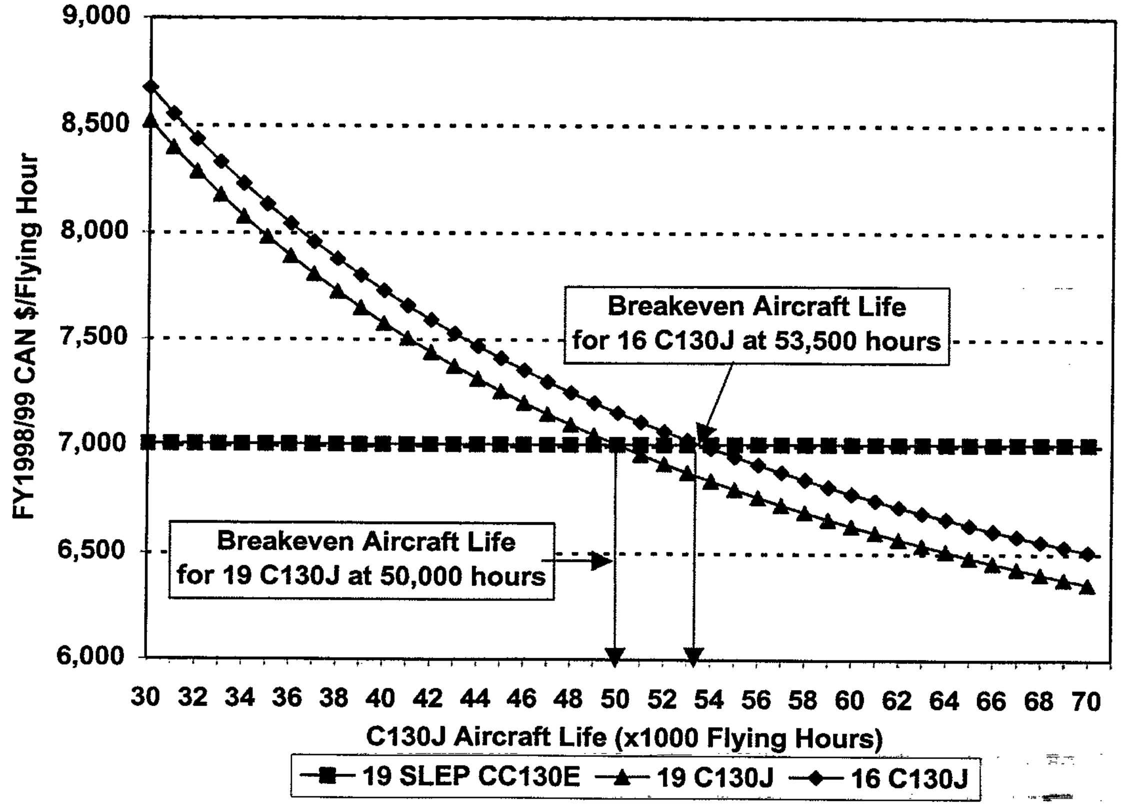

Figure C-4: Normalized Total Cost per Flying Hour as a function of C130J aircraft life, YFR = 30,000 hours.

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This Project Report documents the Life Cycle Cost (LCC) analysis conducted in support of the Combined Operational Effectiveness and Investment Appraisal for the CC130E Replacement Study. This study was conducted because the CC130E fleet is approaching its Estimated Life Expectancy (ELE) of 2010. To go beyond this date, the CC130E aircraft will require significant refurbishment. Two options are considered in order to maintain the current airlift capability beyond 2010. The first option is the refurbishment of the CC130E aircraft. The second option is the replacement of all CC130E by new C130J "Hercules II" aircraft. This study showed that although there are expected savings of about 20% in Personnel, Operation and Maintenance (P, O&M) costs per flying hour for the C130J, the acquisition cost of a replacement fleet is much higher than the cost to refurbish the CC130Es.

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