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DIRECTORATE OF OPERATIONAL RESEARCH (JOINT & LAND)

DOR(J&L) RESEARCH NOTE RN 2000/05

A TOOL TO ESTIMATE THE REQUIREMENT FOR CANADIAN FORCES AND COMMERICAL AIRLIFT

by

Ivan Taylor, JSORT

FEBRUARY 2000

OTTAWA, CANADA

National Defence Défense nationale

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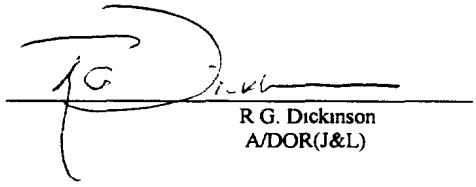
Recommended by  Approved by 

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OTTAWA, ONTARIO FEBRUARY 2000

ABSTRACT

J4 Movements is responsible for tasking Canadian Forces (CF) airlift resources for major operations and, if these resources are insufficient, to contract commercial airlift as well. Recently, J4 Movements has become concerned with combined effects of rapidly increasing cost of commercial airlift, lack of availability of commercial airlift during times of international crisis and the lack of sufficient CF resources. J4 Movements tasked the Joint Staff Operational Research Team to develop a tool to estimate the extent of commercial airlift required to augment the current CF fleets in various planning scenarios.

TABLE OF CONTENTS

List of Figures

A TOOL TO ESTIMATE THE REQUIREMENT FOR CANADIAN FORCES AND COMMERCIAL AIRLIFT

BACKGROUND

1. The Canadian Forces' primary resources for airlift are the CC130 for cargo and CC150 for passengers. In recent years, the demands on these aircraft for airlift of CF equipment and troops around the world have exceeded the capacity even though the official policy has stated we should exercise Capability Based Planning. This has resulted in extensive use of commercial airlift to augment the department's integral capabilities.

2. Fortunately, former Warsaw Pact nations have had excess capacity and have been willing to provide their resources at a price. Unfortunately, these resources are currently in high demand and the prices are increasing correspondingly. Furthermore, in the near future, the air-worthiness of these aircraft may come into question and these capabilities are very expensive to replace. So the future availability of large cargo aircraft on the international commercial market is uncertain.

3. The Air Force has been studying this situation and has requested the support of J4 Movements in specifying the requirement for airlift. In turn, J4 Movements tasked the Joint Staff Operational Research Team to develop a tool that could estimate the requirement for CF and commercial airlift resources for their use and the potential use of the Air Force in developing their statement of operational deficiency and statement of requirement.

4. The authors' experience at the former Air Transport Group developing airlift planning formulae appeared to be excellent background for this project. We found that these airlift planning formulae could be easily adapted to this analysis and implemented in two Excel workbooks that will be described below and documented in Annex A and B.

THE CC130 WORKBOOK

5. The CC130 workbook is divided into three separate spreadsheets: strategic airlift, tactical airlift and air refuelling.

6. A common feature of these spreadsheets is the model of the flying rate. Based on many years of experience, airlift planners have determined that there is a relationship between the average daily flying rate that can be sustained per aircraft assigned to the airlift and the duration of the airlift. Namely, if the airlift is 15 days or less, an average flying rate of 10 hours per day per aircraft can be sustained. Between 15 and 30 days, an average flying rate between 10 and 7 hours can be sustained and beyond 30 days the average flying rate approaches 4 hours a day. A graph of this relationship is shown in Figure 1.

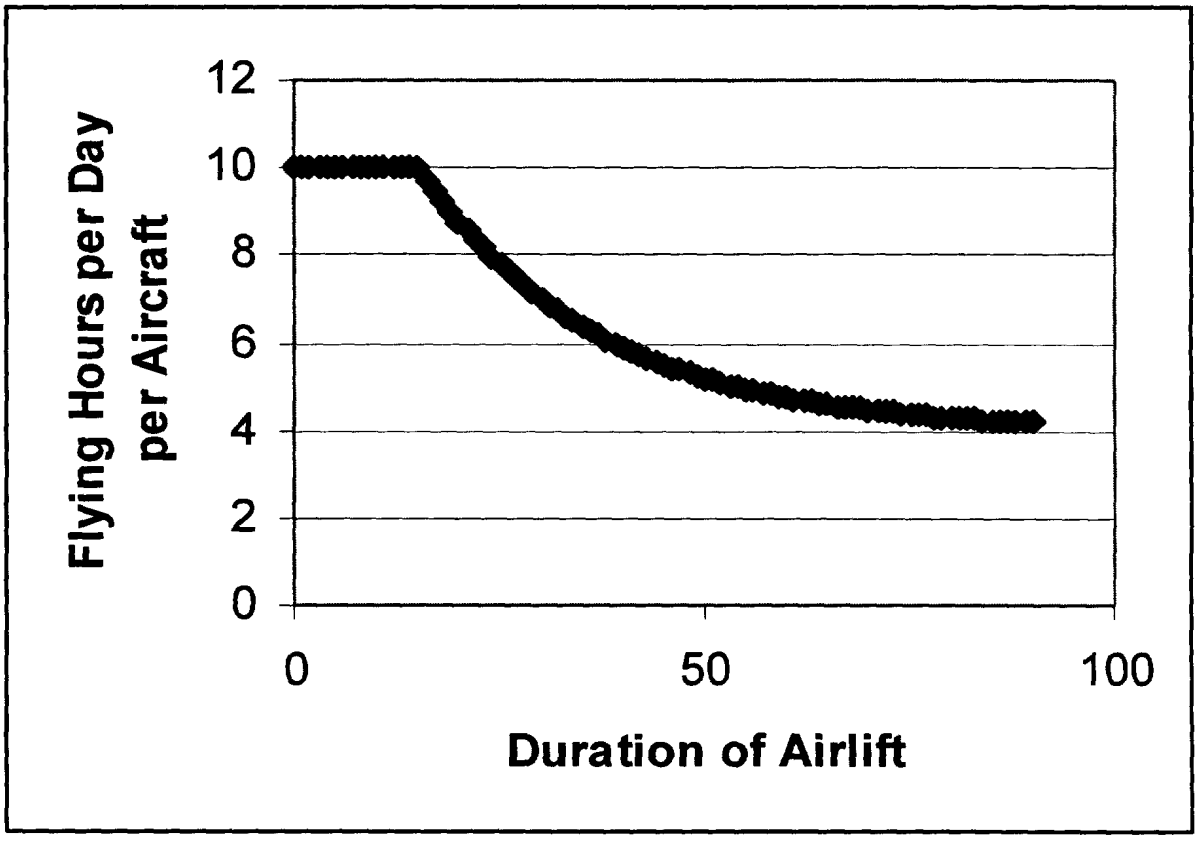

Figure 1: CC130 Average Flying Rate per Day per Aircraft

7. The number of aircrews to support CC130 operations has a similar pattern. As the duration of the airlift increases the average flying rate of the individual aircrews decreases, therefore, if the airlift is less than 15 days the average flying rate per aircrew per day is assumed to be 5 hours a day. Between 15 and 30 days duration, the average flying rate per aircrew per day ranges from 5 to 3.5 hours a day and beyond 30 days, the average aircrew flying rate per day gradually approaches a minimum of 2 hours a day. This equates to an aircraft to aircrew ratio of 1:2.

8. A major assumption used in all of the CC130 sub-models is that the airlift will be self-contained. That is, if the requirement is to complete the mission in 30 days, the aircraft and aircrews will be dedicated to the mission for that period including aircraft unserviceability and aircrew rotations. In fact, real-operations try to minimize the number of aircraft and aircrew in theatre. However, backup aircraft in Canada are required to be available on relatively short notice to replace the aircraft in theatre if they go unserviceable and aircrew in Canada may be accumulating rest and be planned to replace aircrews in theatre.

The CC130 Strategic Airlift Spreadsheet

9. The spreadsheet is divided into three parts: the nominal values, the specific input values and the output values (see Figure 2).

NOMINAL VALUES

	Distance		Chalks		Duration	Flying Rate
Europe/Americas	3000	DART	50	Short	<=15	10 hrs/day/ac
Africa	5000	18 Spectre	90	Medium	15<>=30	7 hrs/day/ac
Asia	10000	Battalion	120	Long	>30	4 hrs/day/ac

INPUT VALUES

	NM		Chalks		Days		
Distance	7500	Chalks	80	Duration	15	Antonov Chalks	4

OUTPUT VALUES

Hercules	**20**
Aircrew	**40**

Figure 2: The CC130 Strategic Airlift Spreadsheet

10. The nominal values are examples of the input values that could be used in the scenario development process but are not used directly in the calculations. The input values are used directly in the calculations and are provided by the user based on the scenario. The output values are calculated based on the formula in Annex A.

11. There are a few assumptions that should be noted in the calculations. First, we assume that the airlift is planned in an attempt to reduce the number of aircraft required. That is, the airflow involves an even spacing of the departures to accomplish the airlift in the specified number of days. The aircrews are pre-positioned along the route to maintain the continuous flow while still obtaining the necessary crew rest. First line aircraft unserviceabilities and crew day considerations are built into the flying rate assumptions. There is another model that provides detailed airflow planning that can support this model if necessary to confirm that the scenario parameters are achievable (Ref. 1). The final assumption concerns the Antonov chalks. It is assumed that one Antonov can carry the equivalent of eight CC130 loads and that they are available on short-notice if necessary.

The Tactical Airlift Spreadsheet

12. The CC130 is ideally suited for tactical airlift. The model for tactical airlift is quite similar to the model for strategic airlift except that distances are shorter, duration is generally longer, the requirement is specified in the number chalks per day and there is no commercial airlift available to augment the capability. Figure 3 shows the spreadsheet. The detailed airflow modelling tool in Reference 1 can be used to verify the achievability of these tactical airlift scenarios.

NOMINAL VALUES

	Distance		Chalks/Day		Duration	Flying Rate
Short	250	Sustainment	3	Short	<=15	10 hrs/day/ac
Medium	500	Boxtop	8	Medium	15<>=30	7 hrs/day/ac
Long	750	End-on-End	10	Long	>30	4 hrs/day/ac

INPUT VALUES

	NM		Chalks/Day		Days
Distance	250	Requirement	20	Duration	60

OUTPUT VALUES

Hercules	**9**
Aircrews	**18**

Figure 3: The CC130 Tactical Airlift Spreadsheet

The Air Refuelling Spreadsheet

13. In the early 1990's, five KC130 aircraft were acquired specifically for tactical air-refuelling of the CF-18. Reference 2 documents a model that was developed to analyze various scenarios in which these aircraft would be employed. The formulae in Reference 2 have been adapted for the air refuelling spreadsheet below.

NOMINAL VALUES

	Distance		Coverage		Duration	Flying Hours
Short	100	Small	0.1	Short	<=15	10 hrs/day/ac
Medium	200	Medium	0.5	Medium	15<>=30	7 hrs/day/ac
Long	400	Large	0.9	Long	>30	4 hrs/day/ac

INPUT VALUES

	NM		Fraction		Days
Distance	250	Coverage	0.3	Duration	60

OUTPUT VALUES

Hercules	**2**
Aircrews	**4**

Figure 4: The KC130 Air Refuelling Spreadsheet

14. The scenario in the tactical air refuelling model involves the KC130 and the CF-18 at the same home base as part of a multi-national force. The goal is for the CF-18 to provide a Combat Air Patrol some distance from that home base a certain fraction of the time for the multi-national force. While the CF-18 is on CAP, the KC130 will be assigned the responsibility of refuelling it.

15. There are a few intermediate calculations used in the air refuelling that are provided for the information at the bottom of the spreadsheet. These include the number of missions to be flown per day, the time for the KC130 to be on station and the total flying time per mission (see Figure 5).

INTERMEDIATE VALUES

Missions/Day	3
TOS	2.5 hrs
Flying Time	4.7 hrs

Figure 5: Intermediate Calculations for Air Refuelling Spreadsheet

THE CC150 WORKBOOK

16. The CC150 is truly a strategic passenger aircraft. It has also been reconfigured as a 'combi' that can carry a half load of passengers and a half load of bulk cargo. There are currently two passenger configured aircraft with the capability of carrying 150 troops with their kit, two 'combi' configured aircraft that can carry 58 troops and their kit and one 'special' that can carry 90 troops and their kit.

17. The 'combi' aircraft can carry 60,000 pounds of bulk cargo. Therefore, there are two primary roles for the CC150, namely, deployment of troops to theatre and sustainment of troops in theatre.

18. Because the CC150 generally flies long-haul missions, it can sustain a higher flying rate than the CC130. Our model is essentially the same, except the CC150 would be able to fly for 12 hours per day over the first 15 days and drop to 10 hours a day by 30 days to an eventual limit of 8 hours a day in the long term.

The Deployment Spreadsheet

19. The primary consideration in CC150 usage is the potential requirement to augment the fleet with commercial airlift. Generally, because the CC150 is such an excellent passenger aircraft, it is highly unlikely that limited capacity would be the reason to augment the fleet with commercial airlift. Figure 6 shows the spreadsheet and Annex B provides the formulae. Again we have assumed that the aircraft to aircrew flying rate is 1:2 and the aircrews are pre-positioned to maintain a continuous flow.

NOMINAL VALUES

	Distance		Troops		Duration
Canada	1000	Battle Group	1000	Rapid	2
Europe	3500	Battalion	1500	Deliberate	15
Africa	7000	Brigade	5000		
Asia	10000	Conflict	10000		

DATA VALUES

Distance	3000	Troops	1000	Duration	7
	PAX	COMBI	SPECIAL	TOTAL	
Aircraft	2	2	1	5	

RESULTS

	Missions
Commercial	**0**

Figure 6: The CC150 Deployment Spreadsheet

20. There are some intermediate calculations that are provided for information at the bottom of the spreadsheet (see Figure 7).

INTERMEDIATE CALCULATIONS

	PAX	COMBI	SPECIAL
Missions	13	13	6
	TOTAL		
Aircrews	12		

Figure 7: Intermediate Calculations for the CC150 Deployment Spreadsheet

The Sustainment Spreadsheet

21. Again the issue here is the amount of commercial augmentation that might be required to handle the sustainment of troops in theatre. However, both the CC150 'combi' and the CC130 can be used in sustainment missions. The spreadsheet is shown in Figure 8.

NOMINAL VALUES

	Distance		Troops		Daily Rate		HSN
Canada	1000	Battle Group	1000	Low	20	Good	0.9
Europe	3500	Battalion	1500	Medium	30	Fair	0.5
Africa	7000	Brigade	5000	High	50	Poor	0.1
Asia	10000	Conflict	10000				

DATA VALUES

Distance	3000	Troops	1000	Daily Rate	30	HSN	0 5
	Hercs	COMBI					
Missions/Week	1	2					

RESULTS

	Missions/Week
Commercial	**0**

Figure 8: The CC150 Strategic Sustainment Spreadsheet

22. Two additional scenario dependent parameters are required in this spreadsheet, namely the Daily Rate of the Requirement in terms of pounds per day per man in theatre and the fraction of this requirement that can be met through Host Nation Support. Demanding scenarios will have a high Daily Rate and low Host Nation Support fraction and therefore a greater strategic sustainment requirement. Again the CC150 and CC130 in combination have an exceptional capability to lift bulk cargo and therefore it would be unusual to require routine commercial flights to handle strategic sustainment.

CONCLUDING REMARKS

23. The development of these workbooks is very timely because the Air Force is currently developing strategic plans to restructure the fleets and are seriously considering the acquisition of a new strategic airlift capability. Similarly, the Navy is considering the acquisition of a new sealift capability and these spreadsheets could be converted to address similar problems for sealift questions.

REFERENCES

1. Taylor, Ivan; PLANNER – A Planning Aid for Major Airlifts; ATGOR Research Note 1/92; February 1992.

2. Tezer, Major Guray, and Ivan Taylor; Planning Tools for KC130 Refuelling Missions; ATGOR Staff Note 3/90, May 1990.

ANNEX A
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THE CC130 FORMULAE

THE STRATEGIC AIRLIFT FORMULAE

1. First of all the average flying rate per day per aircraft should be calculated based on a half life formula,

IF (Duration <= 15) THEN 10 hours per day per aircraft
ELSE (4 + 6 * (0.5)^((duration – 15)/15)) hours per day per aircraft
ENDIF

2. Next, the Antonov offset must be calculated. The number of CC130 chalks replaced by Antonovs is simply

Antonov Offset = (Number of Antonov Missions) * 8 CC130 chalks per Antonov mission

3. Then the number of CC130 aircraft required to complete the airlift in the days specified would be

(Total Distance to be Flown by CC130) / (Total Distance that can be Flown per CC130 Aircraft)
= (2 * Distance * (Total Chalks – Antonov Offset)) / (Average Speed * Flying Rate per Day per Aircraft * Duration of Airlift)

We must roundup this result to the next highest integer and ensure that it is not less than zero in the spreadsheet.

4. Finally, the number of aircrews required is simply,

(2 * CC130 aircraft).

THE TACTICAL AIRLIFT FORMULAE

5. The Tactical Airlift formulae are essentially the same as the Strategic Airlift formulae except there is no Antonov offset. First, we compute the daily flying rate as before and then the number of aircraft as

(2 * Distance * Chalks per Day) / (Average Speed * Flying Hours per Day per Aircraft)

and the number of aircrews is simply twice the number of aircraft.

THE AIR REFUELING FORMULAE

6. In this model, we have used the fuel flow of the CF18 and the CC130 to estimate the time on station and missions per day required to maintain a Combat Air Patrol for a certain number of hours per day. These formulae are derived in Reference 2 from raw data in the Aircraft Operating Instructions.

7. The time on station in hours for the CC130 is

(208.245 – 0.2214 * Distance) / 60

The total flying time per mission is

((2 * (7.778 + 0.222 * Distance)) / 60) + Time on Station

Then the number of missions per day per CC130 would be

(Coverage Fraction * 24) / (Time on Station)

Then the number aircraft equals

(Missions per Day * Flying Time per Mission) / (Flying Rate per Day per Aircraft)

and the number of aircrews equals twice the number of aircraft.

ANNEX B
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THE CC150 FORMULAE

THE DEPLOYMENT FORMULAE

1. The flying rate per day per CC150 is computed using the formula

IF (Duration <= 15 days) THEN 12 hours per day per aircraft
ELSE
(8 + 4 * (0.5) ^ ((Duration – 15) / 15)) hours per day per aircraft
ENDIF

2. The aircrew flying rate for the CC150 is the same as that for the CC130. However, it must be calculated separately because it is not simply 0.5 times the aircraft flying rate.

IF (Duration <= 15 days) THEN 5 hours per day per aircrew
ELSE
(2 + 3 * (0.5) ^ ((Duration – 15) / 15)) hours per day per aircrew
ENDIF

3. Then we must calculate the missions per day that can be flown by the CC150 aircraft during the duration of the airlift for each of the configurations.

(Aircraft * Flying Rate per Day * Duration * Speed) / (2 * Distance)

and this must be rounded-down to an integer.

4. The total number of aircrews required is based on the Aircraft to Aircrew Flying Rate, namely

(Total Aircraft) * (Aircraft Flying Rate per Day) / (Aircrew Flying Rate per Day)

5. The number of commercial missions that need to be contracted is

(Troops – Pax Missions * 150 – Combi Missions * 58 – Special Missions * 90) / 150.

THE SUSTAINMENT FORMULAE

6. We assume in the sustainment flights that missions are flown by the CC130 and CC150 without crew rotations therefore the Aircraft Flying Rate equals the Aircrew Flying Rate (namely, 2 hours a day).

7. The number of CC130 and CC150 aircraft required to support a certain number of Missions per Week is

(2 * Distance * Missions per Week) / (Flying Hours per Day * 7 * Speed)

and the number of aircrew is equal to the number of aircraft.

The weekly sustainment requirement for supply in pounds would be

(7 * Troops * Daily Rate of Supply * (1 – Host Nation Support Fraction))

Then the number of commercial flights required to contract for sustainment would be

(Weekly Requirement – 25000 * CC130 Missions per Week – 60000 * CC150 Missions per Week) / 85000

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