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Toward planning non-forecast strategic airlift missions

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Abstract

Planning airlift missions is one of the most important operations conducted by the Canadian Air Forces. While forecast airlifts are part of periodic airlift programmes maintained by 1 Canadian Air Division (1CAD), Non-Forecast Airlift (NFA) requests may occur on short notice and demand immediate attention often resulting in their omission from the periodic airlift programme. Consequently, a separate planning problem subject to resource contention concurrently emerges. This document is a comprehensive examination of various key issues defining the complexity of the NFA problem, in which mission plans are ultimately characterized by a sequence of flight segments involving appropriate air resources tasking to achieve single or multiple objectives in response to strategic requirements. It provides a clear insight about the basic features to be inevitably considered in building a suitable problem model and proposes some guidance toward the development of an advanced automated decision support system.

Résumé

La planification des activités de transport aérien est l'une des plus importantes opérations conduites par les Forces de l'Air canadiennes. Ces activités de transport sont réparties en deux catégories : opérations de transport prévues et opérations contingentes ou imprévues. Les opérations de transport aérien prévues sont traitées à l'avance par la 1ère Division aérienne du Canada (1DAC) et sont incluses dans les programmes annuel et mensuels des opérations de transport aérien. Par contre, une opération de transport aérien imprévue est assignée à l'Escadre par une notice nécessitant une attention immédiate. Par conséquent, cette dernière opération n'est pas prise en compte dans les programmes de transport aériens périodiques et elle est planifiée indépendamment des opérations prévues tout en tenant compte des ressources déjà engagées pour ces opérations. Ce document présente les différents éléments qui doivent être pris en compte dans la modélisation du problème de planification stratégique d'une opération contingente de transport aérien. Cette dernière peut être définie comme un ensemble de tronçons de vols pour lesquels certaines ressources doivent être affectées dans le but d'atteindre un ou plusieurs objectifs. Le document aborde aussi les éléments les plus importants qui doivent être pris en compte dans le développement d'un système d'aide à la décision destiné à la planification de missions imprévues de transport aérien.

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Executive summary

Airlift mission activities carried out at 8 Wing Trenton come under the Air Mobility Operations. The 8 Wing is responsible for conducting 80% of the requested airlift activities using Hercules and Polaris [11]. Two main types of airlift are carried out at 8-wing: forecast airlift and Non-Forecast Airlift (NFA). The forecast airlift is accommodated within both the Fiscal Year Airlift Programme (FYAP) and the Monthly Airlift Programme (MAP) conducted by 1 Canadian Air Division (1CAD). However, NFA requests occur at critical time preventing timely submission and inclusion in the MAP and usually require immediate attention possibly imposing shorter time reaction.

This document is partially devoted to providing an overview of the different elements regarding planning, programming and tasking of aircraft resources to support NFA request as conducted at 8 Wing Trenton. It also captures the basic features to be inevitably considered in building a suitable problem model and proposes some guidance toward the development of an advanced automated decision support system. Such a decision aid system is intended to interact and be integrated within DSS (Decision Support System). The latter is a prototype that focuses on the forecasted airlifts and does not capture the non-forecast airlift requests. The DSS has been developed under a DND/NSERC project for which the following members have been involved: GERAD, a research group in decision aids from University of Montreal, AD Opt Technologies from Montreal, AIRCOM DCOS Op Rsch, Air Force Command and Control Information System (AFCCIS) project and, DRDC Valcartier. The DSS is dedicated to address the Air Mobility line tasking planning problem. The line tasking problem consists in selecting airlift requests and construct strategic airlift missions to be achieved over a time horizon, generating a monthly or a yearly airlift programme.

The ongoing effort is a contribution to help 8-Wing to significantly improve the quality of the planning solution and ultimately provide an automated decision support capability. Accordingly, the related system will allow more efficient Air Forces resource utilization to support air movement requirements.

Abdeslem Boukhtouta & Jean Berger, (2004). Toward Planning Non-Forecast Strategic Airlift. TM 2002-235. Defence R&D Canada-Valcartier.

Sommaire

Les activités de transport aérien effectuées par la 8ème Escadre à Trenton sont au cœur de la force de mobilité aérienne du Canada. Il faut signaler à cet effet que 80% des opérations de transport aérien utilisant les avions Hercule et Polaris sont sous la responsabilité de la 8ème Escadre [11]. Ces dernières opérations sont réparties en deux catégories : opérations prévues et opérations imprévues. Les opérations prévues sont planifiées à l'avance par la 1ère Division aérienne du Canada (1DAC) et intégrées aux programmes mensuels et annuel des opérations de transport aériens. Les requêtes reliées aux opérations imprévues ne sont pas intégrées à ces programmes et sont assignées à la 8ème Escadre pour être traitées de façon urgente.

Les différents éléments qui rentrent en ligne de compte dans la planification des opérations imprévues de transport aérien assignées à la 8ème Escadre sont traités dans le présent document. Ce dernier aborde les plus importants points à retenir dans la modélisation et le développement d'un système d'aide à la décision pour la planification des opérations imprévues de transport aérien. On suggère dans ce document d'intégrer le système traitant la planification des opérations de transport aérien imprévues au Système d'Aide à la Décision (SAD). Le SAD est un prototype qui a été mis au point pour l'élaboration des programmes de planification des opérations de transport aérien mensuels et annuel. Par contre le SAD ne traite pas la planification des opérations de transport aérien imprévues. Le SAD a été mis au point dans le cadre d'un programme de recherche MDN/CRSNG pour lequel d'autres instances ont participé : le Groupe de recherche GERAD associé à l'Université de Montréal, la compagnie AD Opt basée à Montréal, C AIR SCEM Rop, SIC2FA et RDDC Valcartier.

Le présent travail représente le début des efforts qui seront employés dans le but de mettre au point un système d'aide à la décision pour la planification des opérations de transport aérien imprévues. Ce système permettra une amélioration considérable de la qualité de la planification de la 8ème Escadre. Il permettra aussi, par conséquent, l'utilisation et l'allocation efficientes des ressources des Forces de l'Air et d'automatiser le processus de décision ayant trait à la planification des opérations de transport aérien au niveau de l'Escadre.

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1 Introduction

Planning airlift missions is one of the most important operations conducted by the Canadian Air Forces. Indeed, the Canadian Air Forces carry out two main types of airlift: forecast airlift and Non-Forecast Airlift (NFA). The forecast airlift is effectively accommodated within both the Fiscal Year Airlift Programme (FYAP) and the Monthly Airlift Programme (MAP) conducted by 1 Canadian Air Division (1CAD). On the other hand, Non-Forecast Airlifts are short notice flights requested to support requirements that may arise too late for submission in the FYAP or the MAP process. Further designed to respond to strategic requirements, a NFA mission can be defined as a number of flight legs that involve tasking of appropriate air resources needed to support specific, identified objectives.

Indeed, airlift mission activities carried out at 8 Wing Trenton come under the Air Mobility Operations. The latter Wing is responsible for conducting 80% of the requested airlift activities using Hercules and Polaris [11]. As a result, this document is partially devoted to providing an overview of the different elements regarding planning, programming and tasking of aircraft resources to support NFA request as conducted at 8 Wing Trenton. It also contains a brief description of the 8 Wing Trenton together with an overview of the air mobility operations.

Furthermore, the document includes a comprehensive examination of various key issues surrounding the conception of powerful algorithms and adequate models designed to support the development of an advanced automated decision support system for solving complex NFA decision-making problems. In addition to providing a clear insight into the nature of real NFA problems, the document carries out a thorough investigation of various elements that should be unavoidably considered to create a computer model of a NFA decision-making process under various conditions or events.

Designed to be integrated in a larger prototype such as Decision Support System (DSS) [8], the proposed NFA decision support software will be developed to incorporate novel modeling approaches so as to handle complex problems while ensuring optimum cost effectiveness. In this respect, a sound approach based on new optimization techniques will be eventually the first logical step of a future development of an automated decision support tool to solve complex NFA problems. In short, the present document is designed to form a basic framework for further research required to explore new and innovative approaches to dealing with the NFA planning process.

The memorandum is organized as follows. Chapter 2 outlines a taxonomy introducing general classes of Air Operations for the Canadian Air Forces. Chapter 3 further elaborates on Air Mobility operations. It first defines in more details the nature of specific operations related to this category with an emphasis on airlift. A concise description on the structure, elements and roles of a typical operational Air Force component (8 Wing) mostly responsible for achieving airlift operations is then given. The general process driving the construction of airlift plans leading to the periodic (yearly, monthly) airlift programmes is also briefly presented in Chapter 3. Chapter 4 focuses on the non-forecast airlift planning problem faced by A3 Plans in 8 Wing. A statement and description of the general problem is presented, highlighting the pursued objectives and constraints. Chapter 5 outlines the NFA decision support capabilities. Then, a proposal to develop NFA decision support capabilities in relation with the current state-of-the-art is discussed in Chapter 6. Finally, a short summary is given in Chapter 7.

2 Supporting air operations

The Aerospace Doctrine [6] establishes and provides a conceptual framework within which aerospace military operations are structured into three categories: combat operations, supporting air operations, and sustainment operations. In this context, combat operations encompass all the inter-related groups of air power combat activities required to undertake offensive and defensive operations against enemy forces and positions. On the other hand, supporting air operations are those non-combat air operations generally subdivided into seven categories: airlift operations, air-to-air refuelling, search and rescue, electronic warfare, aerospace surveillance and reconnaissance, airborne early warning and special operations. In accordance with the Aerospace Doctrine, the structure of the supporting air operations is indeed depicted in Figure 1. Finally, sustainment operations are referred to as non-flying activities designed to provide direct support for combat and supporting air operations.

In short, a strategic NFA consistent with Aerospace Doctrine comes within the scope of special flights [6]. However, a more detailed definition refers to strategic NFAs as special flights programmed to achieve specific requirements, i.e. joint exercises, essential transportation of personnel or materiel, and issues of national interest, that cannot be satisfied using scheduled flight programs [1].

Somewhat outdated as a result of rapidly changing technology and operational concepts, the aerospace doctrine mentioned above is partially implemented across Air Force units. The Air Force organizational structure has been changed in 1997 from one where the Tactical Air Group, Maritime Air Group, Fighter Group and Air Transport Group reported to the Air Commander Command to one where the above four mentioned groups were eliminated and all Air Command Wings report directly to 1 Canadian Air Division (1CAD) located in Winnipeg who, in turn, reports to the CAS (Chief of the Air Staff) at NDHQ (National Defence Head Quarter). Based on the recently implemented Wing Concept, the Canadian Air Forces are structured into four air groups: Fighter Force, Air Mobility, Maritime Patrol/Helicopter, and Tactical Aviation (see [10]). Details regarding air operations conducted by various Wings and Squadrons forming the newly introduced air force organizational structure are shown in Figure 2. It is the responsibility of the Air Mobility Group to accommodate NFA requests and conduct the corresponding airlift operations.

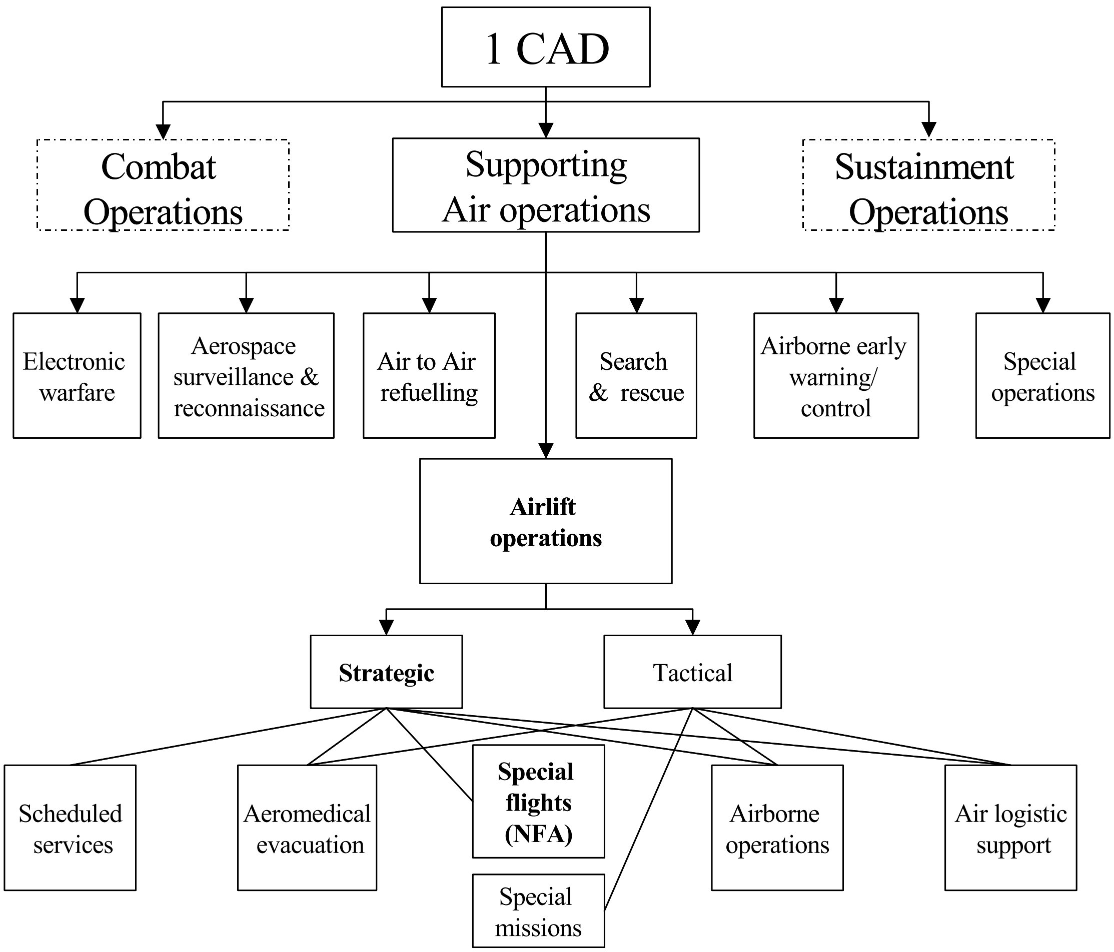

Figure 1. *An overview of the supporting air operations as described in the aerospace doctrine*

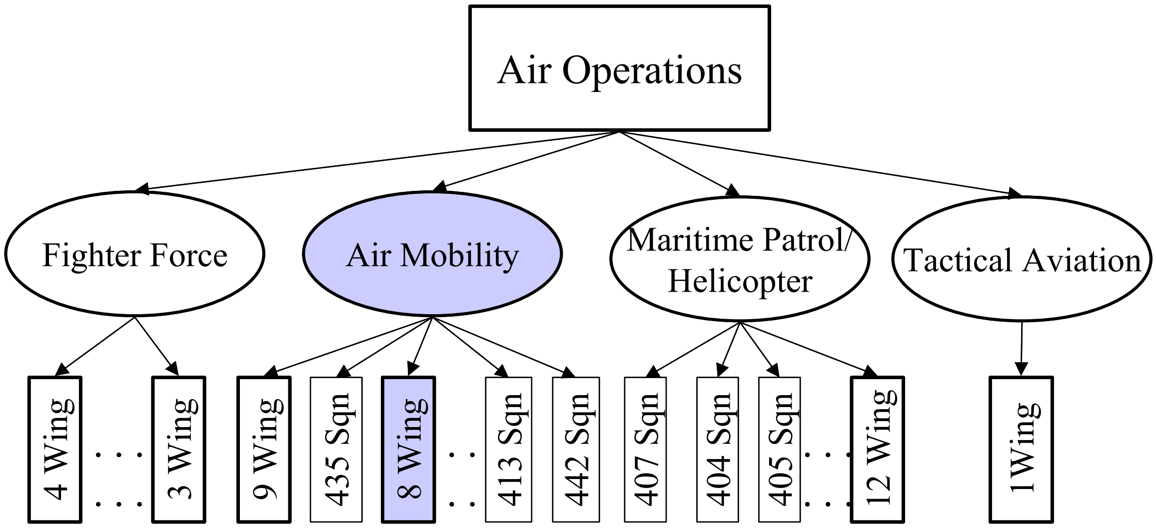

Figure 2. *An overview of the recent structure of the air operations*

3 Air Mobility Operations

The air mobility operations discussed so far mainly involve:

Air-to-air refuelling (AAR) operations consist of all activities designed to support "in-flight transfer of fuel from one aircraft to another" [6]. Using KC-130 Hercules, AAR activities are indeed conducted to support fighter units training and deployment.

Search and rescue (SAR) missions require tasking air resources to search for and rescue personnel in distress on land or at sea [6].

Air transport operations represent the major activity involving both strategic airlift and tactical airlift.

The strategic airlift is provided to support movement of resources into and between areas or theatres of operations [6]. A strategic airlift may also include intermediate landing. Indeed, the 8Wing Trenton provides strategic airlift on Hercules (CC130) and Polaris (CC150).

The tactical airlift is primarily performed to ensure the transport of personnel, equipment or supplies into a theatre of operations [6]. In addition to providing combat support, tactical airlift activities may also be conducted in support of army training. As a result, aircrews of tactical airlift units are equally well suited for regularly conducting training missions. The origin and destination of a tactical airlift would usually remain the same. Although tactical airlift operations are generally deployed and accomplished using mainly Hercules (CC130), various types of aircraft such as Labrador (CH113) and Cormorant (AW520) may however be required to meet the specific mission objectives and requirements.

At the heart of Canada's air mobility forces, the 8 Wing Trenton is dedicated to conducting requested airlift missions across the full range of military operations described above. The range of air operational missions, i.e. strategic airlift, tactical airlift, and search and rescue, generally assigned to the 8 Wing flying squadrons[1] are summarized in Figure 3. As shown in this figure, the air unit is also responsible for tasking appropriate air resources to provide strategic air-to-air refuelling in support to the 435 squadron (1 CAD fighter squadron)[2]. Search and rescue operations are generally conducted from the 9 Wing Gander, home of the 103 Search and Rescue (SAR) Squadron.

[1] Based at Trenton

[2] www.airforce.dnd.ca/8wing/squadron/wingops_e.cfm

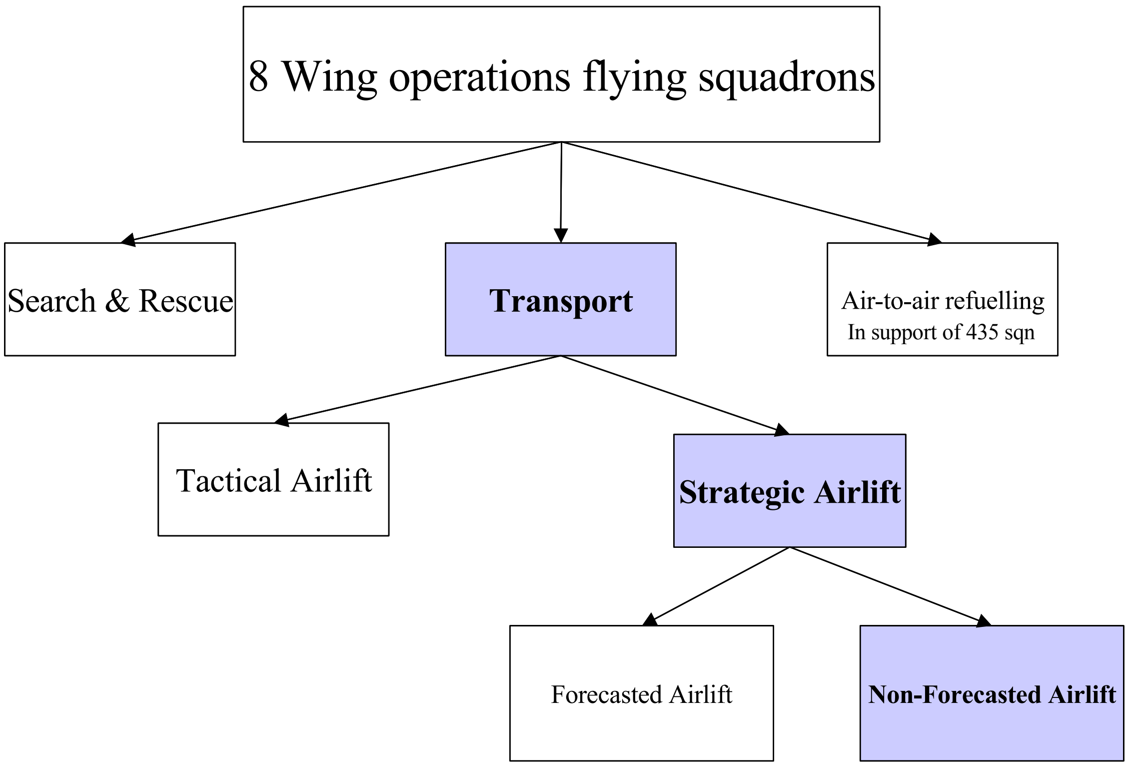

Figure 3. *The main operations conducted by the 8 Wing flying squadrons*

3.1 8 Wing Squadrons

As already mentioned, the 8 Wing Trenton is responsible for identifying and tasking appropriate airlift resources to meet national air mobility requirements as requested by the 1CAD. Indeed, 80% of requested strategic airlift operations are achieved by air units of the 8 Wing Trenton using CC-130 (Hercules) and CC-150 (Polaris) aircraft. On the other hand, the 8 Wing Trenton is also responsible for providing air resources to support tactical airlift missions assigned by the 1CAD. In addition, it serves as a deployed operating base in charge of tasking and coordinating appropriate search and rescue resources using CC-130 and CH-113 (Labrador). Finally, the 8 Wing Trenton is also the home of air force units designed to respond to vital air-to-air refuelling missions in support of the 1CAD fighter squadrons (See [10] and [11]).

Units assigned to the 8 Wing Trenton operational command and control are organized into five flying squadrons and four non-flying squadrons (See Figure 4). The non-flying squadrons are not directly involved in the transport operations. The four non-flying squadrons are:

- **2 Air Movements Squadron (2 AMS)** – the 2 AMS is indeed responsible for processing the 8 Wing's personnel and freight.

- **8 Air Maintenance Squadron (8 AMS)** – the 8 AMS is a dedicated provider of preventive and repair maintenance for CC-130 Hercules and CH-113 Labradors. In addition, the Squadron also provides support to the Canadian Airlines International (Air Canada) in maintaining the CC-150 Polaris.

- **8 Air Communication and Control Squadron (8 ACCS)** – the 8 ACCS is a deployable unit assigned the task of providing communications, information, and traffic control services.

- **8 Air Reserve Flight (8 AR Flt)** – comprised of aircrew, support, and clerical staff who augment all squadrons at 8 Wing.

The five operational flying squadrons are[3]:

- **424 Squadron** – the 424 Squadron is a **Search and Rescue/Transport** Squadron. Using CC-130 and CH-113 aircraft, the 424 Squadron is responsible for covering Central Canada, a region comprising Ontario, most of the Province of Quebec, the Prairie Provinces and the entire Arctic.

- **426 Squadron** – the 426 Squadron is a **Transport and Training Squadron.** It is mandated to training aircrew and technical support personnel needed to operate and maintain the CC-130 Hercules and CC150-Polaris aircraft.

- **429 Squadron –** the 429 **Transport** Squadron is assigned to the difficult but critically important responsibility for operating the CC-130 Hercules. In accordance with its mandate for supporting strategic airlift missions, the Squadron provides effective support to Canadian Forces and embassy personnel throughout the continents - supporting Canadian Forces Station Alert in the High Arctic, re-supplying troops in different countries, etc. Another task assigned to this Squadron consists in training the Army's airborne capability.

- **436 Squadron** - the 436 Squadron is a **Transport** Squadron. Its mandate consists in accomplishing strategic and tactical airlift missions using the CC-130 Hercules. As part of its strategic airlift mission, the Squadron's mandate is to carry personnel and materiel on a global response basis, prepared to deliver 24 hours a day, 7 days a week. Its responsibility to conduct tactical airlift covers, on the other hand, various activities ranging from aerial delivery of troops and equipment to transport of humanitarian aid.

- **437 Squadron –** the 437 Squadron is also a **Transport** Squadron responsible for conducting long-range transport of personnel and equipment using CC-150 Polaris Aircraft.

In addition to the squadrons listed and described above, the 8 Wing Operations include several other units:

[3] 412 squadron (transport) belongs to 8 Wing , but it based at Ottawa and provides airlift for VIPs.

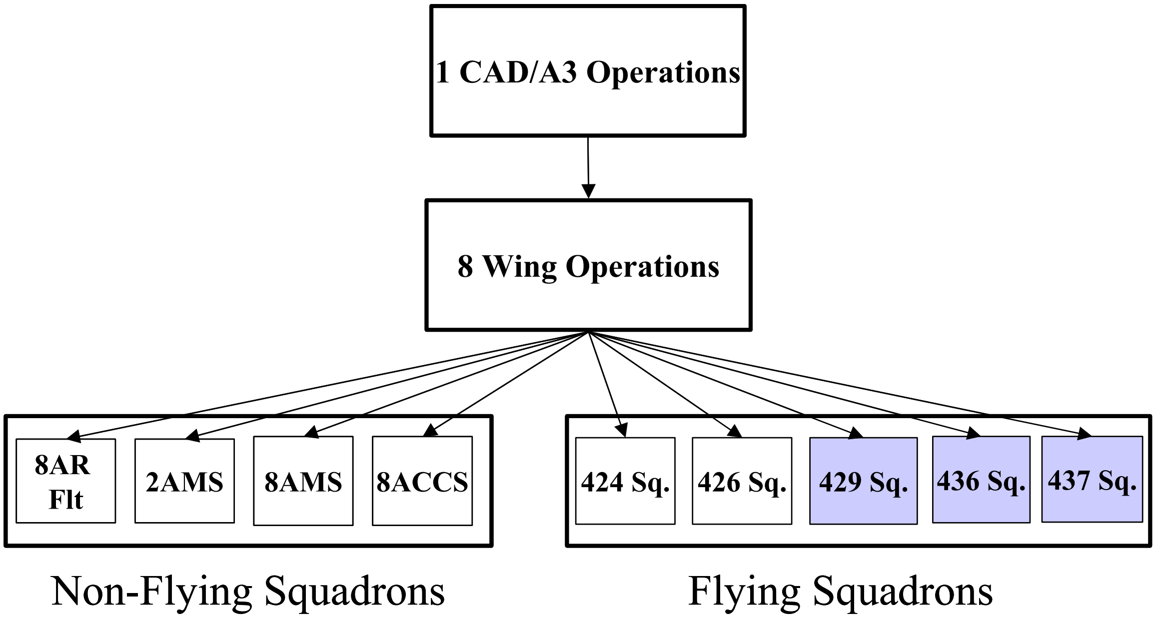

Figure 4. *The 8 Wing Squadrons and the tasking process*

- Wing Despatch Centre
- Air Traffic Control
- Security and Military Police Squadron
- Nuclear, Biological and Chemical Defence Unit
- Trenton Meteorological Squadron

Figure 4 gives an overview of how the 8 Wing Operations are structured and organized into different squadrons, and how the interface to the 1CAD/A3 Operations is provided to ensure effective command and control to the tasking and execution process of aerospace operations. Indeed, National Defence Headquarters (NDHQ) tasks 1 CAD to provide appropriate air resources to meet national movement requirements. In this context, the responsibility of 1 CAD is to identify and task the requested Canadian Forces airlift resources (Wings) required to meet these requests [2]. Note that airlift operations are directed at the 429 Squadron, the 436 Squadron, and the 437 Squadron (see Figure 4).

As already stated, the forecasted airlift operations conducted at the 8 Wing –Trenton are based on the Fiscal Year Airlift Programme (YAP) and the Monthly Airlift Programme (MAP) conducted by 1 Canadian Air Division (1 CAD). Although tasked by the 1 CAD, the NFA requests are however planned at the 8 Wing Operations.

3.2 Fiscal year airlift programme and monthly airlift programme

The planned airlift missions are incorporated into the Fiscal Year Airlift Programme (FYAP) through an ongoing process that starts with the fiscal year on April 1st. Within the scope of the FYAP, A3 Operations/1CAD is indeed responsible for planning, tasking, coordinating, overseeing, and monitoring air operations that are the responsibility of the Air Division. Most of the airlift missions that are first identified and then requested, planned, and incorporated into the FYAP fall under the strategic airlift category.

A FYAP is conceived and divided into twelve parts, each containing information regarding monthly scheduled flights. A Monthly Airlift Programme (MAP) is thus readily generated from the FYAP so as to provide the ability to consider and accurately incorporate requested updates. Normally, changes are submitted in time so that the MAP is obviously examined, finalized, and approved one month prior to flight departure. The monthly-based airlift programme is then published, distributed to appropriate personnel, and forwarded to the Air Mobility Wings and Squadrons.

Within the 8 Wing Trenton, a copy of the MAP is passed to the 8 Wing Operations Officer who in turn dispatches mission orders to the flying squadrons under his command and control. Based on these orders, planners within each squadron are assigned the task to provide appropriate aircrafts and other resources and schedule flights as required within the MAP.

As stated above, airlifts requested to support specific requirements that may arise too late for submission in the YAP and MAP fall under the NFA category. In the absence of dedicated automated planning systems, NFA flights are manually planned at 8 Wing Operations – Trenton – using various databases, i.e. fuel prices, parking fees, etc., to build different scenarios.

4 Planning non-forecast airlift

Within 8 Wing Ops, A3 Plans is the cell responsible for handling the NFA detailed plans and arrangements with the collaboration of the despatch centre. Indeed, a typical NFA mission consists of carrying troops and/or cargo generally from Trenton base to another country. While it often requires few days round trip, such flights are usually performed using various available airfields for refueling and/or crew rest. In addition, a specific airlift operation can also be requested for loading and offloading cargo at intermediate stops. In this respect, a recurrent challenging problem that is difficult to approach lies in the need to select intermediate landing fields so as to minimize operating costs while satisfying user-specified constraints.

The different costs to be minimized

- **Fuel cost**: As mentioned above, a NFA is generally a worldwide flight requiring intermediate stops for refuelling and crew rest. Selecting appropriate intermediate airports to build an optimal mission itinerary minimizing traveled distance can indeed lead to a significant reduction in fuel costs.

- **Temporary duties expenses**: Temporary duties expenses represent the inclusive payment that the Canadian government *(or that a government pays)* pays to aircraft crew members. However, the amount of such remuneration designed to cover temporary duties expenses depends on the destination country or city to a certain extent.

- **Accommodation expenses**: Crew members are also granted additional payments intended to cover the necessary accommodation expenses. However, the refund of accommodation expenses is subjected to the need for the dispatcher to find and choose a hotel for crew members. Indeed, accommodation and hotel rooms are excessively expensive in various well-known cities around the world. In this respect, it is advisable to make a trade-off between accommodation costs and other expenses associated with a given airlift mission. Furthermore, places where the cost of accommodation and hotel rooms is excessively high may be discarded as candidates for intermediate landing airfields.

- **Aircraft landing and parking fees**: Aircraft landing and temporary parking fees vary from one airport to another. However, it is known that various airports around the world provide free aircraft parking.

- **Fixed costs**: Fixed costs are also allocated to various activities associated with NFA missions. These expenses mainly include all fixed cost charges relating to aircraft operation and maintenance.

The constraints to be considered

- **Intelligence**: The Intel Cell located at 1 CAD is responsible for working out, constantly updating, and disseminating a comprehensive list of countries identified as posing serious security risks. This list is (or can be) used to exclude airports located in high-risk countries as candidates for intermediate landing airfields. In this respect, a user-defined threshold can set the critical security level over which an airport cannot be considered as a candidate-landing airfield.

- **Fuel consumption**: The position and weight of loaded cargo are known to affect aircraft fuel consumption. As a result, the freight transported can, in a way, determine the number and location of refuelling airfields.

- **Satisfaction of the aircrew preference**: This abstract constraint would be the most difficult to address when developing a mathematical model to solve a constraint satisfaction NFA problem. Generally, an aircrew member would prefer team *x* rather than *y* and destination *d* rather than *s*.

- **Weather forecast**: JetPlan-software is used to determine the best aircraft flying enroute. This software gives the total flying distance and the quantity of fuel needed to carry-out a given mission. Input data or parameters required are the type of aircraft, loaded freight, and flight date.

- **Time windows constraints**: Fatigue is a true threat to mission safety since it results in reduced decision making and flying abilities due to mental and physical stress. Improving flight safety imposes the need to ensure that crew members rest adequately at intermediate stops. In this respect, crew members are subjected to limited cumulative duty hours between required rest periods.

- **1 CAD constraints**: 1 CAD usually provides all instructions about the expected flight date/time of arrival to final destination. On the other hand, 1 CAD also provides information regarding the content of aircraft cargo (type, quantity, etc.) intended to be shipped.

- **Trade-off between number of landing/take-off and aircraft life cycle**: Excessively serviced aircraft tend to induce high associated life cycle costs of operation and maintenance, as the number of landing/take-off increase dramatically

- **Airfield adequacy**: Certain airfields are better than others in providing adequate support facilities to better accommodate scheduled missions. Selected locations or operating sites must include appropriate fuel and maintenance facilities. Based on mission requirements, different criteria can be defined for selecting adequate intermediate locations and avoiding airfields lacking the required facilities.

- **Possibility of loading freight in intermediate fields**: the operation of the pick-up and delivery can be considered for certain airlifts.

- **Crew rotation**: Long worldwide airlift missions require scheduling adequate crew rest. In this respect, it would appropriately wise considering replacement crews that can take over the flight mission at specific intermediate locations (for Trenton-Australia-Trenton airlift, the first crew can stay at Hawaii to have a rest and the flight crew is replaced by another crew). Crew rotation is important when the on-time freight and passengers' delivery is considered for a long worldwide airlift (NFA from Trenton to East Timor). In short, the movement of the freight and passengers can be constrained spatially and temporally.

- **Other constraints**: Other constraints such as maintenance constraints associated with staggering, resource capacity, crew convention, and user training requests could also be considered.

Other considerations

It is supposed that planners are responsible for deciding which aircraft will be used to accomplish a given NFA mission. As a result, aircraft-related data (capacity, fuel consumption, etc.) are known in advance. On the other hand, mission planning and air resources tasking are obviously constrained by crew availability and aircraft maintenance schedules.

Intermediate airfields selection criteria include not only runways and taxiways capable of accommodating the type of aircraft used but also other support facilities such as fuel storage, loading and unloading equipment, storage and handling facilities, crew resting facilities, etc.

The quantity of needed fuel (from an airfield to another) depends on the load, speed, altitude, and itinerary (air itinerary). The JetPlan[4] software is designed to perform the optimized itinerary from one airfield to another. The optimization process incorporates many factors such as the ambient metrological conditions to determine the optimal trajectory from origin point A to destination point B.

The JetPlan input parameters are:

- The origin and the destination of the leg.
- The weight of the cargo to be carried
- The date of the flight
- Aircraft type (Hercules or Polaris)

The JetPlan-software output data are:

- Expected needed fuel

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[4] Developped by Jespeen

- The full distance from point A to point B
- Detailed itinerary

The JetPlan output parameters enumerated above (for different scenarios) will be used as input data to the non-forecast strategic airlift-planning problem.

5 NFA decision support system capabilities

The goal of this study is a prior step ultimately directed toward the development of an automated planning system to support NFA. Such a system will be designed to offer a sufficient automated support and will determine an optimized network over which a tasked aircraft will fly. The quantity of fuel needed for refuelling in each airfield, the number of hours needed for crew rest, if crew replacement is needed or not, etc, will be provided by the system. The system should be open or flexible to incorporate real-time requirements and/or real-world scheduling constraints: on time delivery of freight for example.

More specifically the purpose of NFA decision support system is to

- Determine the NFA network configuration (routes, etc.).
- Schedule flight crew to ensure on-time freight and passengers' delivery.
- Determine adequate airfields for aircraft intermediate stops.
- Determine fuel quantity needed to conduct a given airlift mission.
- Address what-if questions and contingency plans.
- Evaluate freight and passengers movement requests.
- Allocate airlift resources: airfield resources, aircraft characteristics, and crews
- Develop a schedule for NFA mission while processing information associated with mission requirements.
- Analyse and compare different delivery and routes strategies.
- Provide mission schedule and required data to the DSS for updating its mission plans.
- Provide cost-effective scheduling of NFA missions.
- Ensure on-time delivery of freight and personnel.

6 Interaction between the NFA and the Decision Support System (DSS)

6.1 Overview

Optimal resource management has been recognized as a critical issue to be addressed by the Air Force military community. In 1998, a joint venture involving university, private industry and DND was created to address simultaneous aircraft and crew scheduling (resource management) within the context of air operations and commercial airlines. The $1260K “Decision Support Systems for Simultaneous Aircraft and Crew Scheduling” DND/NSERC three year project involved the following members, namely, GERAD, a research group in decision aids from the University of Montreal, AD Opt Technologies from Montreal, AIRCOM DCOS Op Rsch, Air Force Command and Control Information System (AFCCIS) project and, DRDC Valcartier through the participation and contribution of the co-author.

The project [9] was aimed at developing a methodology and an operational and marketable implementation for the integrated scheduling of airframes and crews, and the selection of itineraries. Research focused on the development of an open-loop decision support system using innovative and promising algorithms and decomposition methods from Operations Research. The mathematical programming methodology was based upon multi-commodity non-linear network static model using column generation as a problem-solving technique.

Targeted military application domains focused on air operations including operational Air Mobility and Tactical Aviation (Figure 2). Even though most modeling and solution implementation efforts were unexpectedly spent toward the Air Mobility domain, some minimal work (see Rancourt and Savard [7]) has been reported on the mission scheduling problem associated with Tactical Aviation. That problem involves the scheduling of tactical and training missions while simultaneously constructing aircrew schedules for tactical units or squadrons operating under Army Aviation Fleet (1 Wing).

The Air Mobility "line tasking" problem (Rancourt and Savard [8]) under study was primarily directed to support strategic airlift mission planning under the responsibility of A3 operations/1 CAD. In this context, mission plan expansion (fleet and crew scheduling) and execution are carried out by Air Transport Fleet (8 Wing) and its subordinated flying squadrons as shown in figure 3 and 4.

The line-tasking problem consists in selecting airlift requests and construct strategic airlift missions to be achieved over a specific time horizon, generating a periodic (monthly, yearly) airlift programme. It can be described as follows: given a set of prioritized requests with time windows, construct a set of valid missions assembled in task lines in order to maximize the number of supported requests while minimizing operational cost subject to a variety of resource (aircraft attributes such as type and fleet size associated to each squadron) and mission constraints (e.g. maximum number simultaneous missions allowed at squadrons). The operational cost has been defined as the sum of travel times associated with scheduled missions. A mission characterizes a plan describing an itinerary for a specific aircraft, including its base and type, the sequence of supported airlift requests (legs) with temporal characteristics as well as related ground tasks (briefings, stops, etc.). A mission is assumed to start and end at the aircraft affiliated base. The generation of scheduled missions achieved under A3 Operations/1 CAD supervision assumes the availability of static accurate information reflected through prior knowledge about the number of lines of tasking for each wing as well as the number of serviceable transport aircraft and types over the targeted time horizon. Crew training missions are also naturally interleaved to the monthly airlift programme imposing additional constraints while constructing the plan. More details on the line tasking problem description and its formulation (problem modeling) may be found in Guex [5] and Rancourt and Savard [8], respectively.

6.2 Components

The DSS relies on a natural and straightforward process. Based on a profile specification, the user can collect valid data inputs and specify directives to generate a scenario in which missions can be manipulated and then, submitted to the optimizer to provide a solution. The results can then be archived, retrieved, or easily visualized. The DSS prototype includes six components, namely, the user manager, the input manager, the mission manager, the scenario manager, the optimizer and the output manager. Figure 5 shows these components and their relationships in the functional model. These components are briefly described next. Additional information may be found in Guex [4,5].

The user manager defines the user (planner) profile establishing privileges and preferences managing interactions with databases and connections to local and remote systems.

The input manager support user interactions in specifying input information to be further submitted to the optimization component. Data inputs are generated and validated through specialized dialog and editing capabilities embedded in suitable interfaces. Accordingly, the user is provided with the flexibility to create or modify sets of inputs either from scratch or based upon current and past scenarios imported from selected databases. Inputs include information such as airfields, bases, resource attributes and characteristics (aircraft, types, number, availability, affiliation, permissible freight combinations, etc. See Guex [5] for more details.

User directives to instruct the optimization engine in mission generation are introduced with system dialogs through the mission manager. Accordingly, the user defines the missions considered as input data for the optimization engine. The operator can create a new set of missions from scratch or modify an existing one. The mission manager supports user definition of airlift requests (sequence of legs, time windows, travel time, etc.) and related constraints as well as explicit missions to be imposed by the user if needed. Solutions from previous optimization runs can also be displayed, edited and modified by the user before reactivating the optimization process.

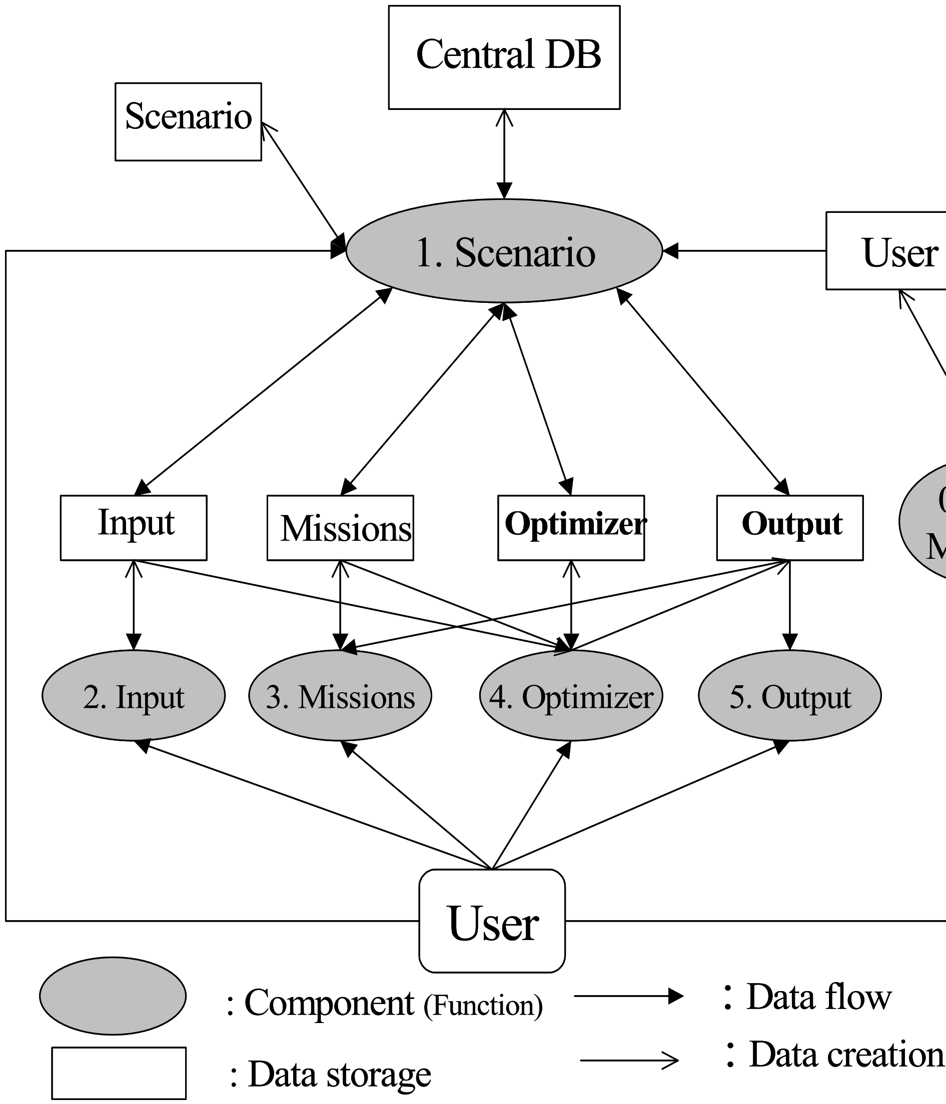

Figure 5. *DSS functional model*

The scenario manager provides the basic tools to piece together scenario elements and then organize or file the resulting scenarios created by the user on external data storage. This component allows the user to create, duplicate, access, destroy or store scenarios. A scenario is then submitted to the optimization engine.

Through a user-system dialog capability, the optimizer manager provides the user with the commands to activate and control the optimization engine for a specific scenario while monitoring its working status. The DSS automatically monitors the evolution of the running optimization process every three seconds and update its status display. The optimization engine uses a column generation technique to solve the problem. Once a solution is found for a targeted scenario, the results are timely displayed for user consumption and then, stored for future use and analysis. The user can easily retrieve stored scenarios and then, initiate new executions or carry out further analysis. Should the situation change or assumptions no longer hold, the optimization process could be promptly interrupted or terminated.

The output manager provides the user with capabilities to visualize the computed solution based on different perspectives and formats. In addition, the output manager supports the edition of the solution enabling the user to shape the mission plans by accepting, modifying or rejecting partial results. As a result, a set of missions is finally presented to the user under the form of task lines. Optimization results are automatically appended and stored with their related scenario file. See Delécluse and Guex [3] for more details.

The DSS prototype has been tested during the international military exercise JWID 2002 offering opportunities for system validation and user requirements refinements. DSS is currently being transited to the AFCCIS project.

6.3 Limitations and challenges

The present DSS prototype focusing primarily on deliberative offline static planning does not satisfactorily capture the current process handling NFA requests. That process mainly relates to deliberative/reactive online dynamic planning. In this regard, a suitable NFA problem model as well as relevant problem-solving procedures will have to be defined and further integrated. While DSS provides some limited capabilities to handle unexpected requests or daily planning, which consists in reactivating a new optimization run for a new constrained static problem instance, NFA requests are tackled separately and in a very different way in practice. NFA requests may either occur at a critical time preventing timely submission and inclusion in the MAP as mentioned in Chapter 4, or require immediate attention (high priority) possibly imposing shorter reaction time. Consequently, the planning task usually achieved by A3 Ops/1CAD is indirectly reassigned at the operational Wing level (at least in the 8 Wing case). The ensuing process then calls for a different problem model characterized by multiple objectives, crew constraints and path planning, while concurrently competing with the MAP planning process for resources over a different time horizon.

Current thoughts on technological challenges imposed by organizational and political constraints suggest a co-evolutionary approach. Initially considering NFA and line tasking as separate problems to be investigated independently subject to minimal interaction (shareable resource) and driven by organization contingencies, related system components could be progressively harnessed in an integrated DSS architecture, leading to a unified framework. Intermediate steps should provide a growing flexibility to naturally interleave loosely coupled NFA system and DSS components while supporting separate execution.

7 Conclusion

Airlift mission activities carried out at 8 Wing Trenton come under the Air Mobility Operations. The planned airlift missions are incorporated into the fiscal year airlift programme (FYAP) and monthly airlift programme (MAP). Airlifts requested to support specific requirements that may arise too late for submission in the FYAP and MAP fall under the NFA (Non-Forecast Airlift) category. In the absence of dedicated automated planning systems, NFA flights are manually planned at 8 Wing Operations – Trenton – using various databases, i.e. fuel prices, parking fees, etc., to build different scenarios.

The different elements that should be considered to model and address the NFA problem as a planning problem have been presented in this document. Specifically, a comprehensive examination of various key issues surrounding the conception of an adequate models designed to support the development of an advanced automated decision aid system for planning NFA has been addressed. The NFA decision support system will be ultimately integrated into the Decision Support System (DSS) which is a prototype that focuses on planning the MAP and the FYAP and does not capture the NFA airlift requests.

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