The Effects of Aircrew Illness and Aircraft Availability on Manning Rates for Selected CF188 Force Employments

D. Gregory Hunter
Directorate of Air Staff Operational Research

DRDC CORA TM 2010-217
October 2010

Defence R&D Canada
Centre for Operational Research and Analysis

Directorate of Air Staff Operational Research
Chief of the Air Staff

The Effects of Aircrew Illness and Aircraft Availability on Manning Rates for Selected CF188 Force Employments

D. Gregory Hunter
Directorate of Air Staff Operational Research

Defence R&D Canada – CORA

Technical Memorandum

DRDC CORA TM 2010-217

October 2010

Principal Author

Original signed by D. Gregory Hunter

D. Gregory Hunter

Approved by

Original signed by D.M. Bergeron, Ph.D.

D.M. Bergeron, Ph.D.
Head Air Section

Approved for release by

Original signed by P. Comeau

P. Comeau
Chief Scientist

The information contained herein has been derived and determined through best practice and adherence to the highest levels of ethical, scientific and engineering investigative principles. The reported results, their interpretation, and any opinions expressed therein, remain those of the authors and do not represent, or otherwise reflect, any official opinion or position of DND or the Government of Canada.

Abstract

This report examines the relationship between the likelihood of overall mission completion and the number of pilots assigned to the executing force for a set of generic but typical force employment scenarios. The scenarios were created in cooperation with A3 Fighter. The effects of factors such as seasonal variation in illness rates and day length, mission duration and intensity and aircraft serviceability are considered. The primary result is a set of tables indicating the probability of achieving various levels of mission completion as a function of the factors indicated above.

Résumé

Le présent rapport examine la relation entre la probabilité d'accomplissement de l'ensemble de la mission et le nombre de pilotes affectés à la force d'exécution pour un jeu de scénarios d'emploi de la force générique, mais typique. Les scénarios ont été établis en collaboration avec l'A3 Chasseurs. On examine les effets de facteurs tels que la variation saisonnière des taux de maladie et la durée de la journée, la durée et l'intensité de la mission ainsi que l'état de fonctionnement des aéronefs. Le principal résultat est un ensemble de tableaux indiquant la probabilité d'accomplir la mission à divers niveaux en fonction des facteurs susmentionnés.

This page intentionally left blank.

Executive summary

The Effects of Aircrew Illness and Aircraft Availability on Manning Rates for Selected CF188 Force Employments

D. Gregory Hunter; DRDC CORA TM 2010-217; Defence R&D Canada – CORA; October 2010.

In April of 2009, DRDC CORA received a request for operational research support from A3 Fighter at 1 Canadian Air Division. The object of the project was to determine the optimum manning levels for a tactical fighter squadron, focusing on the number of pilots required to meet a number of specified tasks.

The tasks ranged in duration from as little as 2 to 14 days for a point defence scenario, up to 6 months for some international commitments. The intensity of operations for the international scenarios went from 12 hours per day, 5 days per week to 24 hours per day, 7 days per week. The initial request envisioned a highly detailed assessment incorporating pilot unavailability due to a variety of reasons, including but not limited to professional development courses, parental leave, and other leave types. In the end, a simplified view of the problem was taken. Individual scenarios were modelled using a stochastic simulation of personnel (un)availability due to illness. The chance of meeting the scenario requirements was then assessed as a function of the total number of pilots.

The request coincided with a task the author received from The Technical Co-operation Program (TTCP) AER TP-1 to investigate this sort of problem. This report is presented in fulfillment of both tasks.

The initial results of this project were communicated to the sponsor in a letter report in June 2009. Following this, additional work was done, expanding the range of situations considered by incorporating into the simulations the effects of different aircraft serviceability rates, and considering under what conditions the assumptions used for the simulation would continue to be valid.

The scenarios under consideration (described below) are relatively simple; it is possible to determine the minimum number of aircrew required using a simple spreadsheet and applying the known sortie requirements and aircrew flight rules. The real problem is not how many personnel are required in the ideal case, but how many are required to cover illness and other unforeseen tasks and events that take personnel away from flying duties. There is also the matter of ensuring that the crew rest and maximum accumulated flying time regulations are adhered to. However, it is the author's conjecture that manning rates sufficient to guarantee that the planned sorties can be performed, given a certain rate of pilot absence due to illness, will render this last concern moot in most cases.

Scenarios

The following scenarios were examined:

1. A continuous (24 hour) Air Patrol over a domestic location during the month of January. Patrol durations of 1, 3, 7 and 14 days are considered.

2. A continuous (24 hour) Air Patrol over a domestic location during the month of July. Patrol durations of 1, 3, 7 and 14 days are considered.
3. An international deployment 6 months in duration, during which 12/5 operations are maintained continuously. Deployments of 6 and 12 CF188 are considered for both summer and winter health conditions, together with a variety of mission parameters.
4. An international deployment 6 months in duration, during which 16/7 operations are maintained continuously. Deployments of 6 and 12 CF188 are considered for both summer and winter health conditions, together with a variety of mission parameters.
5. An international deployment 6 months in duration, during which 24/7 operations are maintained continuously. Deployments of 6 and 12 CF188 are considered for both summer and winter health conditions, together with a variety of mission parameters.

All scenarios were examined using constant daily sorties rates roughly equivalent to 70% for the first sortie of the day and 50% for subsequent sorties. To explore the effects of different aircraft serviceability rates, scenario 3 was re-examined using simulated daily aircraft availability with four different sets of rates.

Results

The main outcome of the study is a set of graphs and tables relating personnel requirements by scenario to the degree of sortie completion, the season, and the probability of success. Success is defined as having sufficient available personnel over the scenario to meet or exceed a specified sortie completion rate. For scenarios 1 and 2, the only sortie completion rate considered is 100%, due to the nature of the scenarios. The results are shown in tables ES-1 and ES-2 respectively.

Table ES-1: *Manning requirements for scenario 1 as a function of duration and probability of success.*

	Pilots required for given probability of success				
	≥50%	≥80%	≥90%	≥95%	≥99.5%
1 day	16	17	17	18	19
3 days	17	18	19	19	21
7 days	18	19	20	21	22
14 days	19	20	20	21	23

Table ES-2: *Manning requirements for scenario 2 as a function of duration and probability of success.*

	Pilots required for given probability of success				
	≥50%	≥80%	≥90%	≥95%	≥99.5%
1 day	8	8	9	9	10
3 days	8	9	9	10	11
7 days	9	9	10	10	11
14 days	9	10	10	11	12

The results for scenarios 3, 4 and 5 consider a variety of sortie completion rates and deployment sizes. Because of this, the resulting tables are too large for inclusion here. As an example, Table ES-

3 shows a subset of the manning requirements for a scenario 4 deployment of 6 aircraft. This table illustrates most of the important characteristics of the result space. First, more personnel are required if the number of sorties flown is to be increased. Second, it can be seen that winter operations require more personnel than do summer operations. This is due to the increased illness rate associated with this season. Third, increasing the *probability* of having the personnel available to fly a given number of sorties, (the probability of success) also requires more personnel. Finally, it can be seen that there is a difference in personnel requirements between the case of a 100% probability of flying 90% of the planned sorties and the case of a 90% probability of flying 100% of the planned sorties. To be more concrete, the former is a 100% probability of being able to man 90 of 100 sorties, while the former is a 90% probability of being able to man 100 of 100 sorties. Overall, it is much more demanding to attempt the latter than the former. The degree of difficulty increases as the sortie completion rate and probability of success approach 100%.

Table ES-3: *An example of the type of results produced for scenarios 3 to 5. The manning requirements and equivalent manning rates for a scenario 4 deployment of 6 aircraft as a function of sortie completion rate, season and probability of success.*

Sortie Completion Rate	Season	Pilots required / manning ratio for given probability of success	
		≥90%	100%
≥90%	Summer	8 / 1.33:1	8 / 1.33:1
	Winter	8 / 1.33:1	9 / 1.5:1
100%	Summer	12 / 2:1	15 / 2.5:1
	Winter	13 / 2.08:1	16 / 2.67:1

For comparison, another set of simulations were performed using the basic scenario 3 parameters, but with varying aircraft serviceability rates. The results were broadly similar, but had somewhat higher pilot requirements than the fixed sortie rate case, even for relatively low serviceability rates. These results are found in Section 3.2.

Some conclusions may be drawn from the results. For all scenarios, the manning requirements can be reduced in two ways: by accepting a higher level of risk that the desired fraction of total planned sorties cannot be flown due to a lack of personnel; or by accepting a lower target for the fraction of total planned sorties. Also, personnel requirements are greater during the winter months due to the illness rate being higher.

Because of the generic nature of the scenarios considered, it is difficult to make hard recommendations on what appropriate manning ratios ought to be. The intent of the author is to provide the AF leadership with some insight into the personnel required to achieve their goals with a given level of probability or risk. Alternatively, one could make a decision on how many personnel will be committed to a given task, then use the tables to find parameter combinations that can be met by that number of pilots.

Sommaire

The Effects of Aircrew Illness and Aircraft Availability on Manning Rates for Selected CF188 Force Employments

D. Gregory Hunter ; DRDC CORA TM 2010-217 ; R & D pour la défense Canada – CARO ; octobre 2010.

En avril 2009, le CARO RDDC a reçu une demande de soutien en recherche opérationnelle de la part de l'A3 Chasseurs de la 1re Division aérienne du Canada. Le projet avait pour objet de déterminer les niveaux optimaux de dotation pour un escadron d'appui tactique, en se concentrant sur le nombre de pilotes requis pour exécuter un certain nombre de tâches spécifiées.

La durée des tâches pouvait aller de deux à 14 jours pour un scénario de défense d'un point, jusqu'à six mois pour certains engagements internationaux. Dans les scénarios internationaux, l'intensité des opérations allait de 12 heures par jour, cinq jours sur sept à 24 heures par jour, sept jours sur sept. Dans la demande initiale, on envisageait une évaluation très détaillée portant sur l'indisponibilité des pilotes pour diverses raisons, y compris, sans s'y limiter, la participation à des cours de perfectionnement professionnel, des congés parentaux et d'autres types de congés. Finalement, on a adopté une vision simplifiée du problème. On a modélisé des scénarios individuels au moyen d'une simulation stochastique de la disponibilité (ou de l'indisponibilité) du personnel pour cause de maladie. La possibilité de répondre aux exigences du scénario a été évaluée en fonction du nombre total de pilotes.

La demande coïncidait avec une autre demande que l'auteur avait reçue du groupe technique 1 du groupe de systèmes aérospatiaux (AER) du Programme de coopération technique (TTCP), qui traitait du même genre de problème. Ce rapport est présenté en réponse à ces deux demandes.

Les premiers résultats du projet ont été communiqués au responsable en juin 2009 dans un rapport sous forme de lettre. Par la suite, on a poursuivi les travaux et élargi l'éventail des situations examinées en incorporant aux simulations les effets de divers taux de disponibilité des aéronefs, et en examinant dans quelles conditions les hypothèses utilisées pour la simulation demeureraient valides.

Les scénarios étudiés (dont vous trouverez la description ci-dessous) sont relativement simples ; il est possible de déterminer le nombre minimal de membres d'équipage nécessaire au moyen d'une simple feuille de calcul et en appliquant les exigences de sortie connues et les règles de vol applicables à l'équipage. Le véritable problème n'est pas de savoir combien de membres d'équipage il faut avoir idéalement, mais plutôt combien il faut en avoir pour que le travail continue en cas de maladie et si certaines autres tâches ou événements imprévus empêchent membres du personnel ne peuvent s'acquitter de leurs fonctions de vol. Il faut également prendre soin d'observer les règles relatives au temps de repos de l'équipage et au nombre maximal d'heures de vol accumulées. Cependant, l'auteur émet l'hypothèse que des taux de dotation suffisants pour garantir l'exécution des sorties planifiées avec un certain taux d'absentéisme des pilotes pour cause de maladie rendra théorique cette dernière préoccupation dans la plupart des cas.

Scénarios

Les scénarios suivants ont été examinés :

1. Une patrouille aérienne continue (24 heures) au-dessus d'un emplacement local durant le mois de janvier. On prévoit des patrouilles d'une durée de 1, 3, 7 ou 14 jours.
2. Une patrouille aérienne continue (24 heures) au-dessus d'un emplacement local durant le mois de juillet. On prévoit des patrouilles d'une durée de 1, 3, 7 ou 14 jours.
3. Un déploiement international d'une durée de 6 mois, au cours desquels on maintient sans interruption entre 12 et 5 opérations. Des déploiements de 6 et 12 CF188 sont prévus en été et en hiver, avec une gamme diversifiée de paramètres de mission.
4. Un déploiement international d'une durée de 6 mois, au cours desquels on maintient sans interruption entre 16 et 7 opérations. Des déploiements de 6 et 12 CF188 sont prévus en été et en hiver, avec une gamme diversifiée de paramètres de mission.
5. Un déploiement international d'une durée de 6 mois, au cours desquels on maintient sans interruption entre 24 et 7 opérations. Des déploiements de 6 et 12 CF188 sont prévus en été et en hiver, avec une gamme diversifiée de paramètres de mission.

Tous les scénarios ont été examinés en utilisant des taux de sorties quotidiennes constantes équivalant approximativement à 70 p. 100 pour la première sortie du jour et à 50 p. 100 pour les sorties suivantes. Pour étudier les effets des différents taux de l'état de fonctionnement des aéronefs, le scénario 3 a été réexaminé en utilisant une simulation de la disponibilité quotidienne des aéronefs, avec quatre ensembles différents de taux.

Résultats

Le principal résultat de l'étude est un ensemble de graphiques et de tableaux portant sur les besoins en personnel en fonction du nombre de sorties à effectuer, de la saison et de la probabilité de succès. Le succès est défini comme étant le fait d'avoir suffisamment de personnel disponible par rapport au scénario, pour atteindre ou dépasser un taux de sorties spécifié. Pour les scénarios 1 et 2, le seul taux de sorties envisagé est 100 p. 100, compte tenu de la nature des scénarios. Les résultats sont indiqués dans les tableaux S.1 et S.2 respectivement.

Tableau S.1: *Besoins en matière de dotation pour le scénario 1 en tant que fonction de la durée et de la probabilité de succès*

	Pilotes requis pour une probabilité de succès donnée				
	$\geq$50%	$\geq$80%	$\geq$90%	$\geq$95%	$\geq$99.5%
1 jour	16	17	17	18	19
3 jours	17	18	19	19	21
7 jours	18	19	20	21	22
14 jours	19	20	20	21	23

Les résultats pour les scénarios 3, 4 et 5 tiennent en compte des variétés de taux de sorties et de tailles des déploiements. Pour cette raison, les tableaux connexes sont trop gros pour être inclus dans le présent rapport. À titre d'exemple, le tableau S.3 donne un sous-ensemble des besoins matière de dotation pour le déploiement de six avions pour le scénario 4. Ce tableau illustre la plupart

Tableau S.2: *Besoins en matière de dotation pour le scénario 2 en tant que fonction de la durée et de la probabilité de succès*

	Pilotes requis pour une probabilité de succès donnée				
	≥50%	≥80%	≥90%	≥95%	≥99.5%
1 jour	8	8	9	9	10
3 jours	8	9	9	10	11
7 jours	9	9	10	10	11
14 jours	9	10	10	11	12

des caractéristiques importantes de l'espace résultat. Premièrement, il faut plus de personnel si l'on doit augmenter le nombre de vols de sortie. Deuxièmement, on peut constater que les opérations nécessitent plus de personnel durant l'hiver que durant l'été. Cela est dû au taux de maladie accru associé à cette saison. Troisièmement, pour augmenter la *probabilité* d'avoir le personnel disponible pour effectuer un certain nombre de vols de sortie (probabilité de succès), il faut aussi plus de personnel. Enfin, on peut constater qu'il y a une différence de besoins en personnel entre la probabilité de 100 p. 100 d'effectuer 90 p. 100 des vols de sortie prévus et la probabilité de 90 p. 100 d'effectuer 100 p. 100 des vols de sortie prévus. Plus concrètement, dans le premier cas, il y a une probabilité de 100 p. 100 de capacité de doter 90 p. 100 des sorties, alors que dans le second cas, il y a une probabilité de 90 p. 100 de capacité de doter 100 p. 100 des sorties. De façon générale, c'est beaucoup plus exigent d'essayer de réussir le deuxième scénario plutôt que le premier. Le niveau de difficulté augmente à mesure que le taux de vols de sorties et la probabilité de succès approche de 100 p. 100.

Tableau S.3: *Exemple du type de résultats obtenus pour les scenarios 3 à 5. Besoins de dotation et taux de dotation équivalents pour un déploiement de 6 aéronefs pour le scénario 4 en tant que fonction de la durée et de la probabilité de succès.*

Sortie – taux comp.	Saison	Pilotes requis/taux de dotation une probabilité donnée de succèss	
		≥90%	100%
≥90%	Été	8 / 1.33 :1	8 / 1.33 :1
	Hiver	8 / 1.33 :1	9 / 1.5 :1
100%	Été	12 / 2 :1	15 / 2.5 :1
	Hiver	13 / 2.08 :1	16 / 2.67 :1

À titre de comparaison, une autre série de simulations ont été réalisée. Les résultats étaient largement semblables, mais ils indiquaient des besoins en pilotes plutôt élevés que le scénario de taux de sorties établi, même pour des taux d'état de fonctionnement relativement faibles. Ces résultats se trouvent à la section 3.2.

On peut tirer quelques conclusions de ces résultats. Pour tous les scénarios, les besoins en dotation peuvent être réduits de deux manières : en acceptant un plus haut niveau de risque qu'une partie des vols prévus ne soit pas réalisée à cause du manque de personnel ou en acceptant un objectif plus modeste de sorties planifiées. Les besoins en personnel sont aussi plus élevés durant les mois d’hiver à cause du taux plus élevé de maladie.

Compte tenu de la nature générique des scénarios envisagés, il est difficile de faire des recommandations définitives sur ce que devraient être les taux de dotation appropriés. Le but de l’auteur est de fournir au commandement de la Force aérienne un aperçu du personnel requis pour réaliser leurs objectifs avec un niveau de probabilité ou de risque donné. On peut aussi prendre une décision en ce qui concerne le nombre de membres du personnel qui doivent être affectés à une tâche donnée, puis utiliser les tableaux pour trouver les combinaisons de paramètres qui peuvent être atteints avec ce nombre de pilotes.

This page intentionally left blank.

Table of contents

List of tables

List of figures

Acknowledgements

Many thanks to Ed Emond, for his good advice on statistics, "good" meaning a positive outcome 19 times out of 20, but without any warranty expressed or implied.

This page intentionally left blank.

1 Introduction

In April of 2009, DRDC CORA received a request for operational research support from A3 Fighter at 1 Canadian Air Division. The object of the project was to determine the optimum manning levels for a tactical fighter squadron, focusing on the number of pilots required to meet a number of specified tasks.

The tasks ranged in duration from as little as 2 to 14 days for a point defence scenario, up to six months for some international commitments. The intensity of operations for the international scenarios went from 12 hours per day, 5 days per week to 24 hours per day, 7 days per week. The initial request envisioned a highly detailed assessment incorporating pilot unavailabilty due to a variety of reasons, including but not limited to professional development courses, parental leave, and other leave types. In the end, a simplified view of the problem was taken. Individual scenarios were modelled using a stochastic simulation of personnel (un)availability due to illness. The chance of meeting the scenario requirements were then assessed as a function of the total number of pilots.

The request from 1 Canadian Air Division coincided with a task the author received from The Technical Co-operation Program (TTCP) AER TP-1 to investigate this sort of problem. This report is presented in response to both tasks.

The first stage of this study resulted in a letter report [1]. This report assumed that the only acceptable rate of sortie [1] aborts due to insufficent personnel was 0%. This technical memorandum expands on that analysis by examining the relationship between the number of personnel assigned to a task and the probability of achieving various sortie completion rates. The first section of this report assumes the same constant personnel requirements as the letter report.

The final portion of the report goes on the examine the effect of using simulated daily aircraft availabilities instead of assuming a constant number of sorties per day [2].

1. A sortie is defined as one flight by one aircraft.
2. The constant number being based on the expected numbers of aircraft available for sorties.

2 Method

The scenarios under consideration (described below) are relatively simple; it is possible to determine the minimum number of aircrew required using a simple spreadsheet and applying the known sortie requirements and aircrew flight rules [2, 3]. The real problem is not how many personnel are required in the ideal case, but how many are required to cover events such as illness and other unforeseen tasks and events that take personnel away from flying duties. There is also the matter of ensuring that the crew rest and maximum accumulated flying time regulations are adhered to. However, it is the author's conjecture that manning rates sufficient to guarantee that the planned sorties can be performed given a certain rate of pilot absence due to illness will render this last concern moot in most cases.

To deal with the problem of sickness, a probabilistic simulation was created. Representative data for the fraction of aircrew flight days lost due to illness were acquired from a published study of US B-52H crews [4]. This study provides means and variances, with 95% confidence intervals, for rates of lost person-days on a yearly basis, for the winter months (December to February) and for the summer months (June to August). The difference between the summer and winter rates was found to be statistically significant. These rates were used as the basis of this statistical simulation of crew availability.

2.1 Scenarios

The following scenarios were examined:

1. A continuous (24 hour) Air Patrol over a domestic location during the month of January. Patrol durations of 1, 3, 7 and 14 days are considered.
2. A continuous (24 hour) Air Patrol over a domestic location during the month of July. Patrol durations of 1, 3, 7 and 14 days are considered.
3. An international deployment 6 months in duration, during which 12/5 operations are maintained continuously. Deployments of 6 and 12 CF188 are considered for both summer and winter health conditions, together with a variety of mission parameters.
4. An international deployment 6 months in duration, during which 16/7 operations are maintained continuously. Deployments of 6 and 12 CF188 are considered for both summer and winter health conditions, together with a variety of mission parameters.
5. An international deployment 6 months in duration, during which 24/7 operations are maintained continuously. Deployments of 6 and 12 CF188 are considered for both summer and winter health conditions, together with a variety of mission parameters.

2.1.1 Scenarios 1 and 2

Scenarios 1 and 2 are continuous Air Patrols. They differ from each other in the time of year during which they are staged. The short days of the winter months results in more sorties being flown using night-vision equipment. Pilots cannot fly as many hours per day under these conditions and more personnel are needed to fly the required sorties [3].

Scenario 1

Scenario 1 is a continuous, 24h per day Air Patrol over a domestic location in the month of January. The time on station for each pair of aircraft is set at two hours, with 15 minutes allowed for transiting on station and 15 minutes to go off station, thus using the entire 2.5 hour (approximate) endurance of the CF188. While it is assumed that the required mission briefing time is minimal, the minimum time before a pilot can fly again is set at one hour. Using these assumptions the number of aircraft sorties required to sustain the air patrol is 24, in sets of 2. (See the illustration in Figure 1.) The length of the pilots' duty day is set at 12 hours on/12 hours off, but the results are the same if the duty day is extended to 16 hours on/8 hours off. It is assumed that sufficient aircraft will be made available to fly all planned sorties.

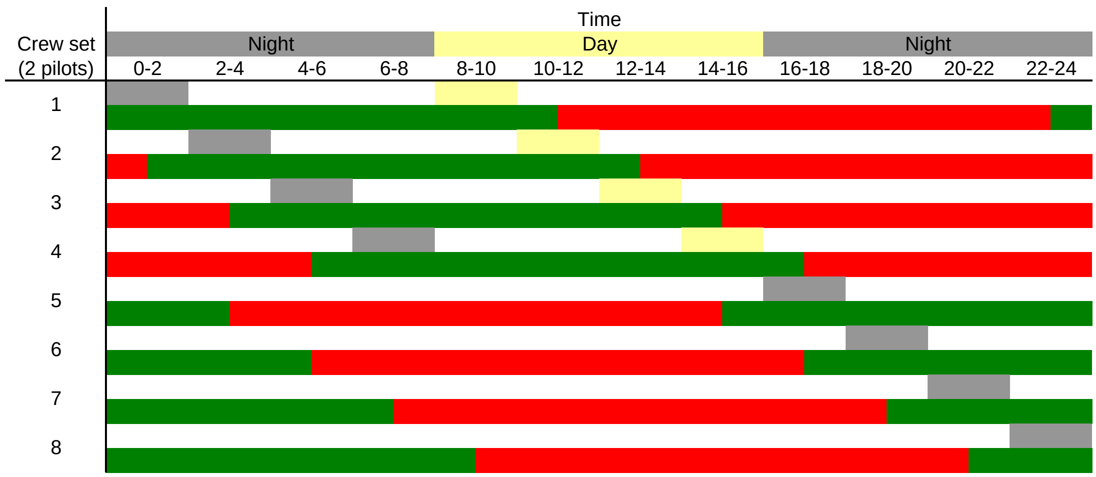

Figure 1: *24 hour schedule showing minimum sustainable number of crews (pilots) required to maintain a continuous winter air patrol of two aircraft on station. The colours indicate the planned twelve-hour duty day for each set of two pilots; green boxes indicate on duty time slots, red off-duty. On station portions of sorties are indicated by grey (night) or yellow (day) boxes. The boxes are two hours across. Not shown are the transit times on and off station.*

The latitude chosen was 49°N. At this latitude and time of the year, there are approximately eight hours of daylight per day. This means that the majority of the remaining 16 hours will be under night flying conditions (See Figure 1). It has been assumed that all missions that overlap this time period will require the use of night vision goggles. The current flight rules [2, 3] restrict pilots to less than 5 hours of night vision goggle flight in any 24 hour period. Because of this and the duty day length, no pilot will fly more than two missions in any 24 period and the average number of mission flown per pilot per day is 1.5 [3]. As a result the absolute minimum number of pilots that could maintain this air patrol is 16. Furthermore, because of the nature of air patrol missions, the only acceptable rate of mission completion is 100%. This is true for scenarios 1 and 2.

3. The distribution of missions between groups of pilots in Figure 1 is notional. As will be seen shortly, the number of pilots on hand will be much greater than the minimum required to make a schedule.

Scenario 2

Scenario 2 is a continuous, 24h per day Air Patrol over a domestic location in the month of July. All of the parameters for the air patrol sorties are as for scenario 1, with the exception of the differing numbers of day and night missions.

The representative latitude chosen was 49°N. At this time of year and latitude, there are approximately 16 hours of daylight per day. It has been assumed that all missions that overlap the remaining eight-hour time period will require the use of night vision goggles. Each pilot could, theoretically, fly 3 missions during a 12 hour duty day. As can be seen from Figure 2, the minimum number of pilots required to maintain an air patrol with these parameters is 8 [4].

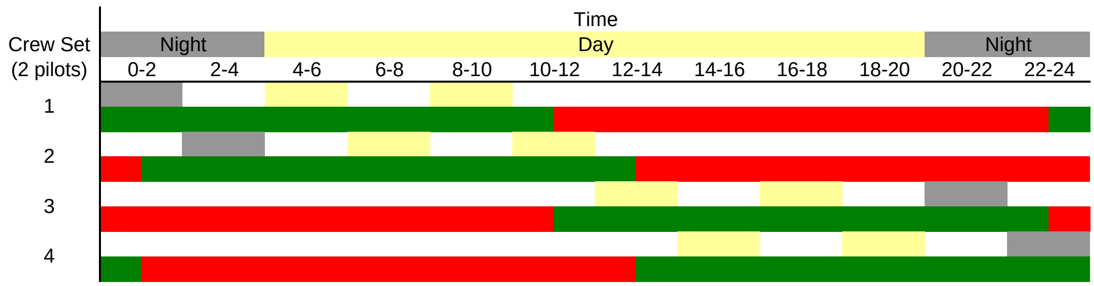

Figure 2: *24 hour schedule showing minimum sustainable number of crews (pilots) required to maintain a continuous summer air patrol of two aircraft on station. The colours indicate the planned twelve-hour duty day for each set of two pilots; green boxes indicate on duty time slots, red off-duty. On station portions of sorties are indicated by grey (night) or yellow (day) boxes. The boxes are two hours across. Not shown are the transit times on and off station.*

2.1.2 Scenarios 3-5

These three scenarios all concern a hypothetical international deployment of 6 or 12 CF188 fighters for 6 months (182 days). The main difference between the scenarios is the planned tempo of operations; 12 hours per day, 5 days a week (12/5) in scenario 3, 16/7 in scenario 4 and 24/7 in scenario 5. For each scenario, the number and duration of sorties and aircraft turning time were varied to create a hypothetical schedule for a week. This schedule was then assumed to repeat 26 times. See Appendix A for details on these schedules [5].

The plans for the number of sorties per day were based on a constant aircraft serviceability rate of 70% for the first set of sorties during the day and 50% for subsequent sets. Significant deviation from this rate requires additional analysis [6], which is discussed in Section 2.3. Assuming that no pilot will fly more than one sortie per day [7], it quickly becomes apparent that the minimum number of pilots required for any given scenario is mostly independent of sortie duration and aircraft

4. The author recognizes the unlikelihood of pilots being pushed this hard except for very short periods of time.
5. The schedules were created based on discussions with A3 Fighter at 1 Canadian Air Division
6. Reference [5] contains reference to a much higher serviceability rate maintained in actual practice, but it does not indicate the time period over which this rate was maintained.
7. This rate is based on the schedules found in Annex A. It is higher than is normally observed in practice.

turnaround time. The minimum number of pilots needed is then equal to the number of sorties per day for that scenario. Simulations of the probable number of pilots available for the scenarios began with these minima and were increased until very high probabilities of success were observed.

Scenario 3

Scenario 3 considers a hypothetical 6 month deployment of 6 or 12 CF188 fighters, during which 12/5 operations are to be maintained continuously. Based on the spreadsheet in Annex A, this will require a minimum of 6 pilots for a deployment of 6 aircraft or 12 pilots for a deployment of 12 aircraft. Simulations of the probability of meeting this requirement given some number of pilots (greater than or equal to the minimum number) were done using both the summer and winter illness distribution data.

This scenario differs somewhat from the following two in that sorties are not conducted continuously for the entire 182 days. Two out of every seven days have no operations, beginning with day six of the simulation. Personnel health is still tracked and simulated for the entire time period; illnesses can extend into, begin and end within the weekend periods. At the end of each iteration, these days are discarded prior to assessing the measures of performance. This results in only 130 of 182 days being used.

Scenario 4

Scenario 4 considers a hypothetical 6 month deployment of 6 or 12 CF188 fighters, during which 16/7 operations will be maintained continuously. Based on the data referenced in Annex A, this will require a minimum of 8 pilots for a deployment of 6 aircraft or 16 pilots for a deployment of 12 aircraft.

Scenario 5

Scenario 5 considers a hypothetical 6 month deployment of 6 or 12 CF188 fighters, during which 24/7 operations will be maintained throughout. There is more variability in the number of sorties that can be flown in this scenario due to the continuous nature of the operations and the different combinations of sortie duration and aircraft turnaround time. The simulations presented here are based on the combinations with the highest sortie rate per day and so the highest pilot requirements [8]. A minimum of 10 pilots is needed for a deployment of 6 aircraft or 20 pilots for a deployment of 12 aircraft.

2.1.3 Other Factors

Not included in these simulations was an allowance for personnel on Home Leave Travel Assistance (HLTA) or other types of leave, training or assignments. For scenarios 1 and 2, this should not be a problem, since these are envisioned as short-term, high-priority force employments during which

8. This is true except when the sorties are significantly in excess of 4 hours; the exact duration at which it is no longer true depends on the total number of pilots. At this point, pilots may begin to exceed their 30-day flying hour limits, necessitating an increase in total crews.

leave will not be granted and other training and assignments postponed. In scenarios 3, 4 and 5, this is not the case. HLTA and Temporary Duty (TD) schedules could be created for each specific case to be simulated, but this was not done in the current study in light of time constraints and the fact that data was not readily available; this could be added at a later date if a subsequent study is required. In any event, the number of pilots that are on HLTA, TD, etc., at any given time must be added to the requirement based on the figures above. Also not considered are factors such as mortality or occupational transfers and the like. The assumption is that permanent or long-term losses of personnel will be back-filled.

2.2 Simulation using constant personnel requirements

The number of personnel entered into the simulation is the total number provided for the scenario. This is determined by the scenario in question; the scenario's minimum requirements are determined by spreadsheet analysis. This number is increased through the sets of simulation runs to create graphs that cover the full range of possible results.

In the simulation, a fixed number of personnel are tracked. Each person's availability for flight duty is tracked on a day-by-day basis. There are two possible states only: available for that 24-hour period or unavailable. Partial day sickness durations are not allowed. For each day of the simulation, a new rate of lost crew-days is drawn from a normal distribution specified using the data from [4] [9]. In order to determine the probability of an individual becoming ill, this rate must be divided by the mean illness duration. Therefore some assumption about the distribution of illness durations must be made. For this study, the illness duration distribution was assumed to be a right triangular one, which was then quantized to whole days by rounding the duration up to the next whole day, with the most probable duration being one day and the least probable being seven days. This is plotted in Figure 3. The longest possible illness duration in the simulation is seven days. The mean illness duration is 2.87 days [10]. It is entirely possible to replace this distribution with any other that is desired. This one was was used in absence of any data to the contrary.

Once that day's chance of illness is determined, each eligible person is checked to see if they become ill by drawing a random number between zero and one and comparing it to the chance of illness; if it is less than or equal to the chance of illness, that person has become sick. All personnel are considered eligible unless a) they are currently sick already, or b) this is their first day back from a previous illness. By design, this prevents an illness from lasting more than 7 consecutive days. It is assumed that any person who is sick for more than one week will be replaced. However, it does skew the illness rate downward by reducing the number of illness checks on days when recovered personnel return to flight duty. Likewise, it is implicit that all personnel are assumed to be healthy at the start of the simulation period.

A person that is found to have become sick then has a random duration drawn from the duration distribution described above. That person's availability record is updated and the simulation moves

9. The use of this distribution assumes that the chance of one person becoming sick is independent of that for all the other personnel, which is probably not true. However, it is a decent first approximation, especially given that we have information that provides for sickness rates to vary as a function of season.

10. The original triangular distribution has an expected illness duration of 2.33 days.

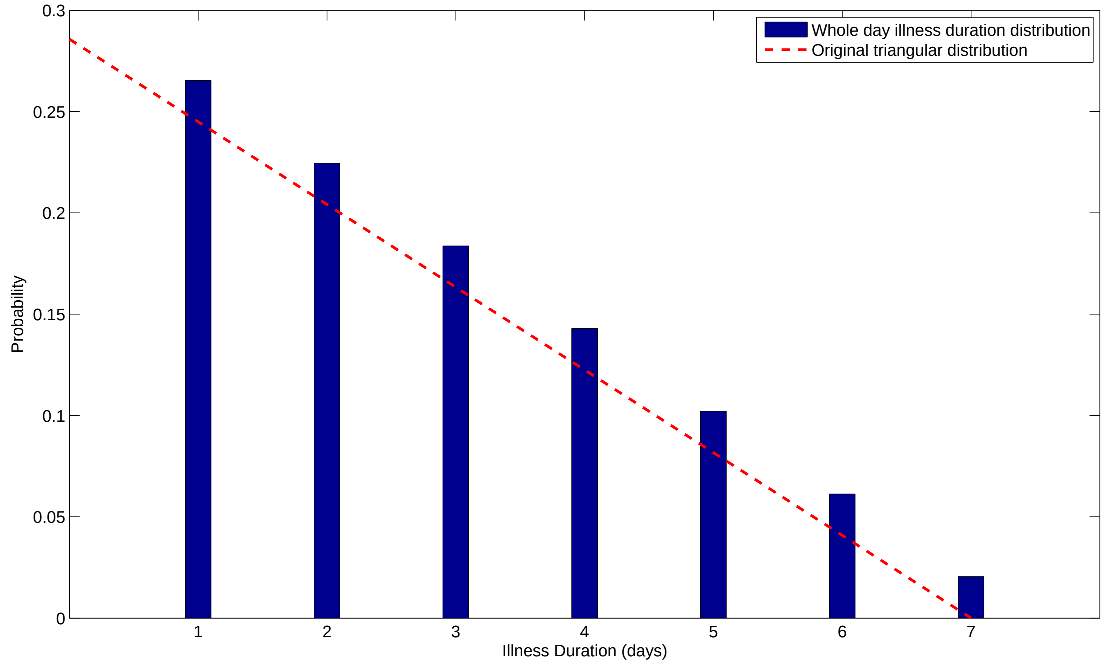

Figure 3: *Quantized probability distribution of illness durations used for the study. The original triangular distribution is included for comparison.*

on to the next person. This process is repeated for each day of the simulation iteration. At the end of the iteration, the number of personnel available on each day is calculated and the minimum value found for the iteration. This is the number of personnel that were available for the entire time period in question. This number is compared to the required number of personnel to determine if the minimum requirements were met.

The simulation was iterated 10,000 times for each number of total personnel and seasonal illness data set. For each iteration, the fraction of attempted/planned sorties for which personnel were available was compiled. This is hereafter referred to as the *completion rate*. These observed completion rates were then compared with a series of specified completion rates (50%, 80%, 90%, 95%, 99% and 100%). The fraction of the total 10,000 observed completion rates that were greater than or equal to the specified completion rate were tabulated and plotted.

An example is shown in Figure 4. This case shows the data for the case of a 182 day force employment with 6 aircraft, using a 12/5 operations schedule. The total number of planned sorties for this case was 780.

These charts of probabilities are the primary output of this study. Rather than have the author make an assumption about the acceptable level of risk, this allows the decision maker to make up his or her own mind. In making this decision, it is important to remember that no allowance has been made for cases where there may not be sufficient serviceable aircraft; it is assumed that sufficient aircraft will be available to fly all planned sorties. (But see Section 2.3 for some results on this subject.) Obviously this may not be the case for all scenarios, particularly the longer ones, but the

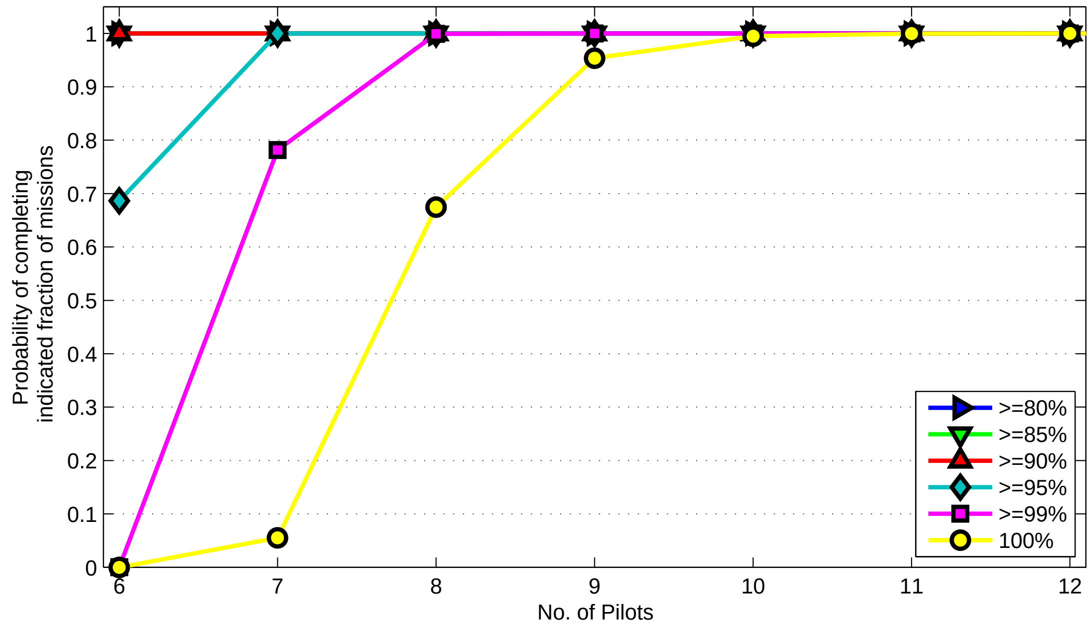

Figure 4: *Example of a graph showing the probability of achieving specified sortie completion rates as a function of the the total number of pilots available. The percentages of sorties completed are given in the legend.*

point of the exercise is to find a manning rate that will not be the limiting factor for the scenario, within an acceptable margin of error.

2.3 Expanded simulation using aircraft availability rates

The number of aircraft available for missions is not constant. The level of serviceability [11] will greatly affect the number of sorties that a fixed number of aircraft can perform. This level is usually given as a rate or probability that any selected aircraft will be fit for service at a specified time. This time is normally daily prior to the beginning of operations, or just before the aircraft is to be used. The exact definition of this variable is both very important and highly variable, with different organizations and fleet communities using their own definitions. For the purposes of this study, we have defined the availability as the probability that the aircraft in question is ready and fit to perform the sortie in question. It is a vector of one or more probabilities, with the N^{th} value corresponding to the N^{th} sortie of the day. The same probabilities are used for every day and every aircraft in the simulation [12].

The availabilities so defined are the long-term mean rates. It is certainly possible to push the availability of some aircraft close to 100% for a period of up to a few weeks. This is accomplished by

11. Or availability.

12. In practice, some aircraft are almost always available and others are unserviceable a large fraction of the time. While this could be simulated if appropriate data were available, the average rates will result in the correct number of available aircraft, which is all that we are interested in here.

focusing the supply of maintenance-hours and spares on the most serviceable aircraft, including the temporary cannibalization of less-serviceable aircraft for parts. This cannot be maintained over a period of months without lavish expenditures, and so the long-term rates have been used.

The number of aircraft available for sorties on a daily basis has been simulated for scenario 3. Scenarios 1 and 2 are short-term scenarios, for which aircraft would likely be made serviceable by means described above.

Four variations of the aircraft availability rate were examined. The rate is specified as the probability of each individual aircraft being fit to fly when required for a mission. The variations are: 50% for the first sortie of the day and 50% for the second; 70% for the first sortie and 50% for subsequent sorties; 70% for the first sortie and 70% for subsequent one; and 90% for the first sortie and 90% for subsequent one. The first represents an aging fleet with serviceability issues; the last a fleet of new aircraft with very high serviceability.

When simulating the number of aircraft available for a set of sorties, an additional constraint was created to reflect real operations. Normally, fighter aircraft operate in pairs. In these simulations, we first simulate the aircraft availability independently for each airframe. Next, the number of planned sorties is checked for both sets of missions for each day. If a given mission has an odd number of aircraft available, the number of planned sorties is reduced by one to make an even number of aircraft.

Figure 5 presents a histogram of the frequency of the number of sorties generated per day. Basic descriptive statistics are found in Table 1. The 70%/50% availability rate has a median daily sortie rate of 6, making it the closest of the four cases to the constant 6 sorties per day used in the previous section. The mean daily sortie rate is 6.20, meaning that there are slightly more sorties in the 70%/50% case than the constant sortie rate case.

Table 1: *Descriptive statistics for daily sortie rate distributions obtained using probabilistic availability rates.*

	Daily Sortie Rate		
Availability Rate	Median	Mean	Standard Deviation
50%/50%	4	5.00	1.87
70%/50%	6	6.20	1.81
70%/70%	8	7.41	1.75
90%/90%	10	10.06	1.50

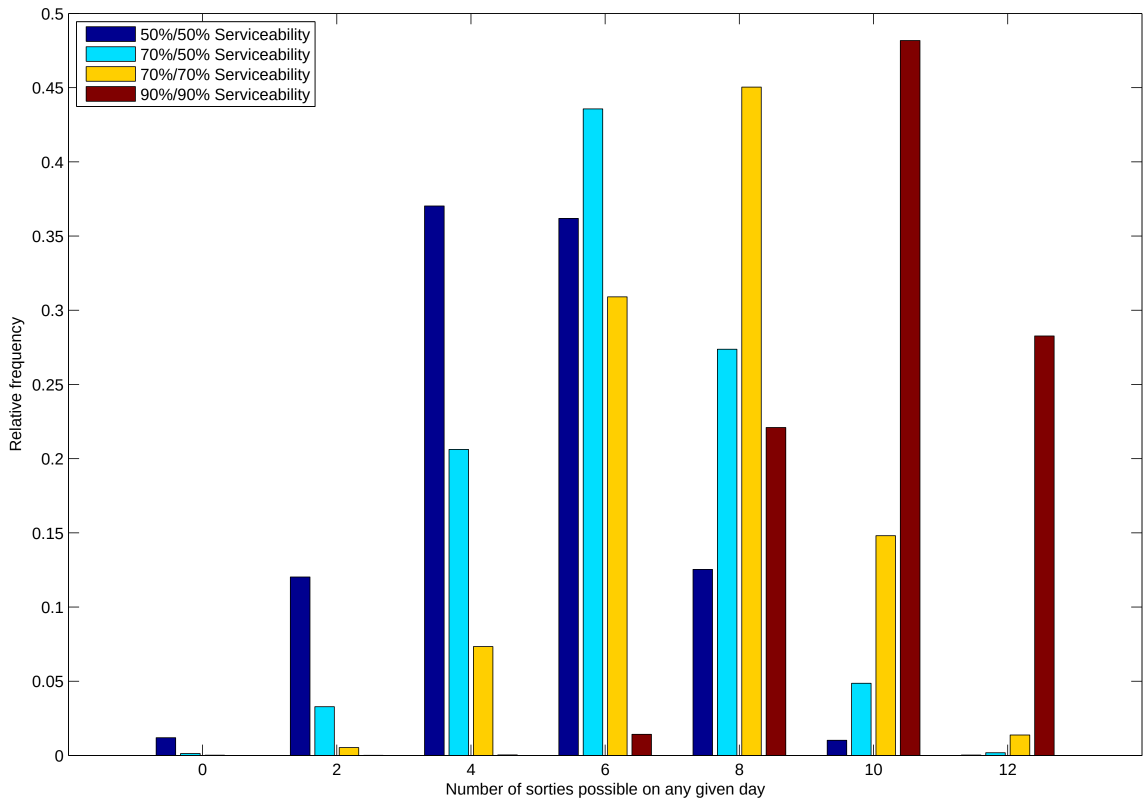

Figure 5: *Histogram of daily sortie rate frequencies generated for a six-aircraft deployment as a function of aircraft availability rate, with a maximum of two sorties per day per aircraft. Considered availability rates are: 50% for the first sortie and 50% for the second; 70% for the first sortie and 50% for the second; 70% for the first sortie and 70% for the second; and 90% for the first sortie and 90% for the second.*

3 Results

3.1 Constant sortie rate scenarios

3.1.1 Scenario 1

For this scenario, the 95% confidence interval of the winter lost aviator-day rate, 6.70%-9.08%, was used.[4] Only the case of 100% sortie completion rate was considered due to the high-priority nature of the mission; failure to fly all of the desired sorties was considered a mission failure. Simulations for periods of 1, 3, 7 and 14 days were run with total pilot numbers ranging from 16 to 22. Each simulation was run for 10000 iterations. The estimated probability of having sufficient pilots as a function of total pilots and air patrol duration is plotted in Figure 6. Table 2 shows the results in tabular form.

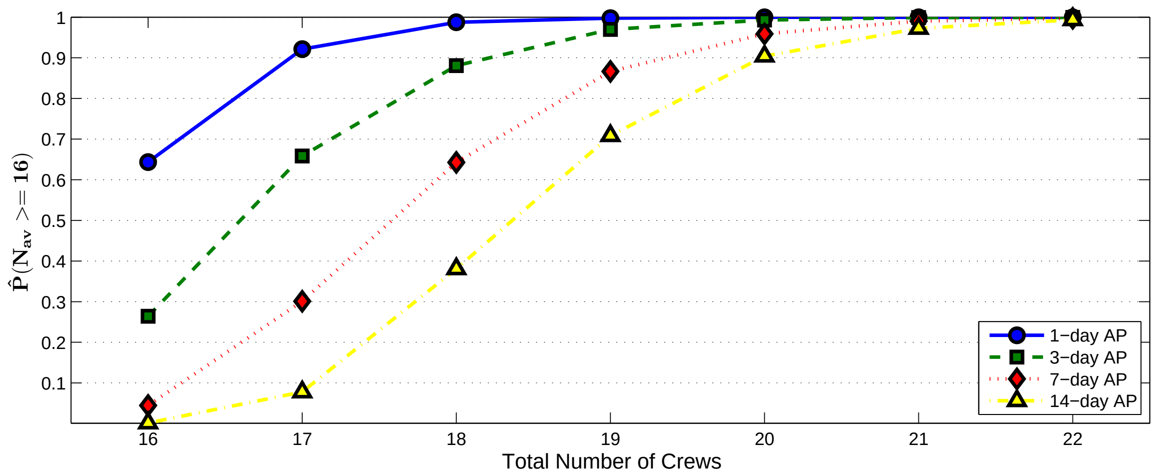

Figure 6: *Estimated probability of meeting manning requirements for a winter air patrol as a function of total number of aircrew and air patrol duration. The minimum manning requirement is 16 crews.*

Table 3 shows the manning requirements for scenario 1 for various levels of probability of success, i.e., the probability of providing all the pilots needed for all planned sorties. The manning rate is not computed because no analysis was done on the number of aircraft required to sustain these operations.

3.1.2 Scenario 2

Scenario 2 is a continuous, 24h per day Air Patrol over a domestic location in the month of July. All of the parameters for the air patrol sorties are as for scenario 1, with the exception of the differing numbers of day and night missions.

For this scenario, the 95% confidence interval of the summer lost aviator-day rate, 3.97%-5.50%, from [4] was used. As was the case for scenario 1, only the 100% sortie completion rate was considered. Simulations for periods of 1, 3, 7 and 14 days were run with total pilot numbers ranging

Table 2: *Estimated probability of meeting manning requirements for a winter air patrol as a function of total number of aircrew and air patrol duration. The minimum manning requirement is 16 crews.*

	Air patrol duration (days)			
Total number of crews	1	3	7	14
16	0.6435	0.2640	0.0447	0.0017
17	0.9212	0.6583	0.3009	0.0780
18	0.9874	0.8809	0.6429	0.3809
19	0.9978	0.9700	0.8665	0.7084
20	0.9999	0.9927	0.9590	0.9040
21	1.000	0.9990	0.9902	0.9725
22	1.000	0.9996	0.9971	0.9935

Table 3: *Manning requirements for scenario 1 as a function of duration and probability of success.*

	Pilots required for given probability of success				
	≥50%	≥80%	≥90%	≥95%	≥99.5%
1 day	16	17	17	18	19
3 days	17	18	19	19	21
7 days	18	19	20	21	22
14 days	19	20	20	21	23

from 8 to 12. Each simulation was run for 10000 iterations. The estimated probability of having sufficient pilots as a function of total pilots and air patrol duration is plotted in Figure 7. Table 4 shows the results in tabular form.

Table 5 shows the manning requirements for scenario 2 for various levels of probability of success. The manning rate is not computed because no analysis was done on the number of aircraft required to sustain these operations.

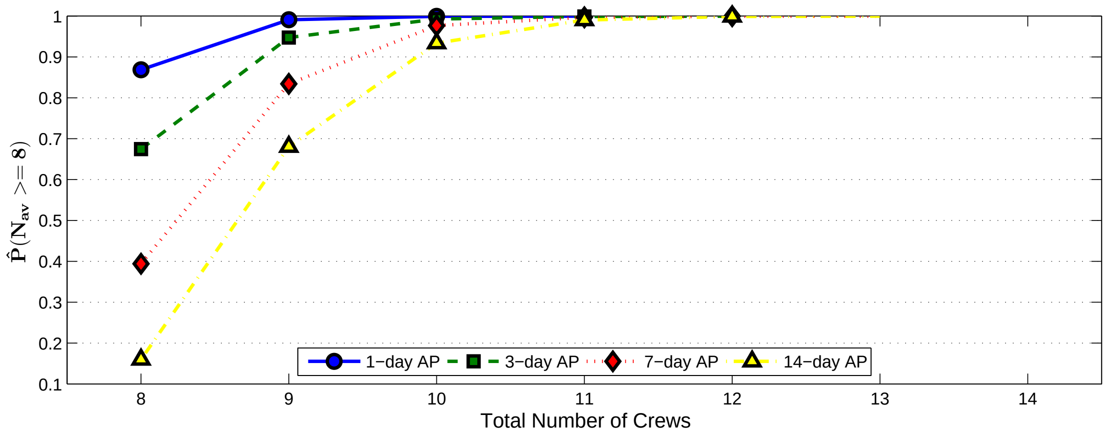

Figure 7: *Estimated probability of meeting manning requirements for a summer air patrol as a function of total number of aircrew and air patrol duration. The minimum manning requirement is 8 crews.*

Table 4: *Estimated probability of meeting manning requirements for a summer air patrol as a function of total number of aircrew and air patrol duration. The minimum manning requirement is 8 crews.*

	Air patrol duration (days)			
Total number of crews	1	3	7	14
8	0.8686	0.6746	0.3940	0.1597
9	0.9910	0.9475	0.8343	0.6807
10	0.9994	0.9928	0.9769	0.9340
11	1.000	0.9991	0.9969	0.9904
12	1.000	1.000	0.9999	0.9990
13	1.000	1.000	1.000	1.000
14	1.000	1.000	1.000	1.000

Table 5: *Manning requirements for scenario 2 as a function of duration and probability of success.*

	Pilots required for given probability of success				
	≥50%	≥80%	≥90%	≥95%	≥99.5%
1 day	8	8	9	9	10
3 days	8	9	9	10	11
7 days	9	9	10	10	11
14 days	9	10	10	11	12

3.1.3 Scenario 3

Scenario 3 considers a hypothetical 6 month deployment of 6 or 12 CF188 fighters, during which 12/5 operations will be maintained continuously. Based on the spreadsheet in Annex A, this will require a minimum of 6 pilots for a deployment of 6 aircraft or 12 pilots for a deployment of 12 aircraft. Simulations of the probability of meeting this requirement given some number of pilots (greater than or equal to the minimum number) were done using both the summer and winter illness distribution data. The results for a 6-aircraft deployment are shown in Figure 8. Figure 9 shows the results for a 12-aircraft deployment. Table B.1 in Annex B contains the results in tabular form.

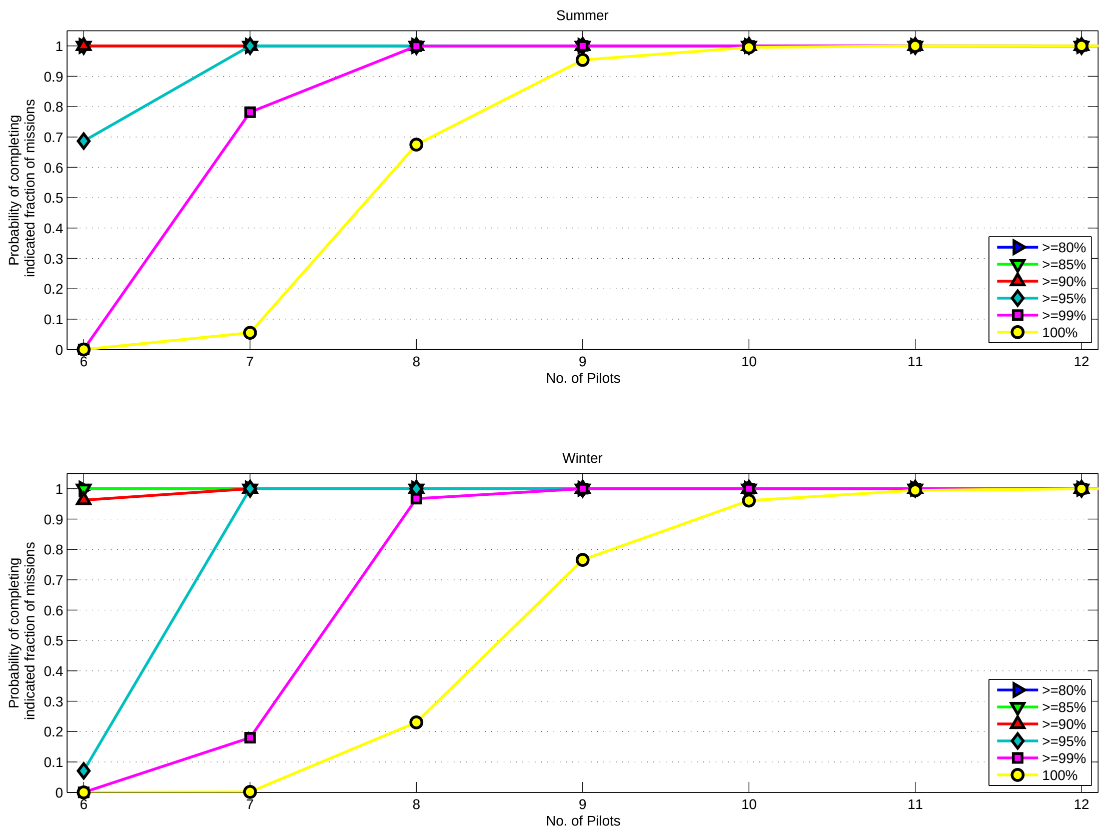

Figure 8: *Estimated probability of meeting manning requirements for a 6 month deployment of 6 CF188 with continuous 12/5 operations as a function of total number of aircrew, aircrew illness parameters and percentage of planned sorties completed. Daily aircrew demand is fixed at 6. The minimum manning requirement is 6 crews.*

The yellow line with circular symbols in Figures 8 shows the estimated probability of meeting the manning requirements for 100% of the 780 planned sorties in the scenario. For example, a deployed unit with 9 pilots has a 95.36% chance of successfully manning all the planned sorties under summer conditions and a 76.56% of manning all planned sorties under winter conditions. The other lines show the probability of meeting some lower percentage of total planned sorties. The magenta line with square data symbols shows the probability of manning *at least* 99% of the 780 planned sorties;

that is, 773 or more sorties. It can be seen that having 8 pilots results in only a 67.47% chance of manning all 780 sorties but a 99.92% probability of manning at least 773 sorties under summer conditions. Under winter conditions, 8 pilots have only a 23.03% probability of manning 780 sorties but a 96.71% chance of manning at least 773 sorties.

With this and the following scenarios, the set of manning rates becomes larger because of the different sortie completion rates. Table 6 shows the manning requirements and ratios [13] for scenario 3 as a function of sortie completion rate, season and probability of success. The reader should note that for this and all subsequent tables, a probability of 100% really means "greater than 99.99%" because 10,000 iterations were run for each simulation.

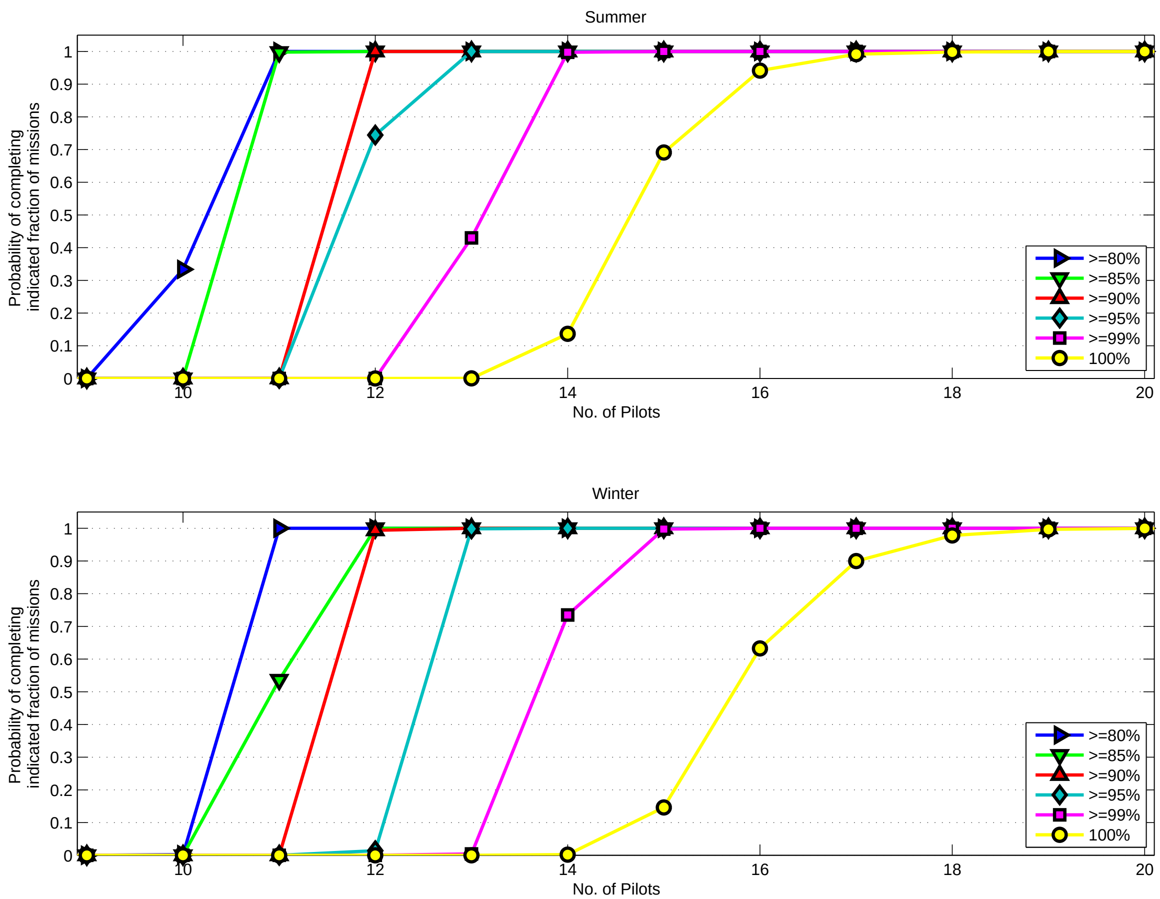

Figure 9: *Estimated probability of meeting manning requirements for a 6 month deployment of 12 CF188 with continuous 12/5 operations as a function of total number of aircrew and aircrew illness parameters. The minimum manning requirement is 12 crews.*

13. The term "manning ratio" is a common one in the operational community and is simply the ratio of pilots or crews to aircraft. A manning ratio of 3:2 means that there are 3 pilots for every two aircraft.

Table 6: *Manning requirements and equivalent manning rates for scenario 3 as a function of sortie completion rate, season and probability of success.*

Sortie Comp. Rate	Season	Aircraft	Pilots required / manning ratio for given probability of success >50%	>80%	>90%	>95%	>99%	100%
≥85%	Summer	6	6 / 1:1	6 / 1:1	6 / 1:1	6 / 1:1	6 / 1:1	6 / 1:1
	Winter	6	6 / 1:1	6 / 1:1	6 / 1:1	6 / 1:1	6 / 1:1	6 / 1:1
	Summer	12	11 / 0.92:1	11 / 0.92:1	11 / 0.92:1	11 / 0.92:1	11 / 0.92:1	12 / 1:1
	Winter	12	11 / 0.92:1	12 / 1:1	12 / 1:1	12 / 1:1	12 / 1:1	12 / 1:1
≥90%	Summer	6	6 / 1:1	6 / 1:1	6 / 1:1	6 / 1:1	6 / 1:1	7 / 1.17:1
	Winter	6	6 / 1:1	6 / 1:1	6 / 1:1	6 / 1:1	7 / 1.17:1	7 / 1.17:1
	Summer	12	12 / 1:1	12 / 1:1	12 / 1:1	12 / 1:1	12 / 1:1	12 / 1:1
	Winter	12	12 / 1:1	12 / 1:1	12 / 1:1	12 / 1:1	12 / 1:1	13 / 1.08:1
≥95%	Summer	6	6 / 1:1	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1
	Winter	6	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1	8 / 1.33:1
	Summer	12	12 / 1:1	13 / 1.08:1	13 / 1.08:1	13 / 1.08:1	13 / 1.08:1	13 / 1.08:1
	Winter	12	13 / 1.08:1	13 / 1.08:1	13 / 1.08:1	13 / 1.08:1	13 / 1.08:1	14 / 1.17:1
≥99%	Summer	6	7 / 1.17:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	9 / 1.5:1
	Winter	6	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	9 / 1.5:1	11 / 1.83:1
	Summer	12	14 / 1.17:1	14 / 1.17:1	14 / 1.17:1	14 / 1.17:1	14 / 1.17:1	15 /1.25:1
	Winter	12	14 / 1.17:1	14 / 1.17:1	14 / 1.17:1	14 / 1.17:1	15 / 1.25:1	16 / 1.33:1
100%	Summer	6	8 / 1.33:1	9 / 1.5:1	9 / 1.5:1	9 / 1.5:1	10 / 1.67:1	12 / 2:1
	Winter	6	9 / 1.5:1	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1	14 / 2.33:1
	Summer	12	15 / 1.25:1	15 / 1.25:1	16 / 1.33:1	17 / 1.42:1	17 / 1.42:1	20 / 1.67:1
	Winter	12	16 / 1.33:1	17 / 1.42:1	18 / 1.5:1	18 / 1.5:1	19 / 1.58:1	21 / 1.75:1

3.1.4 Scenario 4

Scenario 4 considers a hypothetical 6 month deployment of 6 or 12 CF188 fighters, during which 16/7 operations will be maintained continuously. Based on the spreadsheet in Appendix A, this will require a minimum of 8 pilots for a deployment of 6 aircraft or 16 pilots for a deployment of 12 aircraft. The results for a 6-aircraft deployment are shown in Figure 10. Figure 11 shows the results for a 12-aircraft deployment. Table B.2 in Annex B shows the results in tabular form.

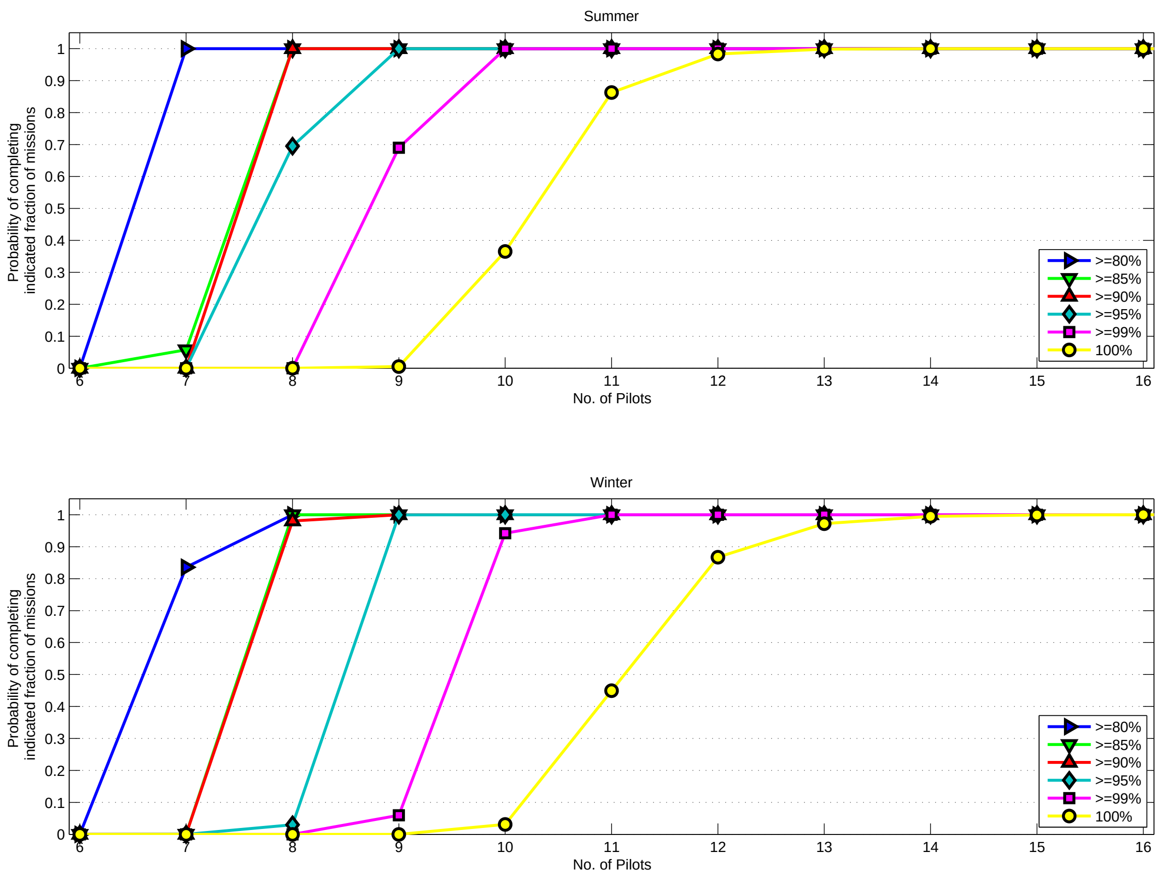

Figure 10: *Estimated probability of meeting manning requirements for a 6 month deployment of 6 CF188 with continuous 16/7 operations as a function of total number of aircrew, aircrew illness parameters and percentage of planned sorties completed. Daily aircrew demand is fixed at 8.*

Table 7 shows the manning requirements and rates for scenario 4 as a function of sortie completion rate, season and probability of success.

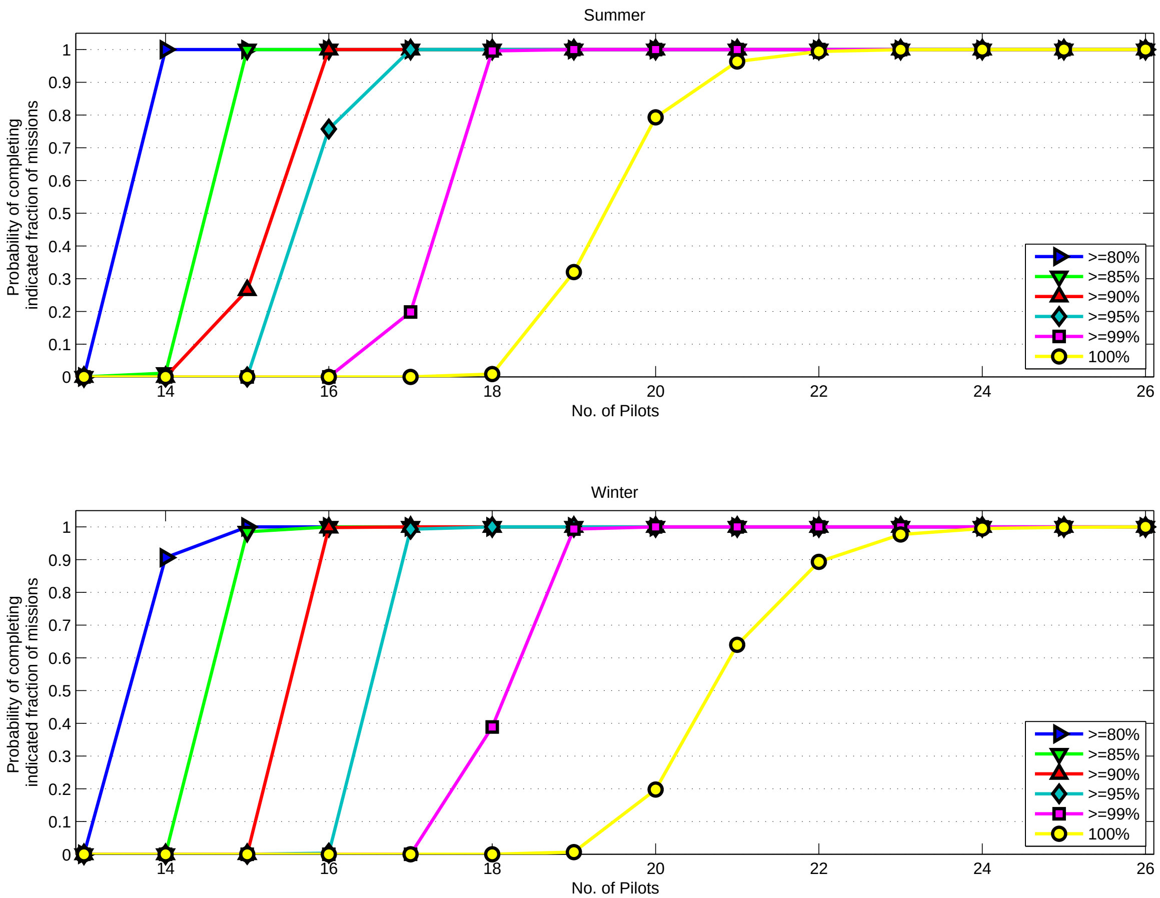

Figure 11: *Estimated probability of meeting manning requirements for a 6 month deployment of 12 CF188 with continuous 16/7 operations as a function of total number of aircrew and aircrew illness parameters. The minimum manning requirement is 12 crews.*

Table 7: *Manning requirements and equivalent manning rates for scenario 4 as a function of sortie completion rate, season and probability of success.*

Sortie Comp. Rate	Season	Aircraft	Pilots required / manning ratio for given probability of success					
			>50%	>80%	>90%	>95%	>99%	100%
≥85%	Summer	6	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1
	Winter	6	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1
	Summer	12	15 / 1.25:1	15 / 1.25:1	15 / 1.25:1	15 / 1.25:1	15 / 1.25:1	15 / 1.25
	Winter	12	15 / 1.25:1	15 / 1.25:1	15 / 1.25:1	15 / 1.25:1	15 / 1.25:1	16 / 1.33:1
≥90%	Summer	6	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1
	Winter	6	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	9 / 1.5:1	9 / 1.5:1
	Summer	12	16 / 1.33:1	16 / 1.33:1	16 / 1.33:1	16 / 1.33:1	16 / 1.33:1	16 / 1.33:1
	Winter	12	16 / 1.33:1	16 / 1.33:1	16 / 1.33:1	16 / 1.33:1	16 / 1.33:1	17 / 1.42:1
≥95%	Summer	6	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	9 / 1.5:1	9 / 1.5:1
	Winter	6	9 / 1.5:1	9 / 1.5:1	9 / 1.5:1	9 / 1.5:1	9 / 1.5:1	10 / 1.67:1
	Summer	12	16 / 1.33:1	17 / 1.42:1	17 / 1.42:1	17 / 1.42:1	17 / 1.42:1	17 / 1.42:1
	Winter	12	17 / 1.42:1	17 / 1.42:1	17 / 1.42:1	17 / 1.42:1	17 / 1.42:1	17 / 1.42:1
≥99%	Summer	6	9 / 1.5:1	9 / 1.5:1	9 / 1.5:1	9 / 1.5:1	10 / 1.67:1	11 / 1.83:1
	Winter	6	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1
	Summer	12	18 / 1.5:1	18 / 1.5:1	18 / 1.5:1	18 / 1.5:1	18 / 1.5:1	19 / 1.58:1
	Winter	12	19 / 1.58:1	19 / 1.58:1	19 / 1.58:1	19 / 1.58:1	19 / 1.58:1	20 / 1.67:1
100%	Summer	6	11 / 1.83:1	11 / 1.83:1	12 / 2:1	12 / 2:1	13 / 2.08:1	15 / 2.5:1
	Winter	6	12 / 2:1	12 / 2:1	13 / 2.08:1	13 / 2.08:1	14 / 2.33:1	16 / 2.67:1
	Summer	12	20 / 1.67:1	21 / 1.75:1	21 / 1.75:1	21 / 1.75:1	22 / 1.83:1	24 / 2:1
	Winter	12	21 / 1.75:1	22 / 1.83:1	23 / 1.92:1	23 / 1.92:1	24 / 2:1	26 / 2.17:1

3.1.5 Scenario 5

Scenario 5 considers a hypothetical 6 month deployment of 6 or 12 CF188 fighters, during which 24/7 operations will be maintained throughout. There is more variability in the number of sorties that can be flown in this scenario due to the continuous nature of the operations and the different combinations of sortie duration and aircraft turnaround time. The simulations presented here are based on the combinations with the highest sortie rate per day and so the highest pilot requirements. If all of the possible sorties are to be flown, a minimum of 10 pilots is needed for a deployment of 6 aircraft or 20 pilots for a deployment of 12 aircraft. The results for a 6-aircraft deployment are shown in Figure 12. Figure 13 shows the results for a 12-aircraft deployment. Tables B.3 and B.4 in Annex B show the results in tabular form. Table 8 shows the manning requirements and rates for scenario 5 as a function of sortie completion rate, season and probability of success.

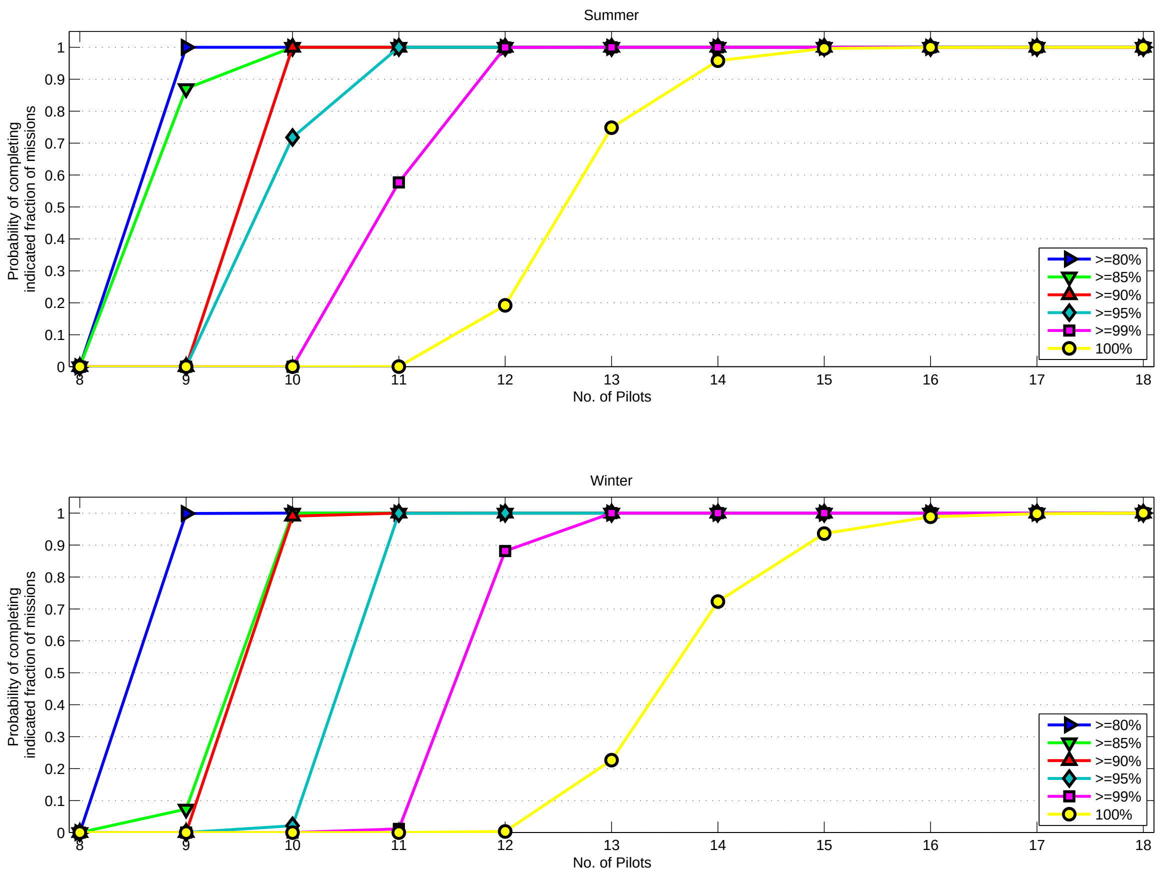

Figure 12: *Estimated probability of meeting manning requirements for a 6 month deployment of 6 CF188 with continuous 24/7 operations as a function of total number of aircrew, aircrew illness parameters and percentage of planned sorties completed. Daily aircrew demand is fixed at 10.*

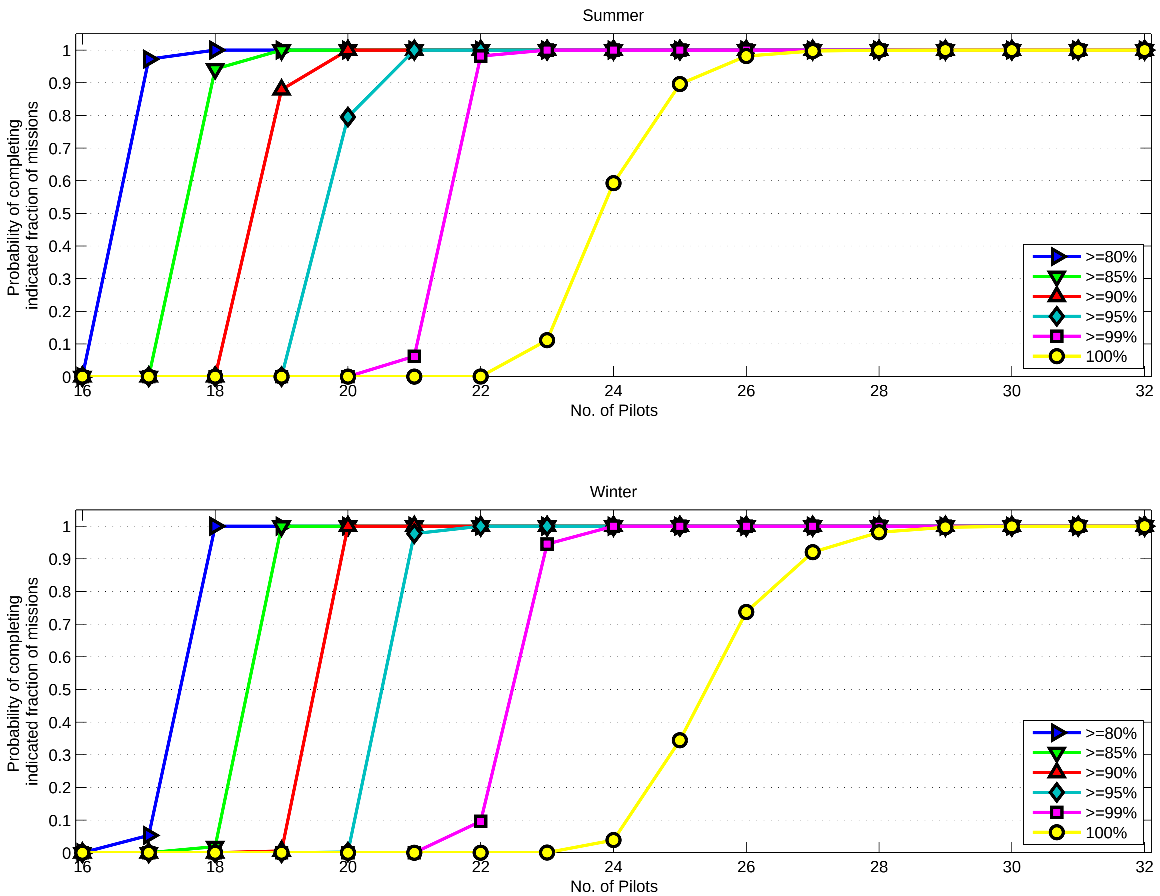

Figure 13: *Estimated probability of meeting manning requirements for a 6 month deployment of 12 CF188 with continuous 24/7 operations as a function of total number of aircrew and aircrew illness parameters. Daily aircrew demand is 20 crews.*

Table 8: *Manning requirements and equivalent manning rates for scenario 5 as a function of sortie completion rate, season and probability of success.*

Sortie Comp. Rate	Season	Aircraft	Pilots required / manning ratio for given probability of success >50%	>80%	>90%	>95%	>99%	100%
≥85%	Summer	6	9 / 1.5:1	9 / 1.5:1	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1
	Winter	6	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1
	Summer	12	18 / 1.5:1	18 / 1.5:1	18 / 1.5:1	19 / 1.58:1	19 / 1.58:1	19 / 1.58:1
	Winter	12	19 / 1.58:1	19 / 1.58:1	19 / 1.58:1	19 / 1.58:1	19 / 1.58:1	20 / 1.67:1
≥90%	Summer	6	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1
	Winter	6	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1
	Summer	12	19 / 1.58:1	19 / 1.58:1	20 / 1.67:1	20 / 1.67:1	20 / 1.67:1	20 / 1.67:1
	Winter	12	20 / 1.67:1	20 / 1.67:1	20 / 1.67:1	20 / 1.67:1	20 / 1.67:1	21 / 1.75:1
≥95%	Summer	6	10 / 1.67:1	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1
	Winter	6	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1	12 / 2:1
	Summer	12	20 / 1.67:1	21 / 1.75:1	21 / 1.75:1	21 / 1.75:1	21 / 1.75:1	21 / 1.75:1
	Winter	12	21 / 1.75:1	21 / 1.75:1	21 / 1.75:1	21 / 1.75:1	22 / 1.83:1	22 / 1.83:1
≥99%	Summer	6	11 / 1.83:1	12 / 2:1	12 / 2:1	12 / 2:1	12 / 2:1	13 / 2.17:1
	Winter	6	12 / 2:1	12 / 2:1	13 / 2.17:1	13 / 2.17:1	13 / 2.17:1	13 / 2.17:1
	Summer	12	22 / 1.83:1	22 / 1.83:1	22 / 1.83:1	22 / 1.83:1	23 / 1.92:1	23 / 1.92:1
	Winter	12	23 / 1.92:1	23 / 1.92:1	23 / 1.92:1	24 / 2:1	24 / 2:1	24 / 2:1
100%	Summer	6	13 / 2.08:1	14 / 2.33:1	14 / 2.33:1	14 / 2.33:1	15 / 2.5:1	18 / 3:1
	Winter	6	14 / 2.33:1	15 / 2.5:1	15 / 2.5:1	16 / 2.67:1	17 / 2.83:1	19 / 3.17:1
	Summer	12	24 / 2:1	25 / 2.08:1	26 / 2.17:1	26 / 2.17:1	27 / 2.25:1	29 / 2.42:1
	Winter	12	26 / 2.17:1	27 / 2.25:1	27 / 2.25:1	28 / 2.33:1	29 / 2.42:1	32 / 2.67:1

3.2 Variable daily aircraft availability

The 6-aircraft version of scenario 3 was revisited with variable aircraft serviceability rates. As described in Section 2.3, the serviceability rates were specified separately for the first and second missions of the day. The chosen rate combinations were 50% and 50%, 70% and 50%, 70% and 70%, and 90% and 90%. Of these, the 70%/50% combination results in a median number of sorties per day equal to the 6 used for the fixed sortie rate case described in 3.1.3 above. As the rate of aircraft serviceability increases, the number of possible sorties per day rises and hence the demand for aircrews as well. Figures 14–17 demonstrate this as well as showing the probability of completing specified proportions of the maximum number of sorties possible for given serviceability rates. The same data is presented in tabular form in Tables B.5–B.8 in Annex B.

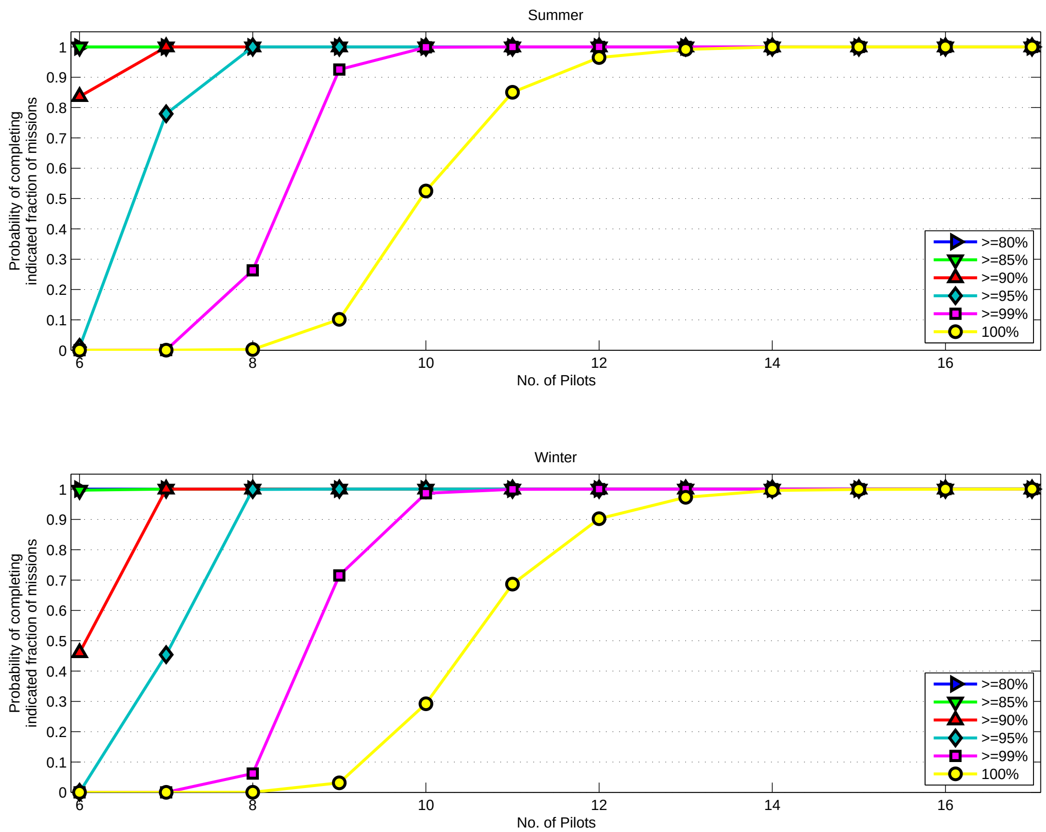

Figure 14: *Probability of meeting manning requirements for 12/5 operations in 6-month deployment of 6 aircraft with aircraft serviceability rates of 50% and 50% as a function of total aircrew.*

Figure 18 compares the effect of the number of aircrew on the probability of completing all possible sorties (that is, the 100% sortie completion rate given in previous figures) across the different serviceability rates. The same result for the fixed sortie rate case is included for comparison [14]. It can be seen that even the lowest serviceability case of 50%/50% creates a greater demand for pilots

14. Additional plots for different sortie completion rates are found in Annex B.

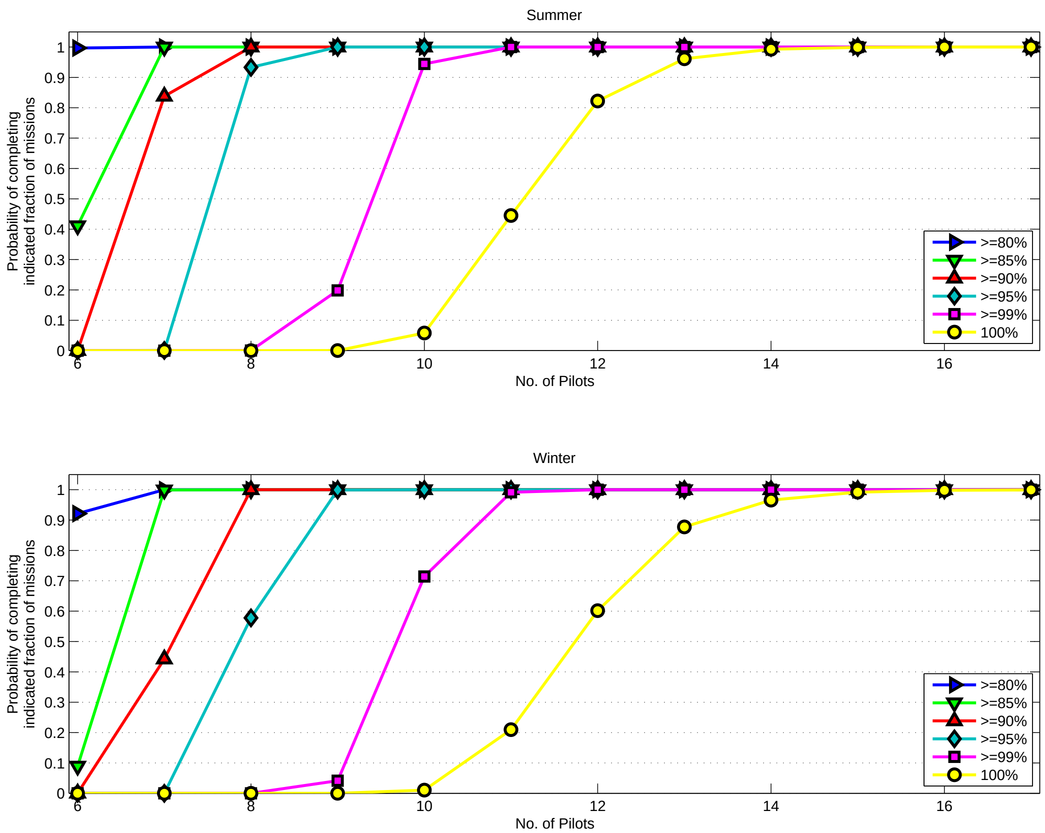

Figure 15: *Probability of meeting manning requirements for 12/5 operations in 6-month deployment of 6 aircraft with aircraft serviceability rates of 70% and 50% as a function of total aircrew.*

than the fixed sortie rate case.

The fixed rate case's 6 sorties per flying day results in 780 attempted sorties during the 182 days simulated. [15] The median attempted sortie rate for the 50%/50% case is 4, with the mean number of attempted sorties per six-month period being 650, but the maximum observed number of attempted sorties being 734; there is a 13.57% probability of more than 6 sorties being possible on any given day, thus making even this case more demanding [16] than the fixed rate case. More crews must be kept on hand to cover surge requirements.

In making these comparisons between the fixed and variable cases, it must be remembered that the objective for this study is to maximize aircraft utilization. Should a different objective be desired – for example, an estimate of the probability of mounting a given number of sorties per day or other time period under the conditions of variable availability of both crews and aircraft – a new analysis would be required.

15. The given 5/12 operation cycle results in 130 flying days during the 182-day period.
16. Meaning demanding in the sense that more pilots are needed. It is less demanding *of* the pilots in terms of workload.

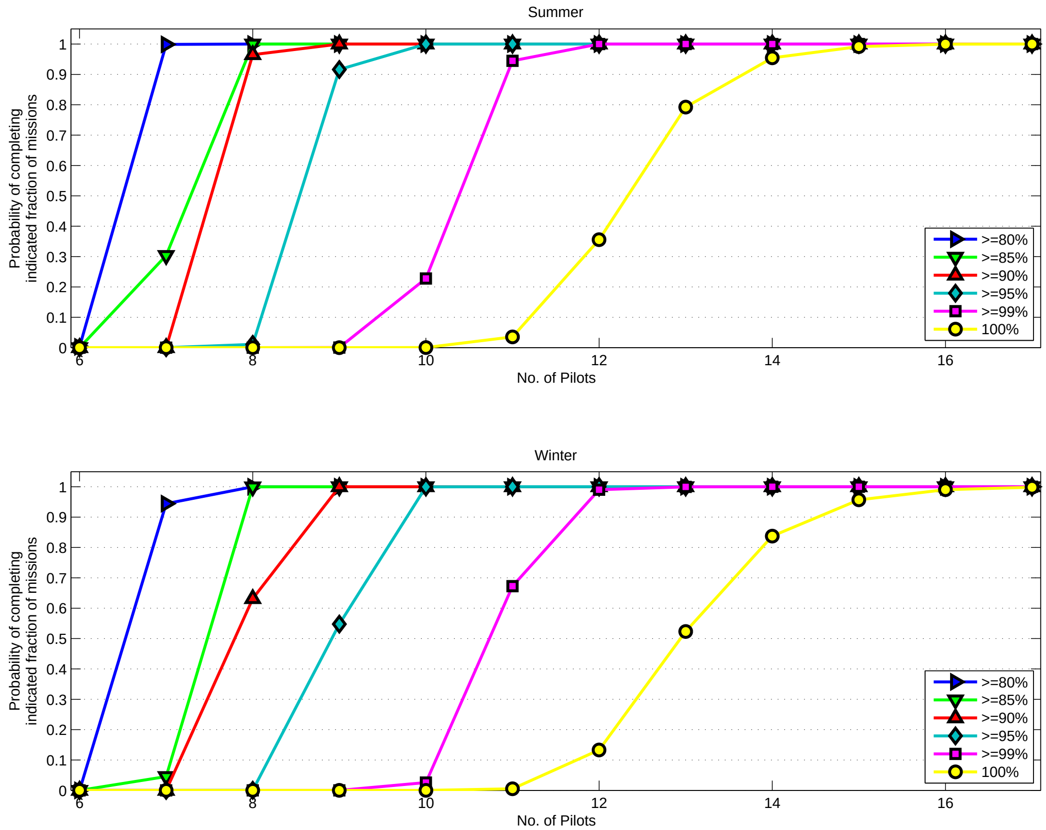

Figure 16: *Probability of meeting manning requirements for 12/5 operations in 6-month deployment of 6 aircraft with aircraft serviceability rates of 70% and 70% as a function of total aircrew.*

Using the results above, a table of manning rates similar to that presented in Section 3.1 has been compiled in Table 9. In the interests of brevity, Table 9 shows the manning rates for the 70%/50% serviceability case only, as the addition of the serviceability rate variable would multiply the number of tables required by four. As is the case for the previous manning rate tables, all of the information used to create the table is already present in the report.

Comparing Table 9 to Table 6, it can be seen that there is a substantial increase in the manning requirements when there is a possibility of completing more than 6 sorties per day.

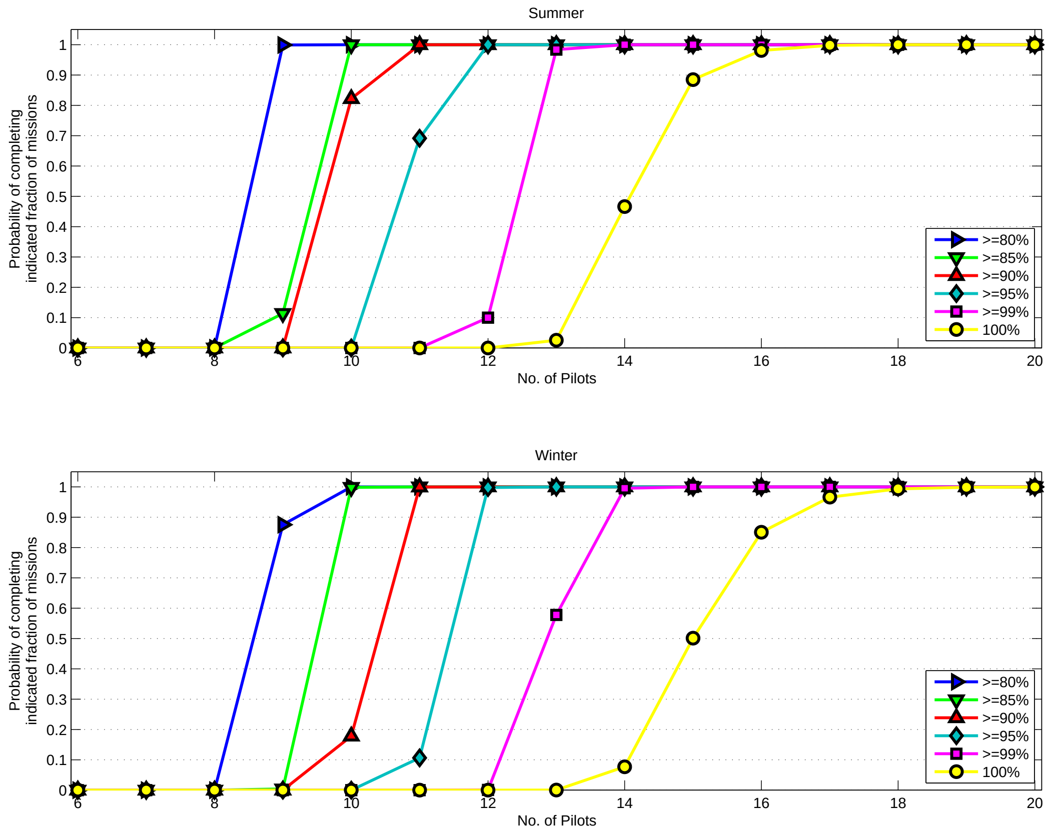

Figure 17: *Probability of meeting manning requirements for 12/5 operations in 6-month deployment of 6 aircraft with aircraft serviceability rates of 90% and 90% as a function of total aircrew.*

Table 9: *Manning requirements and equivalent manning rates for the variable daily aircraft availability simulations as a function of sortie completion rate, season and probability of success. The daily aircraft availability rate is 70%/50%.*

Season	Sortie Completion Rate	Pilots required / manning ratio for given probability of success					
		>50%	>80%	>90%	>95%	>99%	100%
Summer	≥80%	6 / 1:1	6 / 1:1	6 / 1:1	6 / 1:1	6 / 1:1	7 / 1.17:1
Summer	≥85%	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1
Summer	≥90%	7 / 1.17:1	7 / 1.17:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1
Summer	≥95%	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	9 / 1.5:1	9 / 1.5:1	9 / 1.5:1
Summer	≥99%	10 / 1.67:1	10 / 1.67:1	10 / 1.67:1	11 / 1.83:1	11 / 1.83:1	12 / 2:1
Summer	100%	12 / 2:1	12 / 2:1	13 / 2.17:1	13 / 2.17:1	14 / 2.33:1	17 / 2.83:1
Winter	≥80%	6 / 1:1	6 / 1:1	6 / 1:1	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1
Winter	≥85%	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1	7 / 1.17:1	8 / 1.33:1
Winter	≥90%	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1	8 / 1.33:1
Winter	≥95%	8 / 1.33:1	9 / 1.5:1	9 / 1.5:1	9 / 1.5:1	9 / 1.5:1	10 / 1.67:1
Winter	≥99%	10 / 1.67:1	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1	11 / 1.83:1	12 / 2:1
Winter	100%	12 / 2:1	13 / 2.17:1	13 / 2.17:1	14 / 2.33:1	14 / 2.33:1	18 / 3:1

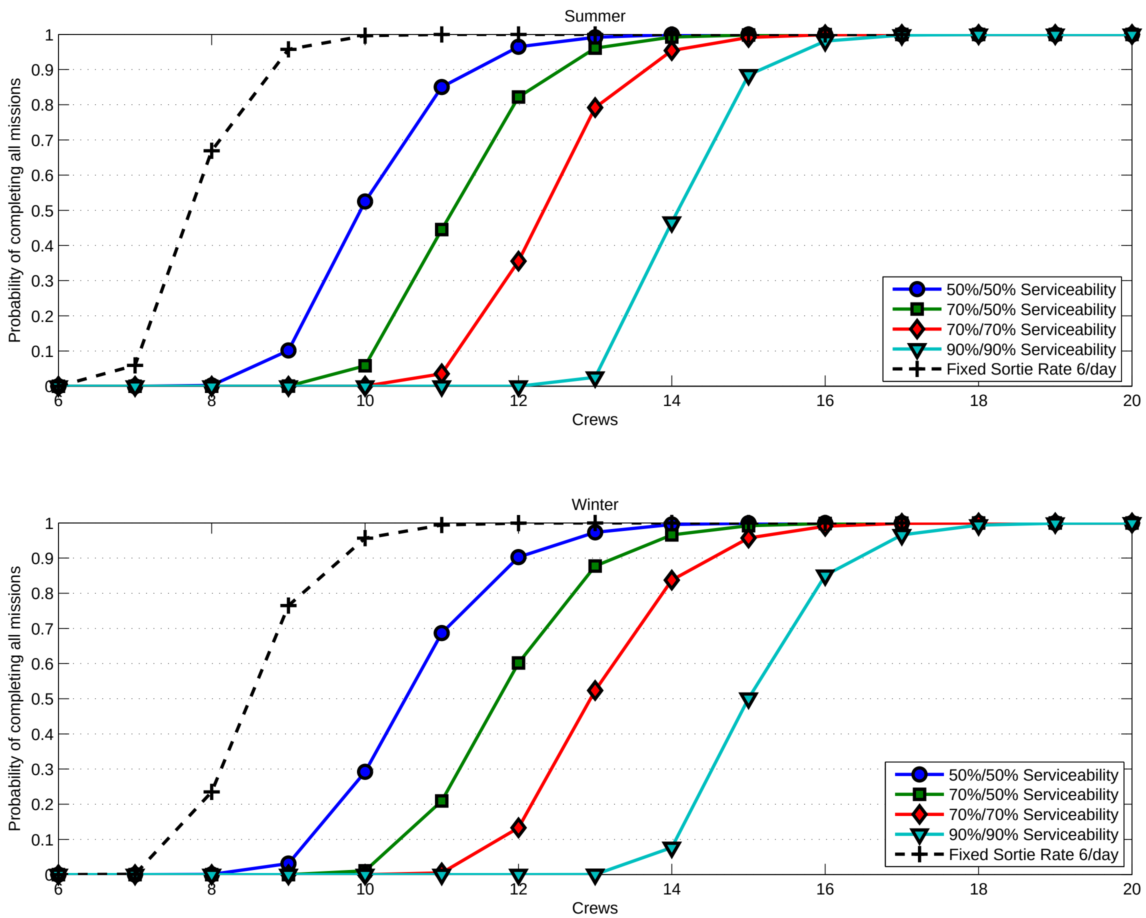

Figure 18: *Probability of meeting all manning requirements for 12/5 operations in 6-month deployment of 6 aircraft as a function of number of crews and aircraft serviceability rates. The comparable probability of success for the fixed rate of 6 sorties per day is included for comparison.*

3.3 Breakdown of assumptions

This study has assumed that the driving factor for crewing requirements is daily aircrew availability rather than flight safety limits on flying rates. For sufficiently long sorties, this assumption will break down. Although the simulations described do not assign sorties to specific crews, we will attempt to set an upper bound on the average sortie duration for which this assumption holds.

The maximum flying rate for fighter crews per 30 day period is 85 hours[3]. A 6-month deployment contains 6.1 30-day periods, so the maximum hours per crew during this period is 518.5 hours. If the flying load is evenly balanced over all crews during this period, then the maximum sortie duration for which our assumption holds is

$$D_{max} = \frac{518.5\ hr}{\max(N_{sorties})/N_{crew}},$$

where D_{max} is the maximum sortie duration in hours, $N_{sorties}$ is the number of sorties and N_{crew} is the number of crews assigned to the deployment. This re-arranges to

$$D_{max} = \frac{(518.5\ hr)(N_{crew})}{\max(N_{sorties})}. \tag{1}$$

For the case of a fixed number of sorties per day, $\max(N_{sorties})$ is the same for all iterations of a given scenario. Also, it should be noted that this simple calculation does not account for sorties not flown due to a lack of personnel on any given day. This makes maximum mean sortie duration calculated for the smaller number of total crews smaller, when in fact many of those sorties cannot be flown for lack of crews.

This distribution of flying time between crews is optimal, whereas reality seldom is. However, this is mitigated somewhat because we have used the maximum of $N_{sorties}$ and that other factors that might reduce the total number of sorties such as the weather, the lack of a need for that many sorties, and so on. It will become apparent shortly that number of crews sufficient to provide a reasonable probability of being able to execute most or all sorties results in maximum sortie durations that are sufficiently large that this factor can usually be neglected, even allowing for sub-optimal distribution of flying time between crews.

Table 10 shows the maximum mean sortie durations for the constant personnel demand scenarios discussed in Section 3.1. Table 11 shows the same for the variable aircraft availability cases of Section 3.2. Because the “acceptable” levels and probabilities of sortie completion are somewhat subjective, the D_{max} has been computed for all values of N_{crew}. The reader should cross-correlate between these two tables and the figures and tables of the previous portions of this chapter to see at what point the study’s assumptions break down for a particular case. For example, consider the case of a Scenario 3 deployment with 6 aircraft and 9 pilots. Examining Table 10, it can be seen that the assumptions of this report will break down when the mean sortie duration for the deployment exceeds 6.0 hours.

Table 10: *Maximum mean sortie duration for constant aircraft availability scenarios as a function of number of deployed crews and daily aircraft serviceability rates. All values are in hours.*

6 Aircraft Scenarios							
	Total number of pilots						
Scenario	6	7	8	9	10	11	12
3	4.0	4.7	5.3	6.0	6.6	7.3	8.0
4	2.1	2.5	2.8	3.2	3.5	3.9	4.3
5	1.7	2.0	2.3	2.6	2.8	3.1	3.4
	Total number of pilots						
Scenario	13	14	15	16	17	18	19
3	8.6	9.3	10.0	10.6	11.3	12.0	12.6
4	4.6	5.0	5.3	5.7	6.0	6.4	6.7
5	3.7	4.0	4.3	4.5	4.8	5.1	5.4

12 Aircraft Scenarios										
	Total number of pilots									
Scenario	13	14	15	16	17	18	19	20	21	22
3	4.3	4.7	5.0	5.3	5.7	6.0	6.3	6.6	7.0	7.3
4	2.3	2.5	2.7	2.8	3.0	3.2	3.4	3.5	3.7	3.9
5	1.8	2.0	2.1	2.3	2.4	2.6	2.7	2.8	3.0	3.1
	Total number of pilots									
Scenario	23	24	25	26	27	28	29	30	31	32
3	7.6	8.0	8.3	8.6	9.0					
4	4.1	4.3	4.4	4.6	4.8					
5	3.3	3.4	3.5	3.7	3.8	4.0	4.1	4.3	4.4	4.5

Table 11: *Maximum mean sortie duration for variable aircraft availability scenarios as a function of number of deployed crews and daily aircraft serviceability rates. The fixed rate case of six sorties per day is included for comparison. All values are in hours.*

Aircraft Availability Rate(s)	Total number of pilots 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6 sorties/day	4.0	4.7	5.3	6.0	6.6	7.3	8.0	8.6	9.3	10.0	10.6	11.3	12.0	12.6	13.3
50%/50%	4.2	4.9	5.7	6.4	7.1	7.8	8.5	9.2	9.9	10.6	11.3	12.0	12.7	13.4	14.1
70%/50%	3.6	4.1	4.7	5.3	5.9	6.5	7.1	7.7	8.3	8.9	9.5	10.1	10.7	11.2	11.8
70%/70%	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
90%/90%	2.3	2.7	3.0	3.4	3.8	4.2	4.5	4.9	5.3	5.7	6.1	6.4	6.8	7.2	7.6

4 Conclusion

Overall, several conclusions may be drawn from the results. For all scenarios, the manning requirements can be reduced in two ways; by accepting a higher level of risk that the desired fraction of total planned sorties cannot be flown due to a lack of personnel, or by accepting a lower target for the fraction of total planned sorties. Also, personnel requirements are greater during the winter months when the illness rate is higher. This report attempts to quantify these factors. The method used is quite flexible, so that the analysis can be repeated with different rules, scenarios or illness rates as desired.

One less-than-obvious result is that a variable daily aircraft availability rate may result in a higher personnel demand than a fixed sortie rate, even for aircraft serviceability rates that result in an average daily sortie rate lower than the fixed rate case. This is because, while the *average* number of sorties per day may be lower for the variable rate case than for the fixed rate case, the *maximum* number of sorties per day is higher. To achieve the same level of mission completion, more personnel must be provided to cover the days when the number of sorties exceeds the number for the fixed rate case. Doing so will raise the mission completion rate at the cost of reducing the pilot utilization rate; i.e., the pilots will be available when needed, but will spend more time doing nothing.

Because of the generic nature of the scenarios considered, it is difficult to make hard recommendations on what appropriate manning ratios ought to be. The intent of the author is to provide the Air Force leadership with some insight into the personnel required to achieve their goals with a given level of probability or risk. Alternatively, one could make a decision on how many personnel will be committed to a given task, then use the tables to find parameter combinations that can be met by that number of pilots.

References

[1] Hunter, D.G. (2009), Aircraft Manning Rates for Selected Force Employment Scenarios, (Letter Report to A3 Fighter 1 Canadian Air Divisions, 3554-1) DRDC CORA.

[2] 1 Cdn Air Div Orders, Vol. 2, 2-003, General Flight Rules.

[3] 1 Cdn Air Div Orders, Vol. 2, 2-003, Annex A, Fighter Force - Duty Day/Alert Cycle, Maximum Accumulated Flying Time, Crew Rest.

[4] Bendrick, USAF MC, Maj Gregg Alexander (1998), Seasonal Variation of Grounding Rate among B-52H Aircrew, *Military Medicine*, 163(10:692).

[5] Squadrons Celebrate Battle Honour, *Crew Brief*, 7(1:19).

Annex A: Typical mission schedules for scenarios 3, 4 and 5

This annex covers the hypothetical weekly mission schedules used for determining the number of pilots required for scenarios 3, 4 and 5. They are broken down by scenario. For each scenario, there are three variables considered:

– The number of aircraft deployed: six or twelve;
– The planned mission durations - the values considered herein were 1.5, 3 and 6 hours;
– Whether or not returning aircraft have expended air-to-ground ordnance. Those that have expended ordnance will require three hours to turn around for another sortie. Those that have not can be turned around in one hour.

All possible combinations of these three variables were considered for each scenario. The resulting crew activities are listed in the Excel file that is included with the electronic distribution of this report.

Additional assumptions were made concerning the availability of aircraft. The number of sorties is based on information provided by A3 Fighter. Built into these numbers is an assumed constant aircraft serviceability rate of 70%; it is not clear to the analyst how this serviceability rate translates to the available aircraft numbers used for the scenarios, so the provided sortie rates have been taken as given. Much higher rates have been maintained in operations, at least for short periods [5]. The effects of differing serviceability rates are examined in sections 2.3 and 3.2.

This page intentionally left blank.

Annex B: Data and Additional Plots

This annex contains data tables and plots that have been moved from the main body of the report to maintain the flow of the document. The reader is reminded that the probabilities presented in the tables are derived from a sample size of 10,000. Therefore any probability of 1.000 (100%) really means "greater than 0.9999" (99.99%).

Table B.1: *Estimated probability of meeting manning requirements for a six-month deployment of 6 or 12 CF188 on 12/5 operations as a function of total number of aircrew and seasonal illness model. The minimum manning requirement is 6 crews for a 6-aircraft deployment and 12 crews for a 12-aircraft deployment.*

Season / Illness Model	Sortie Completion Rate	Total number of pilots for 6 deployed aircraft: 6	7	8	9	10	11	12	13	14
Summer	$\geq$ 80%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 85%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 90%	0.9998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 95%	0.6866	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 99%	0.0002	0.7817	0.9992	1.000	1.000	1.000	1.000	1.000	1.000
Summer	100%	0.0000	0.0551	0.6747	0.9536	0.9950	0.9997	1.000	1.000	1.000
Season/Illness Model: Winter										
Winter	$\geq$ 80%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 85%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 90%	0.9622	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 95%	0.0707	0.9999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 99%	0.0000	0.1796	0.9671	0.9999	0.9999	1.000	1.000	1.000	1.000
Winter	100%	0.0000	0.0014	0.2303	0.7656	0.9608	0.9948	0.9996	0.9997	1.000

Season/ Illness Model	Sortie Completion Rate	Total number of pilots for 12 deployed aircraft: 9	10	11	12	13	14	15	16	17	18	19	20
Summer	$\geq$ 80%	0.0000	0.3334	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 85%	0.0000	0.0000	0.9978	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 90%	0.0000	0.0000	0.0003	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 95%	0.0000	0.0000	0.0000	0.7442	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 99%	0.0000	0.0000	0.0000	0.0000	0.4298	0.9973	1.000	1.000	1.000	1.000	1.000	1.000
Summer	100%	0.0000	0.0000	0.0000	0.0000	0.0002	0.1364	0.6906	0.9414	0.9918	0.9983	0.9999	1.000
Winter	$\geq$ 80%	0.0000	0.0017	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 85%	0.0000	0.0000	0.5365	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 90%	0.0000	0.0000	0.0000	0.9936	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 95%	0.0000	0.0000	0.0000	0.0137	0.9983	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 99%	0.0000	0.0000	0.0000	0.0000	0.0039	0.7349	0.9976	1.000	1.000	1.000	1.000	1.000
Winter	100%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.1464	0.6328	0.8994	0.9781	0.9968	0.9997

Table B.2: *Estimated probability of meeting manning requirements for a six-month deployment of 6 or 12 CF188 on 16/7 operations as a function of total number of aircrew and seasonal illness model. The minimum manning requirement is 8 crews for a 6-aircraft deployment and 16 for a 12-aircraft deployment.*

Sortie Completion Rate	Total number of pilots for 6 deployed aircraft: 6	7	8	9	10	11	12	13	14	15	16
Season/Illness Model: Summer											
≥ 80%	0.0000	0.9999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 85%	0.0000	0.0575	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 90%	0.0000	0.0000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 95%	0.0000	0.0000	0.6949	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 99%	0.0000	0.0000	0.0000	0.6900	0.9995	1.000	1.000	1.000	1.000	1.000	1.000
100%	0.0000	0.0000	0.0000	0.0050	0.3655	0.8625	0.9833	0.9983	0.9998	1.000	1.000
Season/Illness Model: Winter											
≥ 80%	0.0000	0.8356	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 85%	0.0000	0.0002	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 90%	0.0000	0.0000	0.9806	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 95%	0.0000	0.0000	0.0298	0.9995	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 99%	0.0000	0.0000	0.0000	0.0595	0.9421	1.000	1.000	1.000	1.000	1.000	1.000
100%	0.0000	0.0000	0.0000	0.0000	0.0310	0.4493	0.8672	0.9721	0.9951	0.9991	1.000

Season/ Illness Model	Sortie Completion Rate	Total number of pilots for 12 deployed aircraft: 13	14	15	16	17	18	19	20	21	22	23	24	25	26
Summer	≥ 80%	0.0000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	≥ 85%	0.0000	0.0114	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	≥ 90%	0.0000	0.0000	0.2648	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	≥ 95%	0.0000	0.0000	0.0000	0.7572	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	≥ 99%	0.0000	0.0000	0.0000	0.0000	0.1980	0.9957	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	100%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0085	0.3200	0.7930	0.9633	0.9941	0.9995	1.000	1.000	1.000
Winter	≥ 80%	0.0000	0.9062	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	≥ 85%	0.0000	0.0000	0.9850	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	≥ 90%	0.0000	0.0000	0.0001	0.9980	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	≥ 95%	0.0000	0.0000	0.0000	0.0031	0.9928	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	≥ 99%	0.0000	0.0000	0.0000	0.0000	0.0000	0.3887	0.9935	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	100%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0.1972	0.6397	0.8934	0.9766	0.9949	0.9987	1.000

Table B.3: *Estimated probability of meeting manning requirements for a six-month deployment of 6 CF188 on 24/7 operations as a function of total number of aircrew and seasonal illness model. The daily pilot demand is 10.*

Season / Illness Model	Sortie Completion Rate	Total number of pilots for 6 deployed aircraft: 8	9	10	11	12	13	14	15	16	17	18
Summer	$\geq$ 80%	0.0000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 85%	0.0000	0.8705	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 90%	0.0000	0.0000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 95%	0.0000	0.0000	0.7178	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Summer	$\geq$ 99%	0.0000	0.0000	0.0000	0.5769	0.9995	1.000	1.000	1.000	1.000	1.000	1.000
Summer	100%	0.0000	0.0000	0.0000	0.0002	0.1919	0.7482	0.9582	0.9960	0.9995	0.9999	1.000
Winter	$\geq$ 80%	0.0000	0.9989	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 85%	0.0000	0.0733	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 90%	0.0000	0.0000	0.9904	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 95%	0.0000	0.0000	0.0212	0.9993	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Winter	$\geq$ 99%	0.0000	0.0000	0.0000	0.0114	0.8811	1.000	1.000	1.000	1.000	1.000	1.000
Winter	100%	0.0000	0.0000	0.0000	0.0000	0.0031	0.2265	0.7229	0.9362	0.9886	0.9979	0.9998

Table B.4: *Estimated probability of meeting manning requirements for a six-month deployment of 12 CF188 on 24/7 operations as a function of total number of aircrew and seasonal illness model. The daily pilot demand is 20.*

Season/Illness Model: Summer								
Sortie Completion Rate	Total number of pilots 17	18	19	20	21	22	23	24
$\geq$ 80%	0.9722	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 85%	0.0000	0.9420	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 90%	0.0000	0.0000	0.8786	1.000	1.000	1.000	1.000	1.000
$\geq$ 95%	0.0000	0.0000	0.0000	0.7951	1.000	1.000	1.000	1.000
$\geq$ 99%	0.0000	0.0000	0.0000	0.0000	0.0621	0.9816	1.000	1.000
100%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.1114	0.5925
Sortie Completion Rate	Total number of pilots 25	26	27	28	29	30	31	32
$\geq$ 80%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 85%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 90%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 95%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 99%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
100%	0.8960	0.9817	0.9971	0.9996	1.000	1.000	1.000	1.000
Season/Illness Model: Winter								
Sortie Completion Rate	Total number of pilots 17	18	19	20	21	22	23	24
$\geq$ 80%	0.0530	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 85%	0.0000	0.0186	0.9998	1.000	1.000	1.000	1.000	1.000
$\geq$ 90%	0.0000	0.0000	0.0050	0.9998	1.000	1.000	1.000	1.000
$\geq$ 95%	0.0000	0.0000	0.0000	0.0017	0.9772	1.000	1.000	1.000
$\geq$ 99%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0960	0.9452	1.000
100%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0385
Sortie Completion Rate	Total number of pilots 25	26	27	28	29	30	31	32
$\geq$ 80%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 85%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 90%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 95%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 99%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
100%	0.3443	0.7374	0.9202	0.9812	0.9965	0.9995	0.9998	1.000

Table B.5: *Estimated probability of meeting manning requirements for 12/5 operations for a six-month deployment of 6 aircraft with aircraft serviceability rates of 50% and 50% as a function of total number of aircrew and seasonal illness model.*

Season/Illness Model: Summer

Sortie Completion Rate	Total number of pilots											
	6	7	8	9	10	11	12	13	14	15	16	17
≥ 80%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 85%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 90%	0.8361	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 95%	0.0094	0.7794	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 99%	0.0000	0.0001	0.2632	0.9252	0.9985	1.000	1.000	1.000	1.000	1.000	1.000	1.000
100%	0.0000	0.0000	0.0022	0.1016	0.5250	0.8503	0.9648	0.9919	0.9994	0.9998	1.000	1.000

Season/Illness Model: Winter

Sortie Completion Rate	Total number of pilots											
	6	7	8	9	10	11	12	13	14	15	16	17
≥ 80%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 85%	0.9966	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 90%	0.4604	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 95%	0.0001 0.4541	0.9988	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
≥ 99%	0.0000	0.0000	0.0619	0.7155	0.9863	0.9995	1.000	1.000	1.000	1.000	1.000	1.000
100%	0.0000	0.0000	0.0004	0.0312	0.2922	0.6868	0.9027	0.9733	0.9956	0.9989	0.9999	1.000

Table B.6: *Estimated probability of meeting manning requirements for 12/5 operations for a six-month deployment of 6 aircraft with aircraft serviceability rates of 70% and 50% as a function of total number of aircrew and seasonal illness model.*

Season/Illness Model: Summer

Sortie Completion Rate	6	7	8	9	10	11	12	13	14	15	16	17
	Total number of pilots											
$\geq$ 80%	0.9964	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 85%	0.4111	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 90%	0.0002	0.8379	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 95%	0.0000	0.0007	0.9328	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 99%	0.0000	0.0000	0.0003	0.1982	0.9441	0.9996	1.000	1.000	1.000	1.000	1.000	1.000
100%	0.0000	0.0000	0.0000	0.0001	0.0580	0.4450	0.8219	0.9610	0.9925	0.9984	0.9996	1.000

Season/Illness Model: Winter

Sortie Completion Rate	6	7	8	9	10	11	12	13	14	15	16	17
	Total number of pilots											
$\geq$ 80%	0.9217	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 85%	0.0892	0.9992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 90%	0.0001	0.4424	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 95%	0.0000	0.0000	0.5777	0.9994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 99%	0.0000	0.0000	0.0000	0.0413	0.7142	0.9917	1.000	1.000	1.000	1.000	1.000	1.000
100%	0.0000	0.0000	0.0000	0.0000	0.0104	0.2094	0.6017	0.8775	0.9659	0.9920	0.9981	0.9994

Table B.7: *Estimated probability of meeting manning requirements for 12/5 operations for a six-month deployment of 6 aircraft with aircraft serviceability rates of 70% and 70% as a function of total number of aircrew and seasonal illness model.*

Season/Illness Model: Summer

Sortie Completion Rate	Total number of pilots 6	7	8	9	10	11	12	13	14	15	16	17
≥ 80%	0.0025	0.9985	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 85%	0.0000	0.3035	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 90%	0.0000	0.0000	0.9648	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 95%	0.0000	0.0000	0.0108	0.9161	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 99%	0.0000	0.0000	0.0000	0.0001	0.2278	0.9445	0.9997	1.000	1.000	1.000	1.000	1.000
100%	0.0000	0.0000	0.0000	0.0000	0.0002	0.0354	0.3556	0.7921	0.9541	0.9913	0.9992	0.9999

Season/Illness Model: Winter

Sortie Completion Rate	Total number of pilots 6	7	8	9	10	11	12	13	14	15	16	17
≥ 80%	0.0000	0.9447	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 85%	0.0000	0.0454	0.9998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 90%	0.0000	0.0000	0.6316	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 95%	0.0000	0.0000	0.0003	0.5476	0.9997	1.000	1.000	1.000	1.000	1.000	1.000	1.000
≥ 99%	0.0000	0.0000	0.0000	0.0000	0.0257	0.6727	0.9904	0.9997	1.000	1.000	1.000	1.000
100%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049	0.1329	0.5235	0.8375	0.9572	0.9904	0.9986

Table B.8: *Estimated probability of meeting manning requirements for 12/5 operations for a six-month deployment of 6 aircraft with aircraft serviceability rates of 70% and 70% as a function of total number of aircrew and seasonal illness model.*

Season/Illness Model: Summer															
Sortie Completion Rate	Total number of pilots														
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
$\geq$ 80%	0.0000	0.0000	0.0003	0.9988	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 85%	0.0000	0.0000	0.0000	0.1135	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 90%	0.0000	0.0000	0.0000	0.0000	0.8220	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 95%	0.0000	0.0000	0.0000	0.0000	0.0000	0.6912	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 99%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0997	0.9835	1.000	1.000	1.000	1.000	1.000	1.000	1.000
100%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0252	0.4661	0.8847	0.9808	0.9977	0.9998	1.000	1.000

Season/Illness Model: Winter															
Sortie Completion Rate	Total number of pilots														
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
$\geq$ 80%	0.0000	0.0000	0.0000	0.8756	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 85%	0.0000	0.0000	0.0000	0.0039	0.9986	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 90%	0.0000	0.0000	0.0000	0.0000	0.1781	0.9998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 95%	0.0000	0.0000	0.0000	0.0000	0.0000	0.1063	0.9982	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\geq$ 99%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.5780	0.9958	1.000	1.000	1.000	1.000	1.000	1.000
100%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0768	0.5013	0.8506	0.9661	0.9936	0.9989	0.9999

Figures B.1–B.4 show the probabilities of achieving minimum sortie completion rates ranging from 85% to 99%. The results are broadly similar to those seen in Figure 18, with a general tendency for the variable aircraft availability results to become closer to the fixed aircraft availability result as the standards for level of sortie completion are reduced.

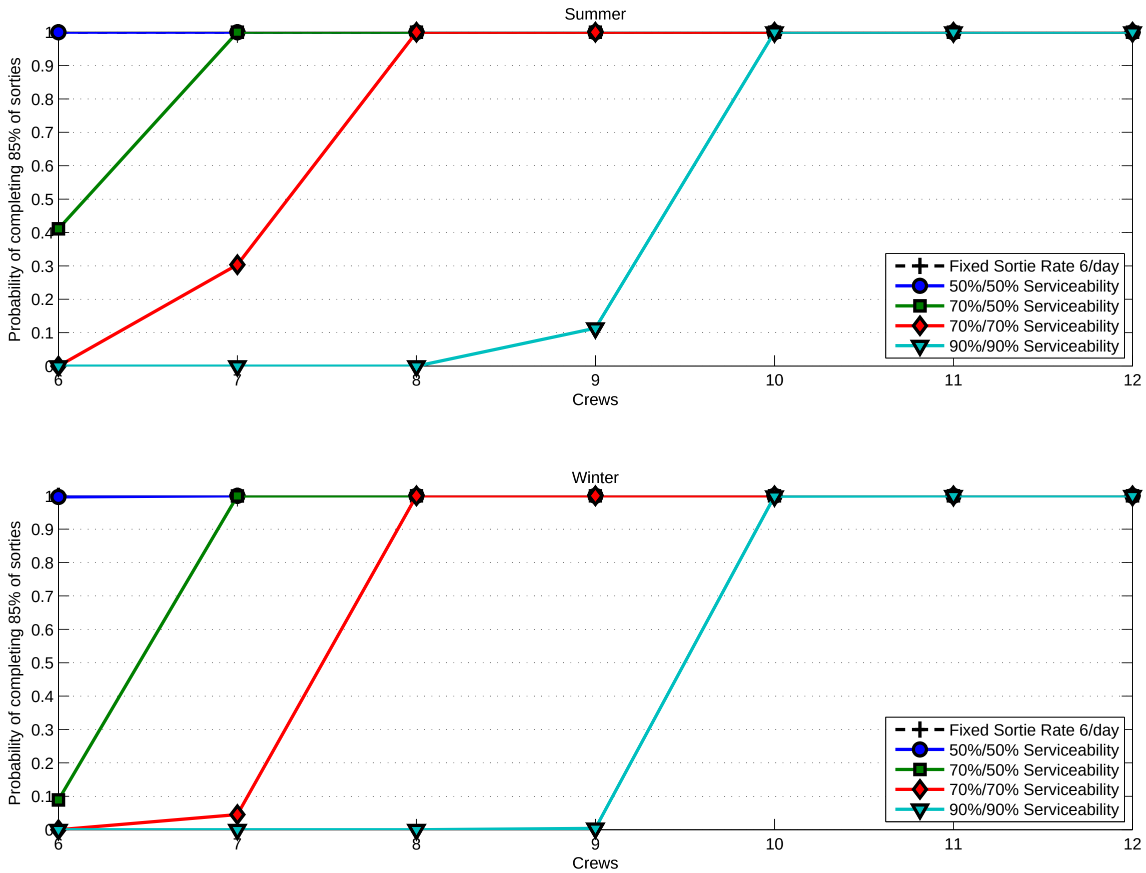

Figure B.1: *Probability of meeting 85% of manning requirements for 12/5 operations for a six-month deployment of 6 aircraft as a function of number of crews and aircraft serviceability rates. The probability of success for the fixed rate of 6 sorties per day is included for comparison; note that it is hidden behind the line for the 50%/50% serviceability case.*

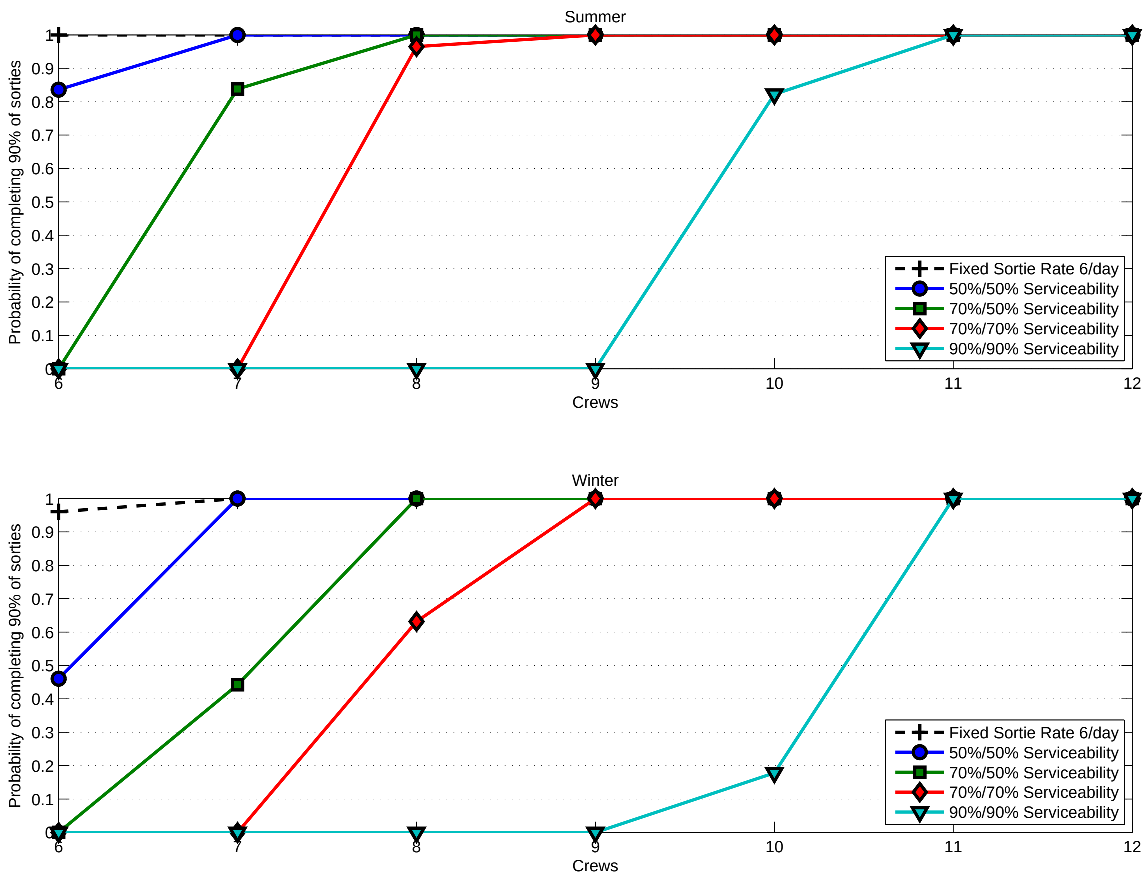

Figure B.2: *Probability of meeting 90% of manning requirements for 12/5 operations for a six-month deployment of 6 aircraft as a function of number of crews and aircraft serviceability rates. The probability of success for the fixed rate of 6 sorties per day is included for comparison.*

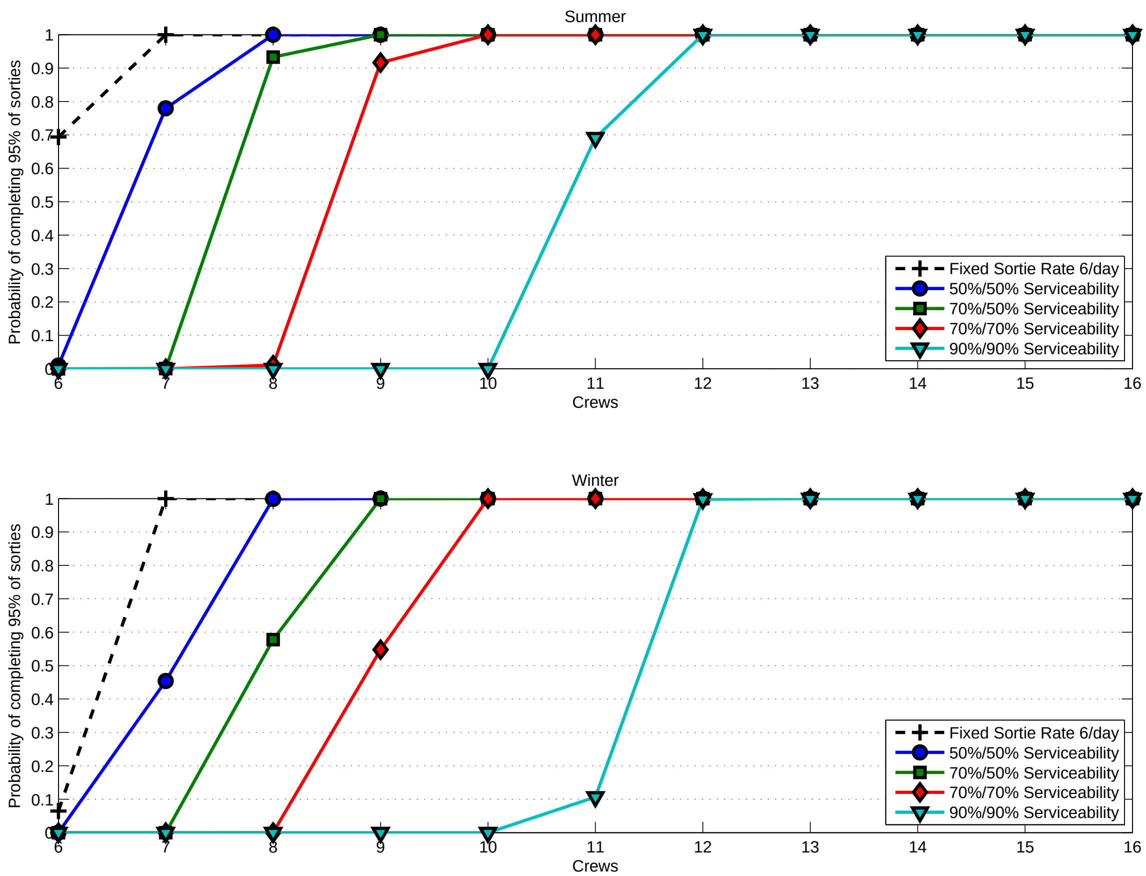

Figure B.3: *Probability of meeting 95% of manning requirements for 12/5 operations for a six-month deployment of 6 aircraft as a function of number of crews and aircraft serviceability rates. The probability of success for the fixed rate of 6 sorties per day is included for comparison.*

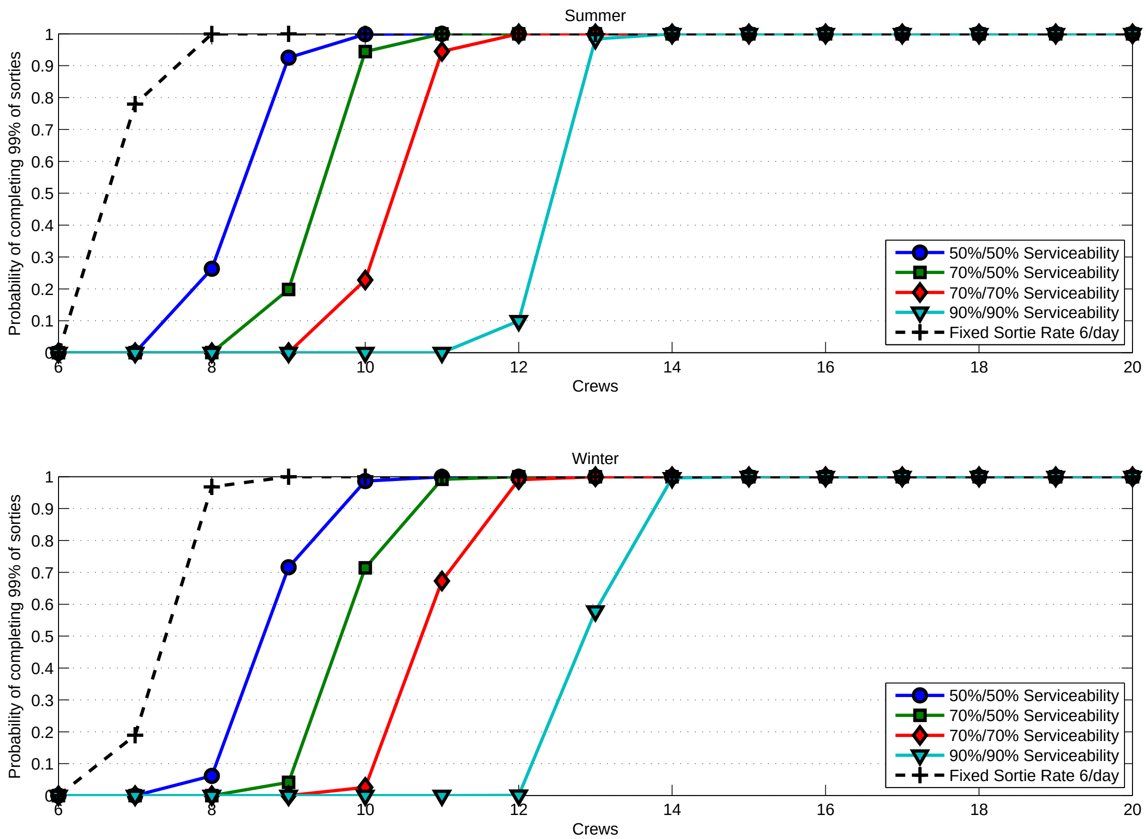

Figure B.4: *Probability of meeting 99% of manning requirements for 12/5 operations for a six-month deployment of 6 aircraft as a function of number of crews and aircraft serviceability rates. The comparate probability of success for the fixed rate of 6 sorties per day is included for comparison.*

List of abbreviations/acronyms

1 Cdn Air Div	1 Canadian Air Division
AF	Air Force
CARO	Centre d'analyse et de recherche opérationnelle
CAS	Chief of the Air Staff
CF	Canadian Forces
CORA	Centre for Operational Research and Analysis
DAC	Division aérienne du Canada
DASOR	Directorate of Air Staff Operational Research
DND	Department of National Defence
DROFA	Directeur - Recherche opérationnelle (Force aérienne)
FA	Force aérienne
OR	Operational Research
OR & A	Operational Research & Analysis
PLT	Pilot

Distribution list

DRDC CORA TM 2010-217

Internal distribution

All copies in electronic format

1 Author

1 Team Leader/Air Staff Operational Research

1 Team Leader/Operational Research and Analysis Directorate

1 Head Air Section

1 Chief Scientist

1 CORA Library

Total internal copies: 6

External distribution

All copies in electronic format

1 Director General Air Force Development

1 Director General Air Personnel

1 Director Air Personnel Strategy

1 Director Air Strategic Plans

1 Director Science & Technology - Air

1 Director Science & Technology - Personnel

1 A3 Fighter

Total external copies: 7

Total copies: 13

This page intentionally left blank.

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.) Defence R&D Canada – CORA Dept. of National Defence, MGen G.R. Pearkes Bldg., 101 Colonel By Drive, Ottawa, Ontario, Canada K1A 0K2	2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.) UNCLASSIFIED

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

The Effects of Aircrew Illness and Aircraft Availability on Manning Rates for Selected CF188 Force Employments

4. AUTHORS (Last name, followed by initials – ranks, titles, etc. not to be used.)

Hunter, D.G.

5. DATE OF PUBLICATION (Month and year of publication of document.) October 2010	6a. NO. OF PAGES (Total containing information. Include Annexes, Appendices, etc.) 72	6b. NO. OF REFS (Total cited in document.) 5

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

Technical Memorandum

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

Defence R&D Canada – CORA
Dept. of National Defence, MGen G.R. Pearkes Bldg., 101 Colonel By Drive, Ottawa, Ontario, Canada K1A 0K2

9a. PROJECT NO. (The applicable research and development project number under which the document was written. Please specify whether project or grant.) N/A	9b. GRANT OR CONTRACT NO. (If appropriate, the applicable number under which the document was written.)
10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.) DRDC CORA TM 2010-217	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification.)

(X) Unlimited distribution
(   ) Defence departments and defence contractors; further distribution only as approved
(   ) Defence departments and Canadian defence contractors; further distribution only as approved
(   ) Government departments and agencies; further distribution only as approved
(   ) Defence departments; further distribution only as approved
(   ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in (11)) is possible, a wider announcement audience may be selected.)

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

This report examines the relationship between the likelihood of overall mission completion and the number of pilots assigned to the executing force for a set of generic but typical force employment scenarios. The scenarios were created in cooperation with A3 Fighter. The effects of factors such as seasonal variation in illness rates and day length, mission duration and intensity and aircraft serviceability are considered. The primary result is a set of tables indicating the probability of achieving various levels of mission completion as a function of the factors indicated above.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Air Force
CF188
Manning Rate
Manning Ratio
Personnel

DEFENCE DÉFENSE

DRDC CORA

www.drdc-rddc.gc.ca