DEPARTMENT OF NATIONAL DEFENCE

CANADA

PROJECTING POWER:
ALTERNATIVE FUTURES FOR CANADA'S AIR FORCE IN 2020

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CANADIAN FORCES AEROSPACE WARFARE CENTRE

The Canadian Forces Aerospace Warfare Centre (CFAWC) is the engine of Air Force transformation. CFAWC is the centre of excellence for aerospace power development in Canada, focusing on concept development and experimentation (CD&E), doctrine development, Air Force research and lessons learned. In addition, CFAWC develops and maintains the Air Force aerospace power knowledge repository and coordinates efforts to provide advanced synthetic environment (SE) as well as modelling and simulation services.

As part of its mandate, CFAWC produces a variety of publications relating to aerospace power, including doctrine, lessons-learned reports, research papers, and reports on emerging concepts and experiments.

FOREWORD

If current future security trends continue to progress as forecasted, the next decade will be challenging to the Air Force's objective of creating an advanced combat effective aerospace force capable of projecting power through precision effects. In 2020, will the Air Force be able to generate, train and retain the professional airmen and women it will need to conduct its highly sophisticated missions? Will the Air Force be relying completely on simulators and virtual reality systems to conduct first stage training? Will the Air Force be flying more unmanned platforms than actual aircraft? Will we have a permanent Air Force presence in the Canadian Arctic?

Examination of the future environment is an important practice for institutions that wish to remain relevant and capable over the long term. This practice is particularly important for the Air Force, as the lead time required to acquire capabilities can be lengthy. Examining future trends and imagining futures scenarios is often employed in order to assist in the identification of future capabilities.

Last year, the Canadian Forces Aerospace Warfare Centre (CFAWC) published *Projecting Power: Trends Shaping Canada's Air Force in the Year 2019,*[1] a discussion paper that took a detailed look at the short term future security environment, specifically, the trends, drivers and strategic shocks that our analysts thought would have the greatest impact on the Air Force of 2019. From that paper, the Chief of the Air Staff (CAS) selected four prominent future security trends, namely **Force Generation Issues**, **Future of Simulators and Training**, **Unmanned Aerial Systems (UAS) Operations** and **Air Force Operations in the Arctic**, and tasked CFAWC to conduct an alternative futures analysis of these four trends.

I am proud to present *Projecting Power: Alternative Futures for Canada's Air Force in 2020*, a discussion paper that is intended to make the reader think about what might come to pass if the current future security trends are displaced by some unforeseen event.

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[1] LCol D. Lachance, et al, *Projecting Power: Trends Shaping Canada's Air Force in the Year 2010.* CFAWC discussion paper dated April 15, 2009.

EXECUTIVE SUMMARY

1. Last year, the CAS tasked CFAWC to conduct an Alternative Futures Study on four prominent future security trends taken from the paper *Projecting Power: Trends Shaping Canada's Air Force in the Year 2019*, namely **Force Generation Issues**, **Future of Simulators and Training**, **Unmanned Aerial Systems (UAS) Operations** and **Air Force Operations in the Arctic**. For each of the four trends, key factors were identified and two scenarios were designed. These scenarios were built by taking the key factors to the extremes of what is deemed possible, and arranging them in such a way as to produce a best and worst case scenario from the perspective of the Air Force. The following lists of takeaways were derived from analysing these alternative futures.

Force Generation Issues:

2. **Over the next 10 years, recruiting will become a serious challenge.** Demographic trends indicate that novel strategies and methods for recruiting, training and retaining may have to be employed. Inspiring the public imagination will be essential to the success of the Air Force in attracting personnel and new recruits.

3. **Force generation issues require modernization.** The Air Force needs greater flexibility and creativity when addressing force generation issues. The challenges associated with recruitment, retention, and the changing nature of potential recruits in 2020 will require novel methods that address societal concerns. Flexible enrolment plans as well as frequent, short-term contracts that do not attract long-term benefits may become the norm. The Canadian Forces (CF) need to re-think the compulsory retirement age (CRA) policy. Currently, the relatively early retirement age of CF members is not reasonable when compared with the majority of Canadian workers.

4. **The Air Force must do more to appeal to visible minorities and women.** Strategies must be broad-based and reach all elements of Canadian society. As competition increases in a dwindling labour pool and an increasingly immigrant-dependant population base, novel yet security-conscious approaches to recruiting will need to be adopted. Renewed efforts will be required in order to entice more women to join the CF and the Air Force.

5. **The Air Force needs efficient, relevant, and fast evolving training.** As the pace of technological advance continues to accelerate, it will be challenging to produce and retain skilled individuals able to operate and manage both legacy and emerging systems. Cooperative approaches with learning institutions and industry are likely to yield considerable mutual benefits. In fact, by 2020, most training activities should be outsourced to private companies.

Future of Simulators and Training:

6. **Cost of flying.** In 2020, the cost of flying operations is likely to be extremely expensive. Consequently, it will be particularly difficult for the Air Force to justify extensive hours of routine training in pretty well any type of aircraft, and especially those which consumes large amount of fuel.

7. **Cost of simulation.** Exponential advances in computers are forecasted to revolutionize simulation technology. By 2020, simulators will be so mature that they should provide a cost effective alternative to a majority of the ab initio training curriculum as well as some recurrent training, such as proficiency rides and instrument check rides. Even at today's relatively cheap price for oil (around $80 a barrel), and notwithstanding the initial acquisition cost, operating simulators is far less expensive than actual flying. By 2020, this ratio will likely be even more tilted in favour of simulation.

8. **Cost of acquisition.** Further research will be required to determine if the Air Force should invest in relatively cheap and easy to acquire virtual part-task trainers or expensive full flight simulator systems. Note, however, that even the acquisition costs can be successfully mitigated as demonstrated by the operational training systems provider (OTSP) model being implemented at 8 Wing Trenton (see note 11).

9. **Hybrid reality.** By combining the data base from advanced simulators and real world feed from special cameras and sensors, a hybrid reality can be simulated which can allow crews to operate under all weather conditions. Complex missions, such as inserting a special operations forces (SOF) squad at night in the middle of a city, could be accurately simulated and rehearsed in a high fidelity environment.

10. **Human acceptance.** For the operator, it is all about the realism of the experience: the better the display and the sensorial effect, the closer to reality (in effect virtual reality) a simulator will feel. For the senior officer and decision maker, embracing simulation will require a paradigm shift, realizing that in 2020, training for a routine mission will be just as effective in a simulator as it is in a real aircraft.

Unmanned Aerial Systems Operations:

11. **Finding the right balance.** Generally, the use of UAS is compelling where the need to avoid aircrew casualties is paramount, or the risk of having a manned platform shot down over hostile territory is unacceptable. UAS offer greater persistence over the operating area, and favour missions which fall into the dull, dirty, and dangerous category. The near future is unlikely to be one where UAS or manned systems have prevalence over the other. Rather, the future will be a hybrid force that employs the right weapon system for the task in question.

12. **UAS are not the panacea to all problems.** Future commanders may increasingly default to the UAS in order to solve complicated tactical challenges. Not only will this not guarantee mission success, but also the dependency on UAS over other aerospace approaches could weaken future air power resolve, attention to detail, and operational and tactical innovation.

13. **UAS as a system of system.** Although a UAS might be cheaper than a manned aircraft, the UAS system as a whole is not always less expensive. To operate UAS, and bring to bear the entire weapon system capability, the personnel manning bill can be significant. In the future, UAS operators will be capable of simultaneously flying multiple UAS, partially restoring the advantage in cost to the unmanned system.

14. **Aside from a micro air vehicle (MAV), there is no such thing as an expendable UAS.** One of the major challenges will be to balance cost with capability. A significant concern with some UAS is the inevitability that the price tag will continue to rise as more sensors and weapons are embodied. The fear is that good designs will incorporate a plethora of expensive electronics that eventually become too expensive to build or too valuable to use (and risk losing) in combat.

15. **Autonomy.** With the spectre of intelligent UAS appearing during the next decade, authorizing a machine to make lethal combat decisions is contingent upon political and military leaders resolving legal and ethical questions. These include the appropriateness of machines possessing this ability, under what circumstances it should be employed, where responsibility for mistakes lies, and what limitations should be placed upon the autonomy of such systems.

16. **ISR in northern regions of Canada.** The need for Arctic surveillance will intensify in the years to come. The cost of a persistent and wide-area intelligence, surveillance and reconnaissance (ISR) capability provided solely by manned aircraft is likely to be prohibitive. By 2020, UAS, surveillance

satellites, high altitude airships (HAA), and other persistent, semi-autonomous sensors will be highly matured, and will likely offer significant cost savings over manned aircraft patrols.

17. **Climatic operating environment.** Currently, UAS have supercritical airfoils which have little aerodynamic tolerance for heavy rain and insect contamination, let alone airframe icing. UAS designs are years away from incorporating airframe anti-icing and de-icing protection. Consequently, it is doubtful that by 2020, a UAS could be reliably operated from a Canadian, let alone a High Arctic airfield, throughout the year, in a precipitation and icing-rich environment.

18. **Regulations.** There is no doubt that UAS are poised to become a significant component of military and perhaps even commercial and enforcement aviation. The wide range of UAS physical and performance characteristics, many of which will be very unlike any current aircraft, will place additional challenges on an air traffic management system that is already under great strain. Routine and safe entry of UAS operations into civil airspace will require a major paradigm shift which is unlikely to occur by 2020.

Air Force Operations in the Arctic:

19. **Climate change.** On the one hand, climate change will dictate Air Force involvement in the Arctic, as a warmer climate will translate into increased activities in the North. On the other hand, a harsher climate may reduce human activities, but it will increase the difficulties to operate in that region should the Air Force be required to deploy into the Arctic.

20. **Arctic surveillance.** Upwards of 50 per cent of the world's undiscovered resources are estimated to lie in the Arctic. Should the Arctic experience an economic boom as a result of resource exploration and extraction, then governance, policing, and surveillance will be challenging given the sheer size of the region. As costly as this task will be, it will remain essential for the Air Force to consider the best possible options, from HAA to tethered aerostats, UAS, and Satellites. Note that, should a threat be detected, securing our remote Arctic border will be a monumental task.

21. **SAR requirement.** The Air Force will need to develop a more agile and robust response to search and rescue (SAR) incidents in the Arctic. At the moment, SAR response time and capabilities in northern regions remain problematic. Clearly, increased permanent presence and economic activities in the Arctic as well as expanding trans-polar air routes will ultimately require greater SAR resources in the North, and greater, Arctic hardened air mobility support. A permanent SAR capability may even become a future requirement.

22. **Increased requirement for Arctic operations.** The government's proposed Canadian Forces Arctic Training Centre (CFATC) in Resolute Bay is expected to house approximately 100 full-time personnel. It is logical to assume that the level of Air Force effort to sustain and support the new CFATC will be more or less on par with that of Canadian Forces Station (CFS) Alert. Likewise, the deepwater seaport at Nanisivik will require some level of airlift to sustain operations at the new base, albeit at a lesser level.

23. **Potential for conflicts.** Mineral extraction and shipping will likely be a source of tension and dispute in the future. New shipping routes may also reshape the global transport system. While these developments offer opportunities for growth, they are potential sources of competition and conflict for access and natural resources. Currently, the CF has few capabilities to project hard power in our High Arctic. For the Air Force and Navy, and to a lesser degree the Army, the High Arctic may become a permanent theatre of deployment located at strategic range.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Never let the future disturb you. You will meet it, if you have to, with the same weapons of reason which today arm you against the present.

Marcus Aurelius Antonius[2]

INTRODUCTION

The World in 2020

1. Projecting trends into the future can be fraught with flaws, especially the longer the outlook. Inaccuracies in prediction often prove to be the result of forecasters' inability to accurately predict human adaptation to change, and even more frequently, the failure to envision unpredictable events (the so-called wild card[3] events) and revolutionary breakthroughs. Projecting trends in a shorter outlook (10 years or less), however, is also fairly challenging because it is often hard to distinguish meaningful differences between a short-term future and the reality of today.

2. Consider, for a moment, what has changed between 2000 and now: back in 2000, there was trouble in the Middle East and in Chechnya; Vladimir Putin became the new Russian leader; world leaders met to discuss global warming and the melting Arctic ice; the human genome had just been deciphered; Intel was unveiling its new Pentium 4 chips while hackers attacked *Yahoo*, *Amazon*, and *Ebay* web sites; reformists won control of Iran; and, the American warship *USS Cole* was attacked in Yemen by terrorists linked to a little known organization named Al-Qaeda. Closer to home, Canada's Air Force (which was suffering low manning level and acute pilot shortage), was flying Hercules aircraft, CF18 jet fighters, and Griffon helicopters in various missions around the World.

3. Well, ten years later, there is still trouble in the Middle East; Putin is now the Russian Prime Minister; we are still talking about global warming and the melting Arctic ice cap; reformists are still in control of Iran; hackers are still wrecking havoc in Cyberspace; Al-Qaeda became a force to reckon with; and, we are still short of people in the Air Force, while we continue to fly Hercules aircraft, CF18 jet fighters, and Griffon helicopters around the Globe. There are, however, striking differences between 2000 and 2010: 9-11 occurred; the United States (US) invaded Iraq; the Air Force is employing UAS in a theatre of war; the Great Recession occurred; and, computers are now at least five times more powerful than they were at the turn of the new millennium.

4. So what will 2020 look like? No one can tell for sure, of course, but chances are it will look a lot like today, just as 2000 was not all that different from 2010. Most analysts would agree that computing power will continue its exponential increase, bringing about amazing breakthroughs in technology; UAS will continue to revolutionize the way we fight wars; climate change will continue to have profound

[2] Marcus Aurelius Antonius (Roman Emperor A.D. 161-180), *Meditations* (written in 200 A.D). Available online at http://www.quotationspage.com/subjects/the+future/ (accessed September 20, 2009).

[3] A wild card event is a high impact, low probability event that would have dramatic consequences if it actually occurred. Wild cards are rare events, beyond the realm of normal expectations, which makes them almost impossible to predict. *9-11* is often cited as being a black swan event because of the impact it had on all our lives.

effects on the Canadian Arctic; and, large enterprises will continue to compete for skilled workers. Of these four prominent trends, computers and technological advances are the trends where we are poised to witness the most profound effects. If the trend continues, artificial intelligence (AI) is forecasted to occur anytime between 2015 and 2020, which will, by itself, be a game changing event. Consequently, it is a safe bet to predict that this incredible progress in computing power will translate into absolutely astonishing advances in many fields, including virtual reality, simulation, augmented reality, and semi-autonomous and even fully autonomous UAS.

Why Study Alternative Futures?

5. By conducting an alternative futures analysis of the four prominent future security trends (**Force Generation Issues**, **Future of Simulators and Training**, **UAS Operations**, and **Air Force Operations in the Arctic)** selected by the CAS, this paper will point out the implications that these futures would have on the Air Force.

6. In *Projecting Power: Trends Shaping Canada's Air Force in the Year 2019*, prominent future security trends were identified. If one were to plot these trends on a timeline, the most likely future would fall in the realm of the Probable (the green zone of figure 1). Note that the further out one peers into the future, the greater the Probable zone gets. This has to do with the inherent uncertainties that are present in the current trends, and the fact that no matter what, predicting the future is certainly not an exact science.

7. When considering alternative futures, certain events are created in order to displace the trend line outside of the probable zone. If the events all collide to produce good effects, then the trend line is moved towards a Best Case Scenario (the blue zone of figure 1). Conversely, negative effects would push the trend line towards a Worst Case Scenario (the red zone of figure 1). Note also that the selected events and their resulting scenarios were deemed sufficiently plausible that the ensuing alternative futures fell within the possible zone rather than the unlikely zone.

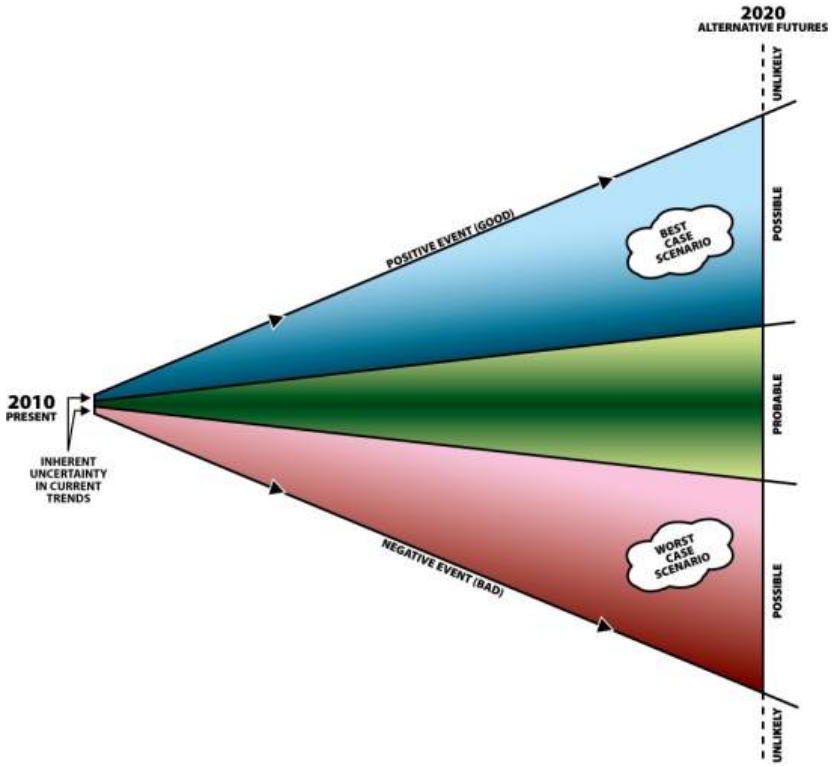

Figure 1. Trend Line Projection

8. Before each scenario is presented, key factors will be identified. These key factors are thought to be the most important contributing features of that future security trend. To create the scenarios, the key factors were made to have extremely positive or negative effects (while remaining plausible) which created a best (utopian) and a worst case (dystopian) scenario—the alternative futures. Theoretically, though acknowledging the tremendous impact of unanticipated strategic shocks and other unforeseen events and conditions, the majority of situations should fall somewhere within those possible extremities. Note that the best and worst case scenarios are from the perspective of future Air Force involvement, and not necessarily from the point of view of the local population, the environment, world politics, etc. It is within these boundaries that we will now describe these alternative futures.

Look after our people, invest in them and give them confidence in the future.

Military HR Strategy 2020[4]

PART 1 - FORCE GENERATION ISSUES

9. Four key factors will affect the ability of the Air Force to recruit, train and retain a skilled, effective, relevant, and sufficient human resource component in 2020 to address the security requirements as determined by the Government of Canada. These are:

- **Demographics: size and composition of target population.** This is the pool of available manpower from which the Air Force draws its future personnel. Significant fluctuations in the numbers, ages, health, and socio-cultural balance of this pool will affect its ability to supply the manpower and human resource needs of the Air Force.
- **Economic conditions.** On the one hand, a prosperous economy encourages a healthy and highly competitive marketplace for skilled manpower. Healthy economies are the underpinning of a solid tax base necessary to support government, including defence spending. On the other hand, attracting and retaining skilled personnel becomes a significant challenge in healthy economic times. Conversely, in strained economic times, although competition will remain for the top performers, broad-based opportunities are generally more limited. Personal economic security and stability become more important and the exodus of personnel typically slows. The drawback is that the tax base is affected adversely, and with deficit budgets, the vulnerability of defence funding becomes apparent.[5]
- **Technology, skill relevance and currency.** The Air Force is highly dependent on maintaining the competitive edge in a rapidly advancing technological aerospace environment. The rate of technological change continues to accelerate at exponential rates, putting great pressure on traditional educational practices to produce and retain individuals with the appropriate, relevant, and current skill sets. Fielding an Air Force peopled by highly skilled and mentally agile individuals will be a challenge as we strive to harmonize human capabilities with the pace of technological change.
- **Public perception and support.** Positive public perceptions of the Air Force are an essential precondition of attracting and retaining the right and sufficient numbers of personnel. Not only

[4] Canada, Department of National Defence, ADM (HR-Mil), *Military HR Strategy 2020 – Facing the People Challenges of the Future* (Ottawa: DND Canada, 2002).

[5] According to Dr. Roussel, if past experiences are a guide, the DND budget is often one of the first to be cut when a government is confronted with budgetary difficulties. See Dr Stéphane Roussel, "Le Canada et les Forces canadiennes en 2018: Vers un retour à la "normal?" *The International System, Canada, Armed Forces and Aerospace Power 2018 and Beyond*, Silver Dart Canadian Aerospace Studies, Volume V, ed. James G. Fergusson (Winnipeg: University of Manitoba, Centre for Defence and Security Studies, January 2009), 130.

must the Air Force be relevant and a source of pride to Canadians, this support is connected, through the parliamentary process, to the provision of resources essential to carry out missions in support of government objectives.

10. How these key factors develop over the next 10 years will shape how the Air Force will force generate in the near future. At this point, the future best case and worst case scenarios shall be examined in the hopes of identifying and exploring future force generation issues.

Wild Card: The Great Flu Pandemic of 2014

In the year 2014, a large-scale viral pandemic ravaged the adult population of the world and especially that of North America. The demographic balance of most Western countries was seriously disturbed, with Canada being one of the most affected. Costs associated with stopping the disaster and mitigating further effects were enormous, forcing the Government to make hard choices between national security and national welfare. This "perfect storm" of dwindling adult population and lack of funding greatly limited the Air Force's ability to force generate and project power. By 2016, faced with the need to meet pressing defence human resource requirements, the Coalition Government urged the official opposition to support a form of mandatory or cooperative military service. Driven by internal pressures to unify a country heavily reliant on wide-scale immigration for its continued economic well-being, as well as external pressures for Canada to meet its obligations as a leader in the global community, the Government felt it had no other choice, since manning and experience level in the CF was falling to dangerously low levels. Ultimately, the motion was defeated, leaving the CF with little choice but to resign itself to becoming a weak constabulary security force.

Best Case Scenario – Force Generation Issues

11. **General.** In this slightly utopian scenario, the cumulative positive effects of all key factors have combined to produce this best case scenario. The economic conditions have improved since the Great Recession of 2008, and new, innovative recruiting and retention initiatives have proven highly effective. Lastly, there is a broad base of support for the Air Force amongst Canadians as a powerful expression of national will within and outside our borders.

12. **Demographics: size and composition of target population.** By 2020, the government has responded judiciously and proactively to counter, mitigate, and alleviate some of the negative aspects of the declining work force (see Figure 2). Immigration policies have brought in large numbers of skilled and motivated young people to Canada. Traditional barriers to enrolling New Canadians have been addressed in response to calls from respective communities to allow their young members the privilege

of serving in the armed forces of their adopted country.[6] Transition and integration as well as flexible enrolment plans allow for limited and highly selective entry into the Air Force and other services as an accelerated path to citizenship.

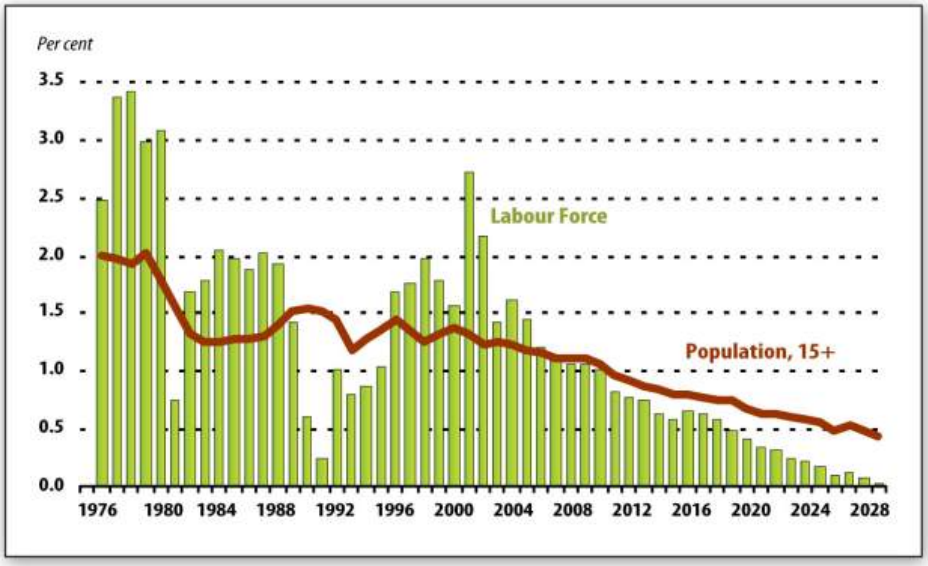

Figure 2. Canadian Labour Force Growth Rate, 1976–2028[7]

13. Other innovative recruiting strategies include the formation of the *1st Royal Canadian Aboriginal Regiment* based in Winnipeg, as well as the aggressive targeting of women for service in the Canadian Forces.[8] Finally, service personnel and those newly discharged from the Air Forces of allied nations were also offered transfer to the Canadian Air Force by a special section of "head-hunter" recruiters. Immigration policies were also adapted to facilitate this initiative, with the granting of citizenship being accelerated in return for the commitment to serve.

14. The decline in the growth of the work force has been mitigated, to some extent, by the desire of middle-aged and older Canadians to continue participating in the workforce and address personal aspirations for rewarding careers. Since the Great Recession of 2008, many who thought they would be retiring by age 60 are no longer able to do so, which alleviates the worst effects of a considerable

[6] Visible minorities are significantly under-represented in the Canadian Forces at only six per cent of all members, compared with 17 per cent of the civilian population. See Jungwe Park, *A Profile of the Canadian Forces.* July 2008 Perspectives (Ottawa: Statistic Canada Catalogue no. 75-001-X, 2008), 21.

[7] Note the ever decreasing labour force growth rate (green bars). Note also that the population growth rate of 15 years old and above is also free falling (red line). See Maxime Fougère, Marcelle Merette and Guohan Zhu, *Population Ageing in Canada and Labour Market Challenges* (Ottawa: Human Resources and Social Development Canada, November 2006), 3.

[8] Although Canada was one of the first NATO member countries to legally admit women to the military (1951), at only 15 per cent of the total military members, this number could be increased significantly. Park, 22.

shortage of younger workers.[9] Essentially, this pool of older but highly skilled workers more than compensates for the smaller pool of young but inexperienced workers. In 2016, service in the Canadian Forces was extended to age 65,[10] in line with most employers though still subject to service-related fitness and health standards. An additional cadre of Secondary Reserve of disabled or transitioning/recuperating personnel (informally referred to as the Veteran's Reserve) has been formed to supplement the Regular Force. As a separate Reserve component created under special legislation, it does not affect Regular Force manning levels or the ability to force generate for operations. It has allowed capable personnel to remain in uniform and serve in meaningful positions performing useful work.

15. In 2013, the Air Force started a highly successful program that sponsored and mentored desirable recruits at earlier ages by awarding scholarships to the Royal Military College (RMC) or to other academic institutions to promising Air Cadets and Air Reservists similar to the way in which a talent scout working for civilian universities look for promising athletes.[11]

16. **Economic conditions.** Prudent fiscal governance and continued demand for natural resources has helped establish Canada as one of the world's most stable and viable economies. A recovering economy has contributed greatly to the tax base, and deficits that had accumulated from 2008 to 2013 have been largely remediated. The belt-tightening of those years is now past and money is available for recruiting, training, and acquiring state-of-the-art equipment. Unemployment rates remain fairly high, which have contributed to slowing the overall release rates amongst Air Force members. Meaningful recruitment, training, and employment of sufficient Air Force personnel commensurate with Canada's prominent place on the world stage has, once again, become a government priority, and the resources are there to back it up.

17. **Technology, skill relevance and currency.** By 2020, the Air Force continues to be a highly technologically oriented organization. In this best case scenario, there are synergistic societal and defence relationships with aerospace industry, educational institutions, and Air Force arrangements that benefit all.

18. Most Air Force training is now carried out by contractors using the OTSP model in place at 8 Wing Trenton.[12] Such innovative ways of delivering highly technical training has allowed the Air Force to keep abreast of the rapidly accelerating pace of aerospace technological change. The OTSP model is proving highly successful as the Air Force gains a continually updated, state-of-the-art training system, while contractors are able to capitalize on lucrative long-term contracts.

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[9] Statistics suggest that since 1997, early retirement trends have halted, and labour force participation of older workers (age 55-65) has increased ever since. See Fougère, Merette and Zhu, 11.

[10] Note that 27 per cent of those who retire at age 55 eventually return to the labour market compared to only 10 per cent of individuals who retire at age 65. See Fougère, Merette and Zhu, 12-13.

[11] A parallel program could address non-commissioned member development where high school graduates would be offered a complete scholarship in a college or trade school in exchange for a definite period of service.

[12] Computer-aided engineering (CAE) provides comprehensive aircrew training services for Canada's C130J and CH47 fleets. The facilities, scheduled to open in 2012 for C130J training, will house two full mission simulators, one flight training device, three integrated procedures trainers, and one fuselage trainer. All students will have laptop-based virtual simulators and all instruction, courseware and equipment will be provided by a cadre of contractors.

19. **Public perception and support.** The highly meritorious performance of the Air Force throughout the mission to Afghanistan that ended in 2011, plus continued yeoman service in subsequent missions in Pakistan and during the Great Red River Flood of 2015, has established that arm of the service as an occupation of choice in the public consciousness. Significantly changing climatic conditions, domestically and throughout the world, requiring humanitarian aid and rapid, far-reaching responses have done much to project the Air Force as the first responder in the minds of Canadians. The Air Force's central role in support of the Government's commitment to the comprehensive approach became a sine qua non of our national and international participation. Closer to home, the efforts of maritime surveillance assets in safeguarding our increasingly challenged sovereignty of the Arctic have also focused the attention of Canadians, and created a feeling of air-mindedness in the consciousness of Canadians.

Worst Case Scenario – Force Generation Issues

20. **General.** In this scenario, the determining factors have all deteriorated to such a degree that when taken together, their effects are devastating and produce the worst case scenario for force generation. Recruiting is at an all time low—a combined effect of fierce competition for a shrinking pool of young recruits, and the fallback from the detainee scandal of 2013. With the disbanding of the Snowbirds, service in the Air Force has ceased to appeal to the popular imagination of Canadians, and the broad base of support for the Air Force has all but completely eroded. The Great Recession of 2008 left the federal government in extremely dire financial posture. In 2020, relatively high unemployment rates continue to persist and the government has been unable to balance its budgets. The federal debt continues to grow even as most government budgets, including that of the Department of National Defence (DND), are slashed to unprecedented levels.[13]

21. **Demographics: size and composition of target population.** Low fertility rates continue to challenge the ability of the Air Force to divert personnel from a struggling labour force to meet its defence and security requirements. Talented young people are being targeted aggressively by industry, and it is clear that the Air Force is unable to compete. The risks and discomfort associated with military service, and of deployed operations in particular, hold little appeal to a comfort-loving, "digital native" generation of young Canadians.[14] Recruiting these young, tech-savvy people failed because the CF failed to accommodate their requirements for flexible employment and retirement plans. Figure 3 below summarizes the challenges that will face recruiters of the future.

[13] In November 2009, the debt was growing at a rate of almost $6.4 million per hour. At this rate, it is estimated that by 2012, all debt repayment of the past eight years will have been wiped out. See the Canadian Tax Payers Federation web site http://www.debtclock.ca/index.php?option=com_content&view=article&id=44&Itemid=41 (accessed January 5, 2010).

[14] A **digital native** is a person for whom digital technologies already existed when they were born, and hence has grown up with widely available digital technology such as computers, the Internet, mobile phones, and MP3s. These young people study, work, write, and interact with each other in ways that are sometimes hard to comprehend for the older generation.

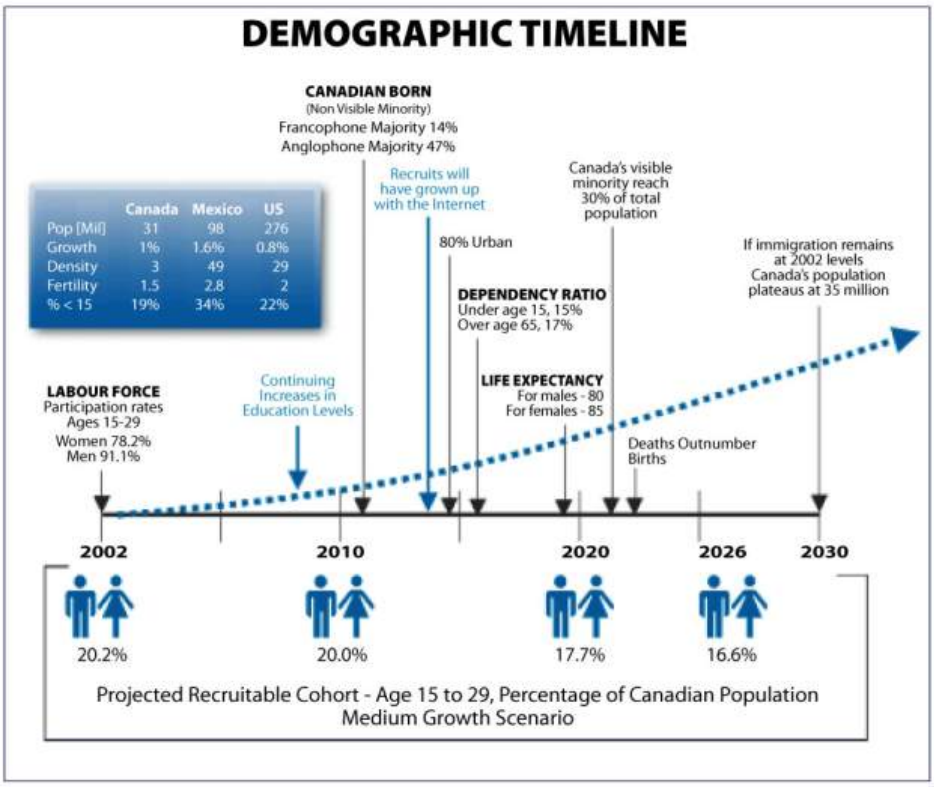


Figure 3. Demographic Timeline[15]

22. Recruiting policies to bring more New Canadians into the Air Force are also failing. The accelerated pathway to citizenship has had some success in providing raw numbers, but the government's efforts at what is regarded by many as social engineering backfired somewhat. The bottom line, however, is that despite significant efforts and targeted recruiting campaigns, it became quite obvious that the majority of these New Canadians were simply not interested in joining the Canadian Forces.

23. Meanwhile, in 2015, as many baby boomers were attaining retirement age,[16] the exodus of older but highly skilled workers from the Air Force accelerated to unprecedented rates, and the demographic imbalance became even more pronounced. Figure 4 below depicts the retirement eligibility of the DND civilian workforce. Note the largest bulge to occur between 2010 and 2020. At the same time, educational institutions, airlines, and aerospace companies were energetically attracting and recruiting

[15] Department of National Defence, Assistant Deputy Minister (Human Resources-Military), *Military HR Strategy 2020 – Facing the People Challenges of the Future* (Ottawa: DND Canada 2002), 19.

[16] The vast majority of the almost 10 million boomers are forecasted to retire between 2007 and 2027 (with a peak around 2015), increasing the number of people in retirement to a level never before seen in Canada.

our trained manpower, making the retention of talented, experienced personnel extremely difficult.[17] The inadequacy of the Air Force to provide sufficiently trained, mission-ready forces for overseas operations and humanitarian assistance impacted on its ability to conduct its mission. Embarrassed, the government was obliged to consider abrogating our active role in traditional military operations on the world stage.

Figure 4. Retirement Eligibility of DND Civilian workforce[18]

24. **Economic conditions.** By 2020, politicians have been forced to choose between the sharply contrasting guns-or-butter polarities. The tax-base has not recovered as had been hoped, and deficits that had accumulated from the worst of the economic downturn from 2008 to 2013 have not been remediated. By 2018, the national debt has risen to such high levels that the World Bank took the rare step to warn Canada of "grave consequences" if appropriate measures were not swiftly implemented.

25. The increasing demographic imbalance between the number of tax-contributing workers and the older, tax-drawers, as well as the relative high unemployment rates continue to act as a brake on discretionary tax dollars. Meanwhile, DND budgets have been frozen since 2016, and it is clear that Canada's once-prominent place on the world stage has ceased to be a government priority due to budgetary and societal constraints. Following the last troop withdrawal from Afghanistan and Pakistan in 2016, there now is a growing sense among many Canadians, that "we have done enough." International commitments are increasingly unpopular with a public that embraces a growing Canada First perspective.

26. Passive measures, including UAS, radar, and satellite surveillance have met the government's needs for cost-effective sovereignty assurance, further marginalising the surveillance and sovereignty role of the Air Force. Cash strapped and short of personnel, the Air Force is forced to contract out many

[17] Business author Edward Gordon predicts that Canada will have a million-person labour shortage by 2020. See Edward Gordon, *The 2010 Meltdown, Solving the Impending Jobs Crisis* (Westport: Praeger Publishers, 2005), 99.

[18] Treasury Board of Canada, "National Defence." Available online at http://www.tbs-sct.gc.ca/rpp/2008-2009/inst/dnd/dnd01-eng.asp (accessed January 5, 2010).

of its core missions. In 2016, the Air Force is obliged to disband the Snowbirds, a decision still regretted today because of the highly negative effects this had on recruiting. By 2018, cheaper commercial providers are now delivering most emergency humanitarian aid in Canada and abroad. Similarly, domestic SAR has been largely out-sourced, further distancing the Air Force from the public it serves.

27. **Technology, skill relevance and currency.** By 2020, most Air Force schools are struggling for survival. The demands for skilled personnel in aerospace and other industries are luring experienced Air Force instructors away. The rapidly accelerating pace of aerospace technological change, plus the clumsy bureaucratic architecture, has outstripped the ability of Air Force institutions to lead or even to stay abreast of these advances.

28. **Public perception and will/support.** Though the general assessment of the Air Force role in the Afghanistan Mission and follow-on missions were favourable, several former service members fed the media gristmill with disturbing revelations. In 2014, rumours of incidents that led to injuries and death of civilians as well as rough treatment of prisoners of war (POWs) are portrayed almost daily in several Canadian news feed. The Minister of National Defence calls for a Royal Commission to investigate the allegations. The wave of Support Our Troops enthusiasm turned into an ebb tide for a public more concerned with the current economic reality and looking for a peace dividend.

29. By 2020, the Air Force reliance on UAS for surveillance and certain combat missions has unexpectedly further distanced the Air Force as an institution of pride. This has created an outcry, domestically and internationally, from human rights groups, civil libertarians, social scientists, and other concerned individuals despite the Air Force's best efforts of demonstrating control and rules of engagement that required a man in the firing sequence as well as respect for human rights and privacy.

30. The success of our relatively bloodless combat engagements, which encouraged the Air Force to adopt even more remote systems, further alienated us from those we were fighting to protect. The Canadian public no longer felt the same degree of connection or personal commitment to its young men and women in uniform carrying out meaningful, often dangerous tasks throughout the world. The earlier thrill and sense of engagement of people integrating with machines in the golden age of flight is irretrievably lost, and the nobility of the warrior culture has vanished. In the public mind, it has been overtaken by the spectre of humans being under constant surveillance, and during active operations, targeted and killed by unmanned flying machines. People may feel gratitude towards those who accept risks on their behalf. Conversely, machines acting in these roles are just sophisticated, albeit useful, heartless tools.

Take Away – Force Generation Issues

31. **A positive public perception of the air force must be maintained.** The Air Force budget is highly vulnerable to how well the federal government is able to manage its finances. In tough economic times, the government will cut programs that it deems less important. Directly correlated to this is public support. Whether the times are hard or not, the government will not cut the funding of an institution that enjoys high public support. Furthermore, from a personnel perspective, inspiring the public imagination will be essential to the success of the Air Force in attracting personnel and new recruits. Canada's Air Force must be balanced in its proportion of manned and unmanned vehicles to find equilibrium between the seductive lure of technology in providing tools to meet defence challenges,

but it must also meet human identity criteria in order for people to relate to and have a sense of connection with their Air Force. Lastly, it should be noted that in hard times, cheaper alternatives may displace traditional Air Force roles that have been accomplished with great success for years. Private military companies (PMCs) or contractors may take on some of our traditional jobs, which will further marginalize the Air Force.

32. **Digital natives have different needs.** The growth of Canada's labour force and population older than 15 will continue to shrink. Consequently, in 2020, there will be increased competition with other employers for potential Air Force recruits. Work place strategies that are not modernized will fail. The Air Force should embrace concepts such as working from home, flex-time, part-time, and enhanced work-life balance.[19] Future CF and Air Force policies will have to accommodate the digital native generation if we are to meet our recruiting targets. In general terms, digital natives are interested in having as many superficial and broad employment experiences as possible. Extended commitments to any one employer will be unattractive; and, consequently, a 35-year career in the Air Force may not appeal to the vast majority. Flexible enrolment plans as well as frequent, short-term contracts that do not attract long-term benefits may become the norm. Furthermore, in the profession of arms, the possibility of serious injury or death will be anathema to the target population. Digital natives grew up in a virtual world where games are action packed and violent, but allow for an infinite number of "lives".

33. **The Air Force must do more to appeal to visible minorities.** As a national institution and an instrument of Canadian sovereignty, the Air Force of 2020 must reflect the makeup of Canadian society. Aggressively targeting New Canadians will become a necessity. These efforts must succeed if the Air Force is to be a viable, effective, and relevant institution to all Canadians in the future. Strategies must be broad-based to reach all elements of Canadian society. As competition increases in a dwindling labour pool and an increasingly immigrant-dependant population base, novel yet security-conscious approaches to recruiting will need to be adopted; otherwise, these potential new recruits will simply turn their backs on the Air Force as a career and concentrate their efforts in civil pursuits. Renewed efforts will be required in order to entice more women to join the CF and the Air Force. Policies for service women wishing to balance family and career opportunities will need to be modernized in order to ensure continued and increased participation by this key group.

34. **The Air Force needs efficient, relevant, and fast evolving training.** The Air Force heavily relies on technology and complex technical support and personnel systems. Consequently, we need skilled experts in areas requiring long timelines to develop. As the pace of technological advance continues to accelerate, it will be challenging to produce and retain skilled individuals able to operate and manage both legacy and emerging systems. Air Force schools will likely struggle to remain abreast of this technological tsunami and retain their instructors when companies are hiring. Cooperative approaches with learning institutions and industry are likely to yield considerable mutual benefits. In

[19] As a way to illustrate this point, consider that the company Google encourages its engineers to spend 20 per cent of their work time on projects that interest them. The company allows employees to bring their dogs (but not cats for some reason!) to work, provides subsidized daycare, massages, and food, as well as many lounges and recreation areas near the work offices so that interaction between employees is maximized and creativity is improved. See Eros Hoagland, "Life in the Googleplex," *Time Magazine*. Available online at http://www.time.com/time/photoessays/2006/inside_google/ (accessed January 6, 2010).

fact, by 2020, most training activities should be outsourced to private companies. Suppliers and/or developers of the products are often best positioned to supply or train the personnel needed to operate and maintain modern weapon systems.

35. **Compulsory retirement age policy must be modernized.** Retirement is a relatively new product of the modern industrial society. Older members of previous generations simply did not retire in the sense we know it today. The CF needs to re-think its CRA policy. Currently, the relatively early retirement age of CF members is not reasonable when compared with the majority of Canadian workers. Raising the CRA to 65 would allow the Air Force to slow the exodus of experienced members while appealing to older potential recruits.[20] Other retention strategies such as allowing the service of disabled personnel should also be considered.

[20] For example, a 40-year-old recruit may like the idea of having potentially 25 years of service ahead, plus a decent prospect for a pension.

There's no such thing as a natural-born pilot.

Chuck Yeager[21]

PART 2 - FUTURE OF SIMULATORS AND TRAINING

36. Modern advancements in technology should lead to a future in which simulators might be used for the majority of first-stage Air Force training. The future use of simulators will be governed by the following key factors:

- **Realism.** In order for simulators to reach a point where they will fully replace aircraft in the training of personnel, future technological developments must lead to increased realism for the trainee. Currently, limitations exist in conveying the realism of images and how certain aircraft movements and manoeuvres feel (i.e. visual motion cues in coordinated turns, feel of touchdown, vibrations, and feel of runway contamination). Simulators are even more limited in their ability to depict the realism of helicopter flight, especially helicopter vibrations and close quarter manoeuvres.
- **Value and Cost.** A case can be made that, notwithstanding the initial cost, acquiring and operating simulators is far less expensive than actual flying. With the rising costs of oil and the maintenance/replacement costs that go along with more complex aircraft, it is practically a given that each hour of actual flight that can be replaced with simulation has a clear advantage from a strictly financial point of view. Financial considerations, however, cannot be the most important factors to consider. In order to move to simulation based training, there must also be a clear demonstration that the replacement of the aircraft by a simulator would not affect or degrade the quality of the training in any way.
- **Technological.** The technology being utilized in modern day simulators has grown by leaps and bounds since the first generation of flight simulators. Aside from increasing the visual display to life-like quality, and perfecting the stick input to visual cue timing, are there further opportunities for future technological improvements and will they be affordable? It will also remain to be seen if the technology will ever meet the needs of the Air Force in terms of realism and adaptability.
- **Human acceptance.** Will pilots' scarves only flap in the breeze from future computer fans used by simulators? There is the possibility that the increased utilization of simulators could meet resistance by both senior Air Force officers, now in positions to make training decisions, and by new pilots entering the system. It will be necessary to mitigate these barriers and evaluate what effect they will have on the future of the training system. There is no doubt that a paradigm shift will be required. At one point in time it was felt that a computer would never be able to beat a chess master at the game of chess; whereas, now, virtually no one would argue such a statement.

[21] Chuck Yeager, "Brainy Quotes." Available online at http://www.brainyquote.com/quotes/authors/c/chuck_yeager.html (accessed January 10, 2010).

Will the future integration of simulators parallel such a path to acceptance? In 2020, will we accept that there are no reasons why a newly winged graduate needs to fly a real aircraft to acquire quality training?

37. How these key factors are developing over the next 10 years will shape the future of simulators and training. Once again, the future best case and worst case scenarios shall now be examined in the hopes of identifying and exploring the future considerations of the integration of simulation into the training and development of aircrew.

Wild Card: Financial Crisis and the Price of Oil

In 2017, the US national debt has climbed to such astonishing levels that the government can't sell US debt to anyone but its own Federal Reserve banks. Virtually all levels of US government are forced to slash spending, sell off assets, and reduce workforces. Hyperinflation destroys the US Bond market, and the price for goods and services accelerate to unprecedented levels. The world is plunged into the worst financial crisis ever documented, with virtually all markets losing 40 to 60 per cent of their values in just a few days. With unemployment rising to well over 16 per cent, social unrest and violent demonstrations are becoming daily occurrence in the hardest hit parts of the country. The situation stabilizes somewhat when the Administration is forced to enact strict price controls and peg the value of the battered American dollar at 50¢ to one Euro. Meanwhile, the cost of oil skyrockets to above 150 €. In Canada, civil aviation virtually grinds to a halt while only essential military flying is permitted. By 2018, most Air Forces of the world train their pilots on new generation virtual reality machines.

Best Case Scenario – Simulation

38. **General.** In this best case alternative future, the use of simulation has virtually replaced all actual flying in initial training as well as recurrent training. Flying, except on operational missions, has become simply too expensive to justify due to the high cost of oil. At the same time, relatively cheap and rapidly expanding technologies have contributed to the development of super-fast computers and highly realistic third generation simulators. Forward thinking Air Force leaders have embraced this affordable alternative, thereby generating considerable cost saving without compromising operational effectiveness.

39. **Realism.** In 2020, computing power[22] has advanced to the point where impressive third generation, full-scale simulators are able to provide a level of realistic training to supplement, and in some cases, even replace actual flight operations. Manufacturers have been able to reduce stick input to simulator reaction time to .03 of a second making it equal to that of an actual aircraft. Similarly, the perfection of the simulator's electrical movement systems has removed the limitations that existed with simulating certain aircraft manoeuvres. Lastly, the improvement of projection quality has continued (see figure 5), making current simulation virtually indistinguishable from the highest quality high definition video.[23]

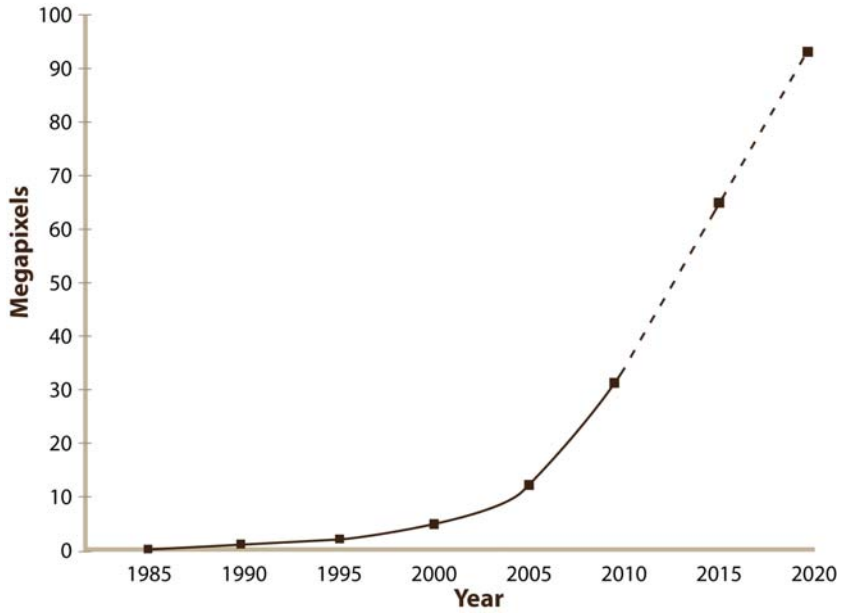


Figure 5. Exponential Rise in Projector Capabilities 1985-2010[24]

40. With these advanced third generation simulators, students can still distinguish a simulation from a real flight, but improvements for the stimulation of other human senses, such as olfactory and auditory cues, are being actively researched. There are already talks of fourth generation simulators, the so-called virtual reality machines that are said to deliver sensorial experiences that are at par with actual flying experiences.

[22] If the increase in computing power continues at the current pace, one can expect a 1,000 to 3,000 per cent increase in computing power by the 2020 time frame. Note also that in the last 12 years, there has been a one-million-fold expansion in synthetic environment data, and that trend is accelerating.

[23] Currently, the best simulators provide visual pictures in the 8-10 megapixels range. Soon, images in the 30 megapixels range (photo perfect images with visual resolution close to the threshold of the human eye) will be attainable.

[24] Graph compiled from information received from CAE on 18 November 2009.

41. **Costs.** Peak oil[25] occurred in 2012, and by 2018, oil finally reached $200 a barrel. By maximizing the use of simulators, it was possible to bring about large cost savings to the Air Force budget, which had become increasingly under stress. By 2020, almost all actual flying in initial training as well as recurrent training (instrument check rides, proficiency, and routine training, etc.) is now simulated. Marketed as a green initiative, the cost savings of switching to simulators (when fuel, maintenance, personnel, and aircraft damage are considered) are impressive,[26] allowing the Air Force greater fiscal flexibility. Figure 6 below is from a recent 1 Canadian Air Division study. Notice that currently, if most fleets would operate simulators, the Air Force would save almost 3,000 hours of yearly flying rate (YFR), as well as 838 pilot-days per year for total savings of almost $20 million a year—a figure likely to be more in the future as the price of oil is forecasted to go up exponentially.

Fleet	Change Required	Simulator Purchase Cost	Support Contract ($/YR)	Hours Saved Per Year	Pilot-days Saved Per Year	Aircraft Operating Cost Savings (or FE Incr) ($/YR)
CF188	Upgrade to R2 Std	Cost Unkn Awaiting cost from Contr	$8.5M	2448	N/A	$52.2M
CP140	Upgrade to Block III	Under Contract	$.5M	750	N/A	$8M
CH146	FMFS Buy	$25M	$1M	238	0	$.7M
CH149	Buy Sim Buy VR Sim	$25.8M	-$.85M	660	144	$4.5M
CC130	Upgrade Sim	$8.5M	+$.5M	823	-40 (435 &413)	$6.5M
CC144	Expand Contract	N/A	+$.4M	300	100	$.9M
CC150	Buy Sim	$15M	+$.4M	270	250	$3.2M
CC177	Buy Sim	$18M	+$.5M	144	384	$3M
CT142	Buy VPT	$.75M	+$.027M	700	N/A	$1.5M
Total		**$68.05M + Bldgs**	**+$1.22M**	**2995 YFR**	**838 Days/yr**	**$19.6M**

Figure 6. Simulator Cost Savings[27]

42. **Technology.** Astonishing technological advancements have contributed to make the simulation extremely realistic. With the latest upgrades, the simulators are able to custom-tailor the training by recognizing the strengths and weaknesses of the student. Furthermore, the business community has unified in the creation of a single format for simulator databases; thereby removing proprietary problems

[25] **Peak oil** refers to the point in time when oil production has peaked and only half of proven reserves remain. The significance in this lies in the fact that the remaining known quantity is finite, and the laws of supply and demand indicate that greater demands for dwindling supplies ultimately translate into higher prices. The date when the world reaches global peak oil production cannot be pegged exactly. The projected dates vary between the most pessimistic in 2010 and the most optimistic in 2035. See Energy Bulletin, Peak Oil Primer, Post Carbon Institute. Available online at http://www.energybulletin.net/primer (accessed September 9, 2009).

[26] CAE currently estimates that one hour of training in a simulator cost 1/10 of one hour of actual flying. By 2020, this ratio will likely be even more tilted in favour of simulation.

[27] Retrieved from deputy commander force generation (DComd FG), Pilot Production/Absorption Proposed Plan, October 8, 36.

that once existed.[28] One of the biggest advancements, however, has come in the integration of system databases with actual flying, and by 2014, hybrid reality has become the standard. With hybrid reality it is now possible for pilots to operate in any weather conditions, including whiteout and brownout.[29] The integration of actual atmospheric conditions as well as real-time data from satellites and UAS in the field has allowed for databases to be highly accurate and constantly updated. This, in turn, allowed for commanders to accurately rehearse missions using simulators.

43. Simulators have also become completely modular, allowing for the easy reconfiguration of aircraft types and systems. This ability to convert the type of aircraft being simulated in a matter of minutes has significantly decreased the costs associated with acquiring simulator systems. Linking simulators amongst Allied nations has also allowed for outstanding multi-national training in a large SE. In 2014, the Air Force decided to integrate even more simulation within first-stage training by including the training of maintenance personnel. Technicians are now able to simulate repairs and aircraft trouble-shooting and diagnostics without any risk to themselves or to the equipment.

44. **Human acceptance.** Just as humans accepted that they could never again beat a computer at chess, so too have pilots accepted the expanded role of simulators. Besides, for the digital natives, it only seemed natural that computers and simulation (like a video game) be part of their training. Although it was a tougher sell with the older generation of Air Force officers (also the decision makers), in the end, forward thinking officers realized that substantial savings could be made without endangering the effectiveness of the Air Force. Soon, simulators were certified for all proficiency rides and instrument check rides recertification. The Air Force training and currency plan of 2018 identified that within the next two to three years it would reach its goal of 100 per cent utilization of simulators in training. In 2020, the next generation of winged graduates completed their unit training phase with only five per cent of their time in an actual aircraft.

Worst Case Scenario – Simulation

45. **General.** As it is very unlikely that technology will find itself slowing down, the worst case scenario is really focused on problems that could arise given the Air Force's procurement challenges as well as decreases in costs of flying operations. In this scenario, the effectiveness of simulators is not widely recognized, and senior leaders are not embracing the new technology, preferring to stick with the proven traditional methods of training aircrew.

46. **Realism.** By 2020, the realism displayed by simulator projectors delivers excellent images, but the motion systems have not yet been able to simulate realistic aircraft feel. Electronic motion systems, although being much more advanced than their hydraulic predecessors, never were able to be sensitive enough to perfectly simulate all of the characteristics associated with actual flight. This lack of realism

[28] CAE, a world leading manufacturer of simulators, has given its competitors access to their common database (CDB), which will allow all companies working in this field the use of a standard databank. For the operators, it means greater ease to connect different systems together into an SE or plug and play between different machines.

[29] CAE's AVS, a type of hybrid reality system, combines aircraft navigation and attitude information, data from multi-sensors, and from synthetic databases (such as the CDB) into an integrated display.

led to continued demands from aircrew for training outside of simulators in order to get the real feel for the aircraft. Simulator manufacturers are still unable to produce the contextual simulations of heat and cold, dirt, threats to mental and physical health, discomfort, real fear, separation from home, et cetera. Consequently, fourth generation simulators are still years away in development. The demand for simulators has plummeted since the combined effects of the Great Recession of 2008 and the Air France Valentine's Day attack of 2014, which had a devastating effect on air travel worldwide, and there have been no indications that the industry is willing to absorb further developmental costs for the next generation of simulators.

47. **Costs.** The amount of oil reserves contained in the Arctic has exceeded expectation by a large margin, and in 2016, when Exxon/Petro Canada announced plans to start exploiting the massive jointly owned Beaufort oil field, the cost of oil fell further to below $100 per barrel for the first time in three years. Given the relative decrease of operating costs for aircraft, the impetus to acquire expensive simulators systems fizzled away.

48. In addition to lowered fuel costs, there has also been a shift towards unmanned flight. By 2015, the Air Force YFR for UAS finally surpassed the YFR for manned aircraft. This shift created significant reductions to the cost of flight operations. Lastly, following the Air France Valentine Day terrorist attacks of 2014, the general public started looking for alternative ways to travel. This led to aircraft manufacturers building fewer aircraft, and airline companies buying fewer simulators. Decreased demand in the civilian market forced simulator manufacturers to increase costs to their military customers. In the end, the rising costs of simulator systems combined with the decreased costs of flying operations solidified the Air Force's decision not to invest in simulation.

49. **Technology.** While technology has delivered, the problem for decision makers is one of value added. Even before Air Force budgets were frozen in 2016, senior officers were struggling with deciding how much to invest in simulation. Whereas a full flight simulator may do 97 per cent of the remit for realistic training, a virtual part-task trainer might hit 91 per cent, and be deliverable in 10 per cent of the time and at 11 per cent of the cost.[30] This became a compelling equation for an Air Force strapped for cash. Essentially, the problem was to decide between a "good enough" package over an expensive all-inclusive solution. In the end, overall costs became the most compelling factor.

50. **Human acceptance.** Human acceptance and the cost were the pre-eminent factors slowing the transition towards simulators. The Air Force still attracts most of its new pilots by the appeal of hands-on flying. The continued availability of cheap oil and the relatively high cost of simulator systems, as well as the belief that "simulators could never replace the real thing," as one pilot put it, resulted in little support to modernize the Air Force first-stage training schools. By 2020, only 20 per cent of the wing training is accomplished by simulators and procedure trainers. Many ex-pilots who now hold key senior positions within the Air Force leadership have been uninterested in embracing revolutionary training methods when traditional ways have proven so successful.

[30] BGen Davies, Director General Air Force Development (DG Air FD), Minute 2 to Director Aerospace Requirements (DAR), 1 Canadian Air Division Initiative on Pilot Production (November 3, 2008).

Take Away – Future of Simulators and Training

51. **Cost of flying.** In 2020, aviation fuel will continue to be the primary energy source for aviation vehicles. The cost of oil is widely predicted to become increasingly prohibitive, with various projections ranging from twice the current costs to much greater multiples.[31] Consequently, the cost of flying operations is likely to be extremely expensive by 2020. At these costs, it will be particularly difficult for the Air Force to justify extensive hours of "touch & go" (or any other type of routine training, for that matter) in pretty well any type of aircraft, and especially those which consume large amounts of fuel, such as a Globemaster, a Chinook helicopter, an Airbus, or a Fighter aircraft.

52. **Cost of simulation.** Exponential advances in computers are forecasted to revolutionize simulation technology. Even at today's relatively cheap price for oil (around $80 a barrel), and notwithstanding the initial acquisition cost, operating simulators is far less expensive than actual flying. By 2020, this ratio will likely be even more tilted in favour of simulation.

53. **Cost of acquisition.** Further research will be required to determine if the Air Force should invest in relatively cheap and easy to acquire virtual part-task trainers or expensive full-flight simulator systems. Note, however, that even the acquisition costs can be successfully mitigated as demonstrated by the OTSP model being implemented at 8 Wing Trenton (see note 11).

54. **What can be simulated.** By 2020, simulators will be so mature that they should provide a cost effective alternative to replace a majority of the ab initio training curriculum as well as some recurrent training, such as proficiency rides and instrument check rides. Of great benefit to commanders will be the ability to simulate an actual operation to apply different courses of action (COAs) using the actual lay-out of the landscape/urban areas of the mission objectives in accurate details. Imagine the benefit for the crew if complex missions, such as inserting an SOF squad at night in the middle of a foreign city, could be accurately simulated and rehearsed in a high fidelity, hybrid-reality environment.

55. **Hybrid reality.** By combining the database from advanced simulators and real world feed from special cameras and sensors, a hybrid reality can be simulated, which can allow crews to operate under all weather conditions. Computer-aided engineering estimates that their augmented visionics system (AVS) will allow a helicopter to land precisely (we are talking about a precision approach measured in centimetres!) in adverse conditions such as brownouts and whiteouts. Clearly, this is just the beginning; the future will see even greater applications that will blend the real world and the virtual world.

56. **Human acceptance.** For the operator, it is all about the realism of the experience: the better the display and the sensorial effect, the closer to reality (or should we say virtual reality?) a simulator will feel. If advances in technology and computing power continue at the same rate—and there are no indications that they will not—high fidelity systems will be available in the near future. For the senior officer and decision maker, embracing simulation will require a paradigm shift, realizing that in 2020, training for a routine mission will be just as effective in a simulator as it is in a real aircraft.

[31] Note that there are very few analysts that are predicting cheaper oil in the next ten years, even when considering the massive untapped Arctic reserves.

Who will be man's successor? To which the answer is: We are creating our own successors. Man will become to the machine what the horse and the dog are to man.

Samuel Butler, 1863[32]

PART 3 - UAS OPERATIONS

57. In the last 10 years, UAS[33] have completely revolutionized the battlefield. Will this trend continue? In fact, modern advancements in technology and miniaturization have many analysts predicting that future Air Force operations, from SAR to ISR to force application, will be accomplished mostly by UAS. Essentially, the future of UAS will be governed by the following key factors:

- **Technology.**[34] Projected increases in computing power should result in more mature onboard controllers and communication links as well as semi-autonomous flight management systems. Coupled with forecasted improvements in engineered materials (due to advances in the field of nanotechnology), it is fully expected that UAS will become all-weather capable, much stronger, smaller and lighter over the next 10 to 20 years. Their range, endurance (with flying time measured in months and even years), payload capability, and imagery resolution are all predicted to increase. Are we at the brink of large scale adoption of UAS[35] as the platform of choice to conduct persistent surveillance and stand-off missions? Will UAS also become the platform of choice for conducting selected high risk force application missions, thereby heralding the demise of manned fighter aircraft? Or, will technology become the Achilles heel of these sophisticated but highly vulnerable and somewhat fragile machines?
- **Costs.** As discussed in Part 2, the cost of flying aircraft is forecasted to become prohibitively expensive in the future. Aside from massive increases in the price of fuel, the cost of acquiring sophisticated modern aircraft has also risen to unprecedented level. For example, on the one hand, the cost of a single joint strike fighter (JSF), which in 2001 was estimated to be around $30 million, has ballooned to anywhere between $80 to $100 million per copy. On the other hand, the cost to train UAS operators and maintain the drones is much less than comparable expenses for conventional aircraft. This is certainly tipping the balance in favour of UAS, but when

[32] Samuel Butler quoted in Peter W. Singer, *Wired for War* (New York: The Penguin Press, 2009), 414.

[33] The term "**Unmanned Aerial System - UAS**" is actually preferable to "**Unmanned Aerial Vehicle - UAV**" because discussing unmanned aircraft only in terms of a flying platform does not paint a realistic image of the equipment and the payload it carries, or the system which enables piloting by remote control, the information downlink system, the information processing, exploitation, and dissemination network, and personnel costs associated with unmanned aerial vehicles. The entire package, with the ground environment which supports it, must be viewed as a holistic entity in terms of purchase price, life-cycle cost, and numbers of task-dedicated personnel.

[34] "We are on track to experience about 20,000 years of progress in the 21st century, one thousand times more than we did in the 20th century," predicts Raymond Kurzweil (renowned technology guru), as quoted in Singer, *Wired for War*, 102.

[35] It should be noted, however, that off-the-shelf UAS will be readily available to friend and foe alike. Consequently, the Air Force should start preparing to defend against new adversarial tactics.

considering that there will be no loss of life if a UAS is lost or shot down, the arguments become compelling. However, upon greater examination, UAS may not be the panacea to all flying operations. Once thought of as expendable, the cost to acquire UAS is also soaring. Considering that a Global Hawk costs $35 million per copy and carries a large logistical tail, cost alone as a determining factor can be misleading.

- **Regulations.** Assuming that technology delivers the required systems to improve real time communication with the UAS operator as well as a reliable way to sense and avoid both cooperative and non-cooperative air vehicles, there will still be a requirement for Air Regulations to be extensively amended if UAS are to be used widely in domestic missions within controlled areas. While this might be technically possible, significant human involvement will be required, especially for UAS ground operations at airports where manned aircraft are also operating.
- **Human acceptance.** One can easily envision a future where UAS are performing almost all tasks that are done by conventional aircraft today. From fishery patrol to Arctic surveillance, and from air searches to force application and even air mobility, there are no reasons to think that UAS could not do these tasks more efficiently than and as safely as manned aircraft. We can envision such things, but are we ready to embrace them? A hundred years ago it would have been difficult to convince passengers to get into a train without a conductor and an engineer in the locomotive. Today, nobody flinches at the idea of an automated subway or monorail train; advances in technology as well as proven safety records made us accept these innovations. Will UAS also benefit from a similar acceptance or will we always insist on having a human in the loop? Ultimately, with the advent of artificial intelligence and the possibility of having a completely autonomous UAS, we will soon have to decide if it is even desirable for us to send drones to fight wars on our behalf.

58. How these key factors develop over the next 10 years will shape the future of UAS operations within the Air Force. Once more, the future best case and worst case scenarios shall now be examined and considerations for UAS Operations will be identified.

Wild Card: Micro Air Vehicle (MAV) caught in NATO HQ

In 2018, a Spy-Fly is discovered in the Office of the Secretary General in Brussels. According to NATO officials, the threat was easily neutralized by agents working for the newly formed office of Counter Entomological Espionage (CEE). The MAV, comparable to 5th generation Cyborg MAV recently developed in Japan, was carrying a complete sensor suite, but was not equipped to destroy or alter data. The consequences could not be fully assessed yet, but could be quite damaging. The origins of the bug are under examination, but officials are giving few details as the investigation is highly classified.

Best Case Scenario – UAS Operations

59. **General.** In this best case scenario, super-computers, AI, and semi-autonomous systems are all a reality. Empowered by this technology, UAS are in the process of virtually replacing manned aircraft and are being employed in a growing number of Air Force missions. Cost savings and efficiencies of scale are being constantly realized, making the little drones the weapon of choice in almost all circumstances. Due partly to their almost perfect safety record, the population at large is embracing pilotless surveillance and force application.

60. **Technology.** In 2020, technological advances provide significant leverage to the newest generation of UAS. New sensor and weapon payloads are smaller, lighter, and more capable, providing great capability per unit of weight. New data links, traditionally the Achilles heel of unmanned systems, can provide high bandwidth connectivity for vehicle command and control and data transfer. Advances in microprocessor technology, software development, inertial navigation, and global positioning systems have enabled the development of robust semi-autonomous flight control systems, and, more importantly, onboard processing of sensor data. New composite materials and improved propulsion systems have produced lighter, smaller, and stealthier airframes, resulting in levels of performance that far exceed human tolerance. Of all the technological advances, it is automation and miniaturization that have had the most profound effect on the employment of UAS.

61. In early 2019, the United States Air Force (USAF) unveiled the Intelligent-UAS (iUAS). Although its actual specifications are still classified, iUAS is rumoured to be the first truly autonomous[36] UAS. The iUAS features learning software which includes a built-in ethical governor as well as a guilt system,[37] which, if a serious error is made, forces the drone to start behaving more cautiously.

62. The development of MAVs is in full force and by 2015, MAVs as small as a dragonfly and as fast as a hummingbird (see Figure 7) are in existence. By 2020, MAVs have swarming capabilities, and are capable of blending within cities and flying into buildings (or caves) in order to spy on or even assassinate an adversary.

Figure 7. UAS and Miniaturization[38]

[36] To achieve that goal, machine processing will have to match that of the human brain in speed, memory, and quality of algorithms, or thinking patterns. Microprocessor speed is predicted to reach parity with the human brain around 2015, although some less optimistic assessments suggest that this might happen closer to 2030. As to when or how many lines of software code equate to "thinking" is still an open question.

[37] Early prototypes of ethical governors and guilt systems already exist. See T. Simonite, "Plan to Teach Military Robots the Rules of War," *New Scientist*. Available online at http://www.newscientist.com/article/dn17332-plan-to-teach-military-robots-the-rules-of-war.html (accessed January 24, 2010).

[38] Available at http://www.timboucher.com/journal/wp-content/uploads/2009/03/delfly-micro-robot.jpg (accessed December 2, 2009).

63. Advancements have also been made in HALE (high altitude long endurance) UAS.[39] In 2019, the Air Force acquired an HAA UAS, a large HALE surveillance platform that is capable of staying aloft for several months (see Figure 8). The HAA receives its power from the outer skin of the airship, which is coated with solar cells. Its capabilities include a highly advanced radar system and a sophisticated camera, which are able to provide persistent, high-definition coverage of high interest areas. Currently, the Air Force is exploring the possibility of providing the HAA with the ability to dock with and refuel other HALE UAS.

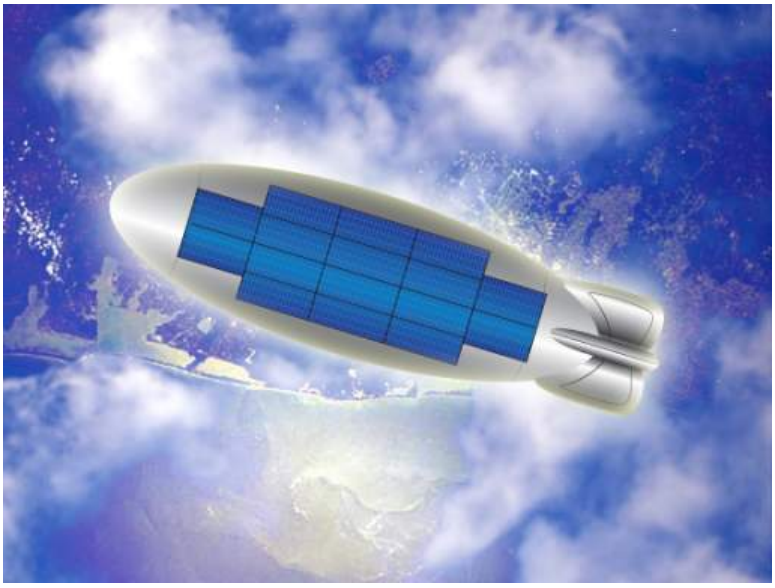


Figure 8. High Altitude Airship (HAA) UAS [40]

64. **Costs.** With the record high cost of oil, there is no question that operating the newer generation of UAS is cheaper than operating the larger manned aircraft in the Air Force inventory, many of which are still equipped with gas-thirsty, older jet engine technology. Also, the new generation of drones now have a variety of self-sustaining power sources that require little maintenance. Most newer UAS can now be powered via alcohol, hydrogen fuel cells, solar power, and even harnessed energy from biomechanical processes. With the recent developments in AI, one operator can control multiple semi-autonomous UAS at once. Lastly, the costs of acquiring UAS have also fallen dramatically, thanks to advancements in technology and the strong demand for the drones.

65. With the further development of expendable surveillance technology (one basic surveillance MAV now costs less than $100), these little drones offer effective and highly affordable ways to map

[39] DARPA (the research and development arm of the U.S. Department of Defense) is currently working on the VULTURE (very high altitude, ultra-endurance, loitering, theater, unmanned reconnaissance element) drone, which the agency hopes will be able to stay aloft for as long as five years. See http://www.darpa.mil/ (accessed January 13, 2010).

[40] Photo composite by the Canadian Forces Aerospace Warfare Centre.

and monitor buildings and cities. Furthermore, one operator can now control a multitude of MAV in swarming mode.

66. The greatest saving brought about by unmanned technology has been in terms of saving human lives. With each step towards further utilization of unmanned technology, humans have been further removed from the dangers of war. Since piloting operations are now conducted outside of conflicted areas in secure locations, it is now possible for operators to carry out coordinated surveillance, movements, assassinations, and tactical strikes with relative ease and in complete safety.

67. **Regulations.** After an initial lag, the regulations, policies and procedures for unmanned vehicles have caught up with technology. Soon after the rapid proliferation of unmanned technology in the early 2010's, it was realized that unmanned aircraft technology was progressing much faster than the rules and regulations governing flight. This became particularly obvious after the Qatar Flight 165 collision with the Australian Heron back in 2012. While there was no loss of life, the accident brought about an increased focus on how unmanned missions are to be conducted and how control is to be shared amongst all parties. Shortly thereafter, the International Committee Aeronautical Organisation (ICAO) established international regulations and policies governing unmanned aircraft in controlled areas. To get this certification, UAS needed to have 4-D flight[41] capability, be equipped with two way communication, a functional transponder, and a sense-and-avoid system, such as traffic alert and collision avoidance system (TCAS).

68. **Human acceptance.** While there was much controversy about ethical connotations of unmanned technology, as well much resistance from the senior officers within the Air Force in the early 2010s, today, there is an overwhelming acceptance of the use of UAS in a tactical and surveillance role, and a growing support for further integration. By 2020, most Air Force senior officers are comfortable with an Air Force that mostly employs UAS. This is also the case with the general population, and that is likely attributable to the dramatic reduction in Canadian casualties in the ongoing conflict in northern Pakistan since the Air Force started to employ UAS in combat operations. Furthermore, Canadians are also quite pleased with the HAA Arctic surveillance program, which was able to record and prosecute several illegal entries into the Northwest Passage.

Worst Case Scenario – UAS Operations

69. **General.** In this dystopian scenario, UAS integration in Air Force operations has suffered numerous set-backs. While technology has delivered impressive machines, their costs have remained high, and so has their manpower bill. While UAS continue to be widely used for routine observation and surveillance duties, they have had limited success in other Air Force missions. In combat operations in northern Pakistan, most UAS, aside from highly sophisticated new generation UAS, have been easily destroyed or disabled by innovative new methods. Most will also recall the two American Global Hawk UAS that were hijacked by hackers in 2016. At the time, it was rumoured that the US government paid out an estimated $50 million ransom to get back control of the drones. In Canada, many UAS have

[41] Flight plans that are 4-D will reduce uncertainty and increase predictably for both air traffic service users and providers; 4-D flight plans include a selected latitude, longitude, and altitude (similar to the current system), and scheduled self-delivering to a series of 4-D waypoints.

failed to operate adequately in the Arctic temperature extremes and harsh flight conditions. Lastly, following the 2012 disastrous mid-air collision between an Australian UAS and a passenger jet, there has also been very low acceptance by the general population for further integration, and to date, UAS are still prohibited for use in most domestic air space.[42]

70. **Technology.** In 2020, UAS designs have evolved somewhat, but nothing overly revolutionary has occurred.[43] Granted, UAS are stealthier, smaller, lighter, and stronger than early models, but the new generation are becoming expensive weapon systems that only top tier militaries can afford. By 2020, both Israel and the US are rumoured to have developed intelligent UAS, drones that apparently are fully autonomous and able to make decisions based on a sophisticated AI program.

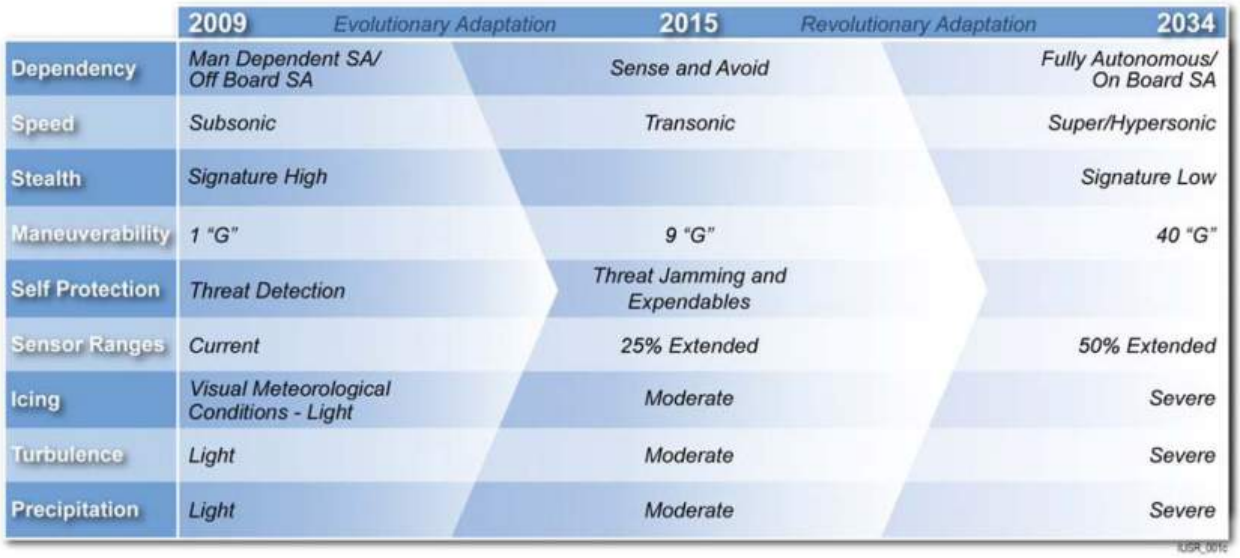
71. There are, however, a plethora of ethical problems with giving robots the ability to decide to kill a human, and there has been considerable uproar against their use on the battlefield. In 2019, Sweden formally introduced a motion that the Geneva Convention be amended so that autonomous systems become a banned weapon. NATO is also divided on the use of autonomous systems and where the final kill decision should reside.[44]

72. By 2020, developers have not successfully resolved the problems associated with the durability and robustness of the UAS airframe. UAS remain particularly vulnerable to the natural elements as well as to meteorological events, such as icing, wind gusts and turbulence (see figure 9). And, while these conditions present serious challenges to medium and large-scale UAS, they usually prove fatal for small and micro-scale UAS.

[42] This fictional scenario is not all that far-fetched. Just as it was the case with manned aircraft, trust in UAS will evolve slowly and will take time. Should UAS suffer a catastrophic failure resulting in death or destruction (as witnessed, for example, with Zeppelins), it is possible that the technology could find itself completely removed from common application altogether and sit for decades before returning to use.

[43] One could make a case that, indeed, the development of UAS will follow very similar a path as existing manned aircraft, where incremental conceptual and design advances will come at considerable investment in both time and money. See Dr. Andrew Godefroy, *Future Challenges and Limitations of Unmanned Aerial Vehicles (UAV) Out to the Year 2020*, Report prepared for the Canadian Forces Aerospace Warfare Centre, September 30, 2009, 10.

[44] To let a machine make the decision to kill a human is inherently anathema to human authority. The prospect of even a single such strike going awry would almost completely negate the granting of such autonomy for the foreseeable future. See Dr. Scott Robertson, *UAVs in 2020: The Prospects*, Report prepared for the Canadian Forces Aerospace Warfare Centre, November 2009, 19-20.



	2009 Evolutionary Adaptation	2015 Revolutionary Adaptation	2034
Dependency	Man Dependent SA/ Off Board SA	Sense and Avoid	Fully Autonomous/ On Board SA
Speed	Subsonic	Transonic	Super/Hypersonic
Stealth	Signature High		Signature Low
Maneuverability	1 "G"	9 "G"	40 "G"
Self Protection	Threat Detection	Threat Jamming and Expendables	
Sensor Ranges	Current	25% Extended	50% Extended
Icing	Visual Meteorological Conditions - Light	Moderate	Severe
Turbulence	Light	Moderate	Severe
Precipitation	Light	Moderate	Severe

Figure 9. Future Performance of UAS[45]

73. It is now widely acknowledged that the Achilles heel of UAS is the satellite-relay for control.[46] This became painfully obvious during the Indo-Pakistani War of 2015, when the Indian Air Force successfully disabled the satellite link of several Pakistani RQ-7 Shadow UAS. As mentioned earlier, the USAF was also embarrassed when two of its Global Hawks were hijacked by suspected Chinese hackers. The problem is that most UAS rely on commercial off the shelf (COTS), unencrypted satellite links that can be easily intercepted or jammed by inexpensive jammers.[47] Solutions are available, from complex encryptions to counter jammers, and even a dedicated array of satellites for the command and control of UAS, but the costs are enormous. This is why the USAF favours autonomous UAS, since these drones would not require massive bandwidth for command and control as they would make their own decisions once they were programmed with mission objectives and parameters.

74. **Costs.** In this scenario, the costs for the top of the line UAS have remained quite high and barely affordable for a medium-size Air Force. As the UAS platform becomes more capable, there is also a tendency to pack more devices and weapons into them, making the drones more and more expensive.

[45] Retrieved from Department of Defense United States of America, "FY 2009-2034 Unmanned Systems Integrated Roadmap" (Washington: DoD, 2009), 30.

[46] On average, it currently takes anywhere from seven to ten seconds for a remote operator's instructions to be transmitted to the UAS, and this assumes no interference with either the uplink or the downlink to the craft. Beyond natural and other unintended environmental effects that could either temporarily or permanently sever the link between operator and machine, this fragile tether may also find itself being actively attacked in the future.

[47] Note that by 2020, aside from hijacking, adversaries may have developed and possibly deployed effective countermeasures to future UAS technologies, such as other UAS designed to hunt and kill UAS, advanced air defence systems, electromagnetic pulse shots, hacking and reprogramming attacks, shotgun defences, air obstacles, and other swarms designed to engulf and damage UAS.

Furthermore, UAS squadrons remain manpower intensive.[48] USAF experiments with operators controlling multiple UAS in theatres of war have all resulted in a noted drop in mission efficiency, while operator burnout and operational stress become unmanageable.[49] Incidentally, the results of these experiments are further reasons why the USAF is pushing for greater UAS autonomy.

75. In 2020, most UAS power plant designs are still based on a single-engine concept. With no backup power available, there is a constant risk of losing a precious resource. Even when an emergency landing is achievable, alternative landing capabilities are few, and because of the assignments given to UAS, recovery is too often either impossible or simply not worth the risk to human lives. Lastly, UAS also continue to suffer a far greater rate of mishap than their manned counterparts, which is greatly disconcerting, considering the ever increasing cost for these machines makes them anything but expendable.[50]

76. **Regulations.** The rules and regulations governing UAS flight have lagged behind the development of the UAS. By 2020, only a few countries even allow unmanned flights in their domestic air space. Noted exceptions are the North American Aerospace Defence Command (NORAD) drones patrolling the maritime coasts of North America, and even those are extremely limited when it comes to operations within domestic airspace. In 2012, Qatar Flight 165 collided with an Australian Heron, killing all 134 people on board. The official report is classified, but most experts are blaming a malfunctioning sense and avoid system, and the long delay in communication between air traffic control and the UAS operator. The unclassified accident report that came out in 2015 recommended a long list of mandatory equipment and requirements for certification of a UAS for flights in controlled airspace.

77. **Human acceptance.** By 2020, there is still significant major resistance amongst senior Air Force officers and decision makers.[51] Most argue that the drones are unaffordable for an Air Force our size due to the long logistical tail required to enable the whole system. After years of debate, the Air Force is still hampered by the so-called silk scarf syndrome.[52] The Air Force insists on fielding air combat systems officers (ACSO) and pilots (in certain cases) to operate the UAS. Whereas it costs so

[48] Data on the cost benefit and cost effectiveness of UAS versus manned aerospace missions remains sparse. On the surface, however, it would appear that there are considerable cost savings to be made by employing UAS assets in lieu of manned systems. For example, a 2005 USAF study calculated that the average cost to train 15 B-52 pilots was $685,051 per person; whereas, the average cost to train 15 UAS operators was only $13,000 per person. However, this apparent advantage does not take into consideration the fact that manned B-52 bombers can deliver far more capability, ordnance, and mission options than any UAV currently in operation. See Godefroy, 23.

[49] Recent studies have shown that UAS operators are having much higher rates of post-traumatic stress disorder (PTSD) and other mental problems than soldiers actually on the ground. Ibid., 18.

[50] Between 2008 and 2009, the USAF reported that UAS rate of mishap was over four times as high as compared to the manned aircraft rate of mishap. This exceedingly high disparity was attributed to many factors, including the physical disconnect between pilot and vehicle, poor air awareness, and rudimentary remote pilot flight training. Ibid., 12.

[51] It will not be easy for the aviation culture to adapt to flying aircraft from the ground as opposed to controlling an aircraft from the cockpit. This may be one of the most difficult hurdles to overcome. Robertson, 16.

[52] It is not difficult to see why many Air Forces have been hesitant to adopt UAS, let alone allowing non-pilots at the controls. With a culture deeply steeped in flying aircraft, there is a natural resistance to the notion of non-pilots operating flying machines. Also, the very idea is a threat to the livelihood of an agency of aviators. Perhaps the greatest challenge will be to accept unmanned capabilities as equals to those provided by manned aircraft.

much less to train a UAS Operator, many arguments have been put forward that only professional air operators can do these jobs. There is also much push back by frustrated winged officers who "did not join the service to fly a keyboard," as one pilot recently put it.

78. Those outside the Air Force are still much more sceptical of unmanned technologies. There has been little integration of unmanned systems into the world of civilian transport, and ever since the Air Qatar accident, there has been very little interest in pursuing this any further.

79. There are also many editorials in the Western press arguing that the 2018 assassination of Ayman al-Zawahiri (al-Qaeda Operations Chief) by a USAF MAV in a northern Pakistan cave actually further alienated the US from the Muslim world. A few academics have even posited that remote control assassinations such as al-Zawahiri's are considered distasteful by most Muslims.[53] Even some traditional allies of the US were quoted as branding these types of assassination as "the way of the coward."

80. After-action analysis of operations overseas revealed that efforts to save our personnel from danger by exploiting the war-fighting capabilities of UAS have had significant and unexpected negative results. Our image as one of the "good guys" on the international stage has been damaged. Canada and most technologically advanced Western nations engaged in operations are now cast as techno-bullies unwilling to face their adversaries in a fair fight with accepted risks.

Take Away – UAS Operations

81. **Finding the right balance.** Generally, the use of UAS is compelling where the need to avoid aircrew casualties is paramount, or the risk of having a manned platform shot down over hostile territory is unacceptable. UAS are well suited where human physiology limits mission execution (e.g. persistence, speed of reaction, contaminated environment), and for the so-called dirty, dumb, dull, and dangerous missions. In some circumstances, however, UAS bring less flexibility due to the length of time needed for mission planning. The near future is unlikely to be one where UAS or manned systems have prevalence over the other. Rather, the future will be a hybrid force that employs the right weapon system for the task in question. For instance, a manned aircraft could act as the mother ship for UAS. In such a case, the human operator would launch multiple wingmen UAS, command and control the swarm, and once the mission is over, allow the surviving UAS to dock back into the mother ship.

82. **UAS are not the panacea to all problems.** Future commanders may increasingly default to UAS in order to solve complicated tactical challenges.[54] Not only will this not guarantee mission success, the dependency on UAS over other aerospace approaches could weaken future air power resolve, attention to detail, and operational and tactical innovation. Analogous to the rise of the cult of the bomb and grenade during the First World War to solve the deadlock of clearing trenches, UAS may provide a short-term fix to tactical problems, but no real long-term solutions to future aerospace operations or strategic success.

[53] P.W. Singer argues that such assassinations may be seen as a sign of America's unwillingness to face death. It can be seen as an "unrespectable" way to fight a war. Singer. *Wired for War*, 307.

[54] The analogy that "when one only has a hammer in the tool box, all problems become nails" is very germane to this line of thought.

83. **UAS as a system of system.** Although UAS might be cheaper than manned aircraft, the UAS system as a whole is not always less expensive. To operate UAS and bring to bear the entire weapon system capability, the personnel manning bill is significant. In the future, UAS operators will be capable of simultaneously flying multiple UAS, partially restoring the advantage in cost to the unmanned system. Note, for example, that while the cost of one Global Hawk (arguably one of the most expensive UAS) is $ 35 million, the overall support system adds another $123 million for each UAS in use.[55]

84. **Aside from MAV, there is no such thing as an expendable UAS.** One of the major UAS challenges will be to balance cost with capability. A significant concern with UAS is the inevitability that the price tag will continue to rise as more sensors and weapons are embodied. The fear is that good designs will incorporate a plethora of expensive electronics that eventually become too expensive to build or too valuable to use (and risk losing) in combat. There are two schools of thought for UAS employment that could help balance cost with capability. One is to field many cheaper, less capable UAS commanded and controlled by robust communications networks. A second school of thought advocates fielding fewer, more expensive and more capable UAS.[56] Again, finding the right balance will be critical.

85. **Autonomy.** With the spectre of intelligent UAS appearing during the next decade, authorizing a machine to make lethal combat decisions is contingent upon political and military leaders resolving legal and ethical questions. These include the appropriateness of machines possessing this ability, under what circumstances it should be employed, where responsibility for mistakes lies, and what limitations should be placed upon the autonomy of such systems. Ethical discussions and policy decisions must take place in the near term in order to guide the development of future UAS capabilities, rather than allowing the development to take its own path apart from this critical guidance.

86. **Proliferation of ISR systems.** Advances in satellite and UAS miniaturization as well as the affordability of ISR systems promise greater acuity, persistence, and reliability. The reduced size and cost of this capability will permit smaller states and non-national entities to acquire and exploit ISR for their own purposes and will require a counter-ISR capability on our part. Lastly, this proliferation of systems means that there will be an increased flow of data which may overwhelm the decision makers. The manpower bill for a substantial Air Force UAS-ISR enterprise could also be heavy. The processing, exploitation, and dissemination of the massive amount of information collected by UAS requires a substantial supporting cast of intelligence analysts and technicians, without whom the raw product cannot be fully exploited.

87. **ISR in northern regions of Canada.** The need for Arctic surveillance will intensify in the years to come. The cost of a persistent and wide-area ISR capability provided solely by manned aircraft is likely to be prohibitive. By 2020, UAS, surveillance satellites, HAA,[57] and other persistent, semi-

[55] Peter W. Singer, "Military Robots and the Laws of War," *The News Atlantis* (Winter 2009), 38.

[56] Robertson, 8.

[57] Note that it is possible that solar powered HAA may not be a possibility due to the high latitude that the HAA would be required to operate over the High Arctic.

autonomous sensors will be highly matured and will likely offer significant cost savings over manned aircraft patrols.

88. **Climatic operating environment.** Currently, UAS have supercritical airfoils which have little aerodynamic tolerance for heavy rain and insect contamination, let alone airframe icing. UAS designs are years away from incorporating airframe anti-icing and de-icing protection. Consequently, it is doubtful that by 2020, a UAS could be reliably operated from a Canadian, let alone a High Arctic airfield, year-round, in a precipitation and icing-rich environment.

89. **Regulations.** There is no doubt that UAS are poised to become a significant component of military and perhaps even commercial and enforcement aviation. The wide range of UAS physical and performance characteristics, many of which will be very unlike any current aircraft, will place additional challenges on an air traffic management system that is already under great strain. Routine and safe entry of UAS operations into civil airspace will require a major paradigm shift which is unlikely to occur by 2020.

Canada is a Northern nation. The North is a fundamental part of our heritage and our national identity, and it is vital to our future.

Honourable Chuck Strahl,
Minister of Indian Affairs and
Northern Development[58]

PART 4 - AIR FORCE OPERATIONS IN THE ARCTIC

90. Three key factors will affect the framework of possible scenarios when it comes to future Air Force involvement in the Arctic. They are:

- **Climate.** The rate of climate change over the next 10 years is subject to significant debate. There is considerable scientific evidence that the Arctic climate will continue to follow a warming trend. There is also a correlation between the level of human activity and temperature. The greater the shift towards warmer temperatures, the more we can expect human activity to increase. Conversely, colder temperatures will temper human activity. Notwithstanding the above, it should be noted that there is a growing body of academic opinion that argues that we are on the verge of a new cooling period as opposed to global warming.
- **Governance.** Governing an extremely vast territory with limited fiscal resources, sparse population, and few developed assets can be an extremely daunting endeavour. With the deadlines for the United Nations Convention on the Laws of the Sea (UNCLOS)[59] fast approaching, Nordic states are staking their Arctic claims, many of which are overlapping. Some analysts are warning of potential confrontation while others are seeing signs of increased cooperation.
- **Resources.** The Arctic not only possesses significant reserves of fossil fuels, it is also rich with large coal deposits and strategic minerals. Extracting these resources can be very expensive and is directly related to the market price of these commodities, the harshness of the environment, and the level and quality of governance of the region.

[58] Canada, Minister of Public Works and Government Services, *Canada's Northern Strategy, Our North, Our Heritage, Our Future* (Ottawa: Public Works, 2009).

[59] The **United Nations Convention on the Law of the Sea** (**UNCLOS**) is an international agreement that defines the rights and responsibilities of nations in their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources. The Convention, which came into force in 1994, has important ramifications for Arctic states. It allows those states to claim the right to harvest mineral and non-living material in the subsoil of its continental shelf beyond the current 200 nautical miles economic zone. Note that once ratified, states have 10 years to file their claims for access and jurisdiction based on geological and other evidence.

91. How these key factors are developed over the next 10 years will shape the future of Air Force operations in the Arctic. Once again, the future best case and worst case scenarios shall now be examined, and future considerations for Air Force operations in the Arctic will be highlighted.

Wild Card: Runaway Global Warming

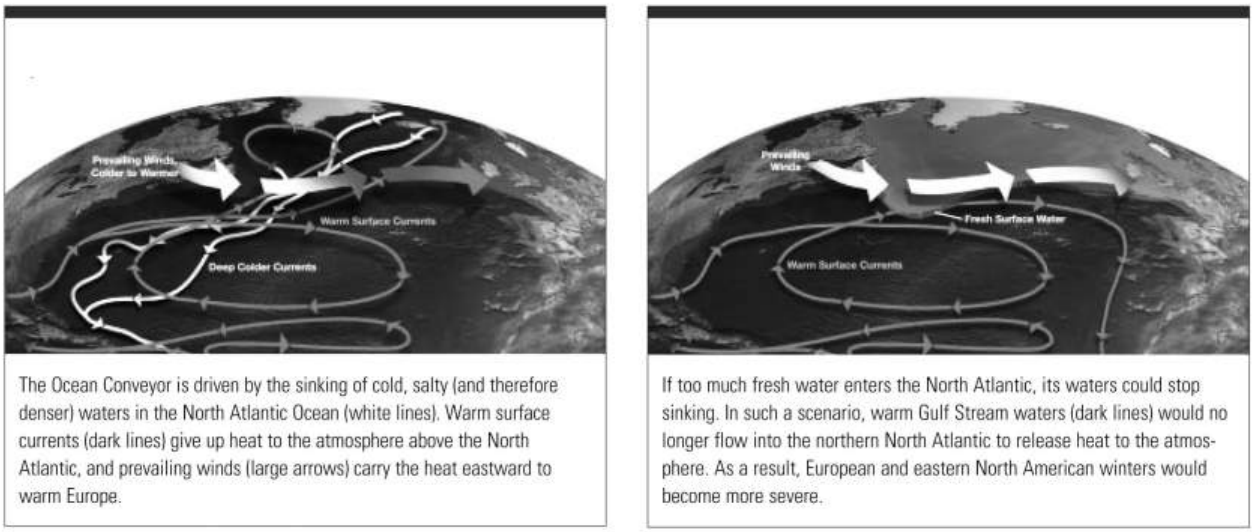
By 2019, following years of record Arctic melting, most scientists are now predicting that within five years, the current trends in global warming will lead to massive permafrost melting. Aside from considerable infrastructure damages, as most buildings, pipelines, roads, rails, and runways are built on permafrost, the release of methane stored in permafrost will cause abrupt and severe global warming as methane is a powerful greenhouse gas. There is enough methane stored in the Arctic permafrost that if only 10 per cent of the stored methane were to be released, it would have an effect equivalent to a factor of 10 increases in atmospheric CO_2 concentrations. Compounding the problem is the fact that methane is 20 times more effective than CO_2 at trapping heat in the atmosphere.

Best Case Scenario – The Arctic Frozen Hinterland

92. **General.** Because the Canadian Forces and the Air Force are likely to continue having limited means to operate in the North, the best case scenario (from an Air Force point of view) would be a scenario where there are few reasons for the Air Force to increase its presence in the North. In such a scenario, the Arctic remains frozen in some sort of economic hinterland where even good governance is not enough to kick-start any sustainable economic development due principally to the harshness of the environment.

93. **Climate.** In 2020, global warming continues to be a highly debated topic. Most scientists now believe that climate changes are occurring unevenly around the globe. While the western shores of North America are warmer and dryer than 20 years ago, its eastern shores are colder and much wetter. In fact, the Eastern Canada winters of 2017 and 2018 have both produced the largest snowfall seasons ever recorded. Many renowned academics are now theorizing that years of global warming have introduced a large amount of fresh water to the North Atlantic, which has disrupted the thermohaline

circulation (THC)[60] of the North Atlantic Drift, also known as the Ocean Conveyor (see figure 10). In 2019, Britain recorded the coldest month of June since 1652. Consequently, many are now forecasting the return to a mini ice-age.[61]



The Ocean Conveyor is driven by the sinking of cold, salty (and therefore denser) waters in the North Atlantic Ocean (white lines). Warm surface currents (dark lines) give up heat to the atmosphere above the North Atlantic, and prevailing winds (large arrows) carry the heat eastward to warm Europe.

If too much fresh water enters the North Atlantic, its waters could stop sinking. In such a scenario, warm Gulf Stream waters (dark lines) would no longer flow into the northern North Atlantic to release heat to the atmosphere. As a result, European and eastern North American winters would become more severe.

Figure 10. The North Atlantic Ocean-Atmosphere System.[62]

94. And so, after several years of warming trends, Canada's Arctic mean temperature has stabilized and has actually started to cool down drastically since the record highs of 2011. The Northwest Passage never really became a practical maritime transport route due to the constant presence of icebergs and unpredictable ice flows. In fact, most commercial companies preferred the relatively safer waters of Russia's Northern Sea Route[63] (see figure 11).

[60] The term **thermohaline circulation** (**THC**) refers to the part of the large-scale ocean circulation that is driven by global density gradients created by surface heat and freshwater fluxes. The adjective thermohaline derives from *thermo-* referring to temperature and *-haline* referring to salt content, factors which together determine the density of sea water.

[61] This is in reference to the climatological era known as the Little Ice Age, a period that began about 1350 CE, in which average wintertime temperatures abruptly turned cooler in the North Atlantic region and persisted that way for roughly 500 years.

[62] Richard F. Pittenger and Robert B. Gagosian, "Global Warming Could Have a Chilling Effect on the Military" *Defense Horizons* Number 33 (October 2003). Available online at http://www.ndu.edu/inss/DefHor/DH33/DH33.pdf (accessed December 17, 2009).

[63] Estimates indicate that the Arctic routes could reduce transportation costs by an average of 40 per cent on key Asian-European routes and cut some key route distances by two-thirds. The simple use of economic data indicates that such reductions imply that Arctic open water could attract up to 80 per cent of the global transportation market.

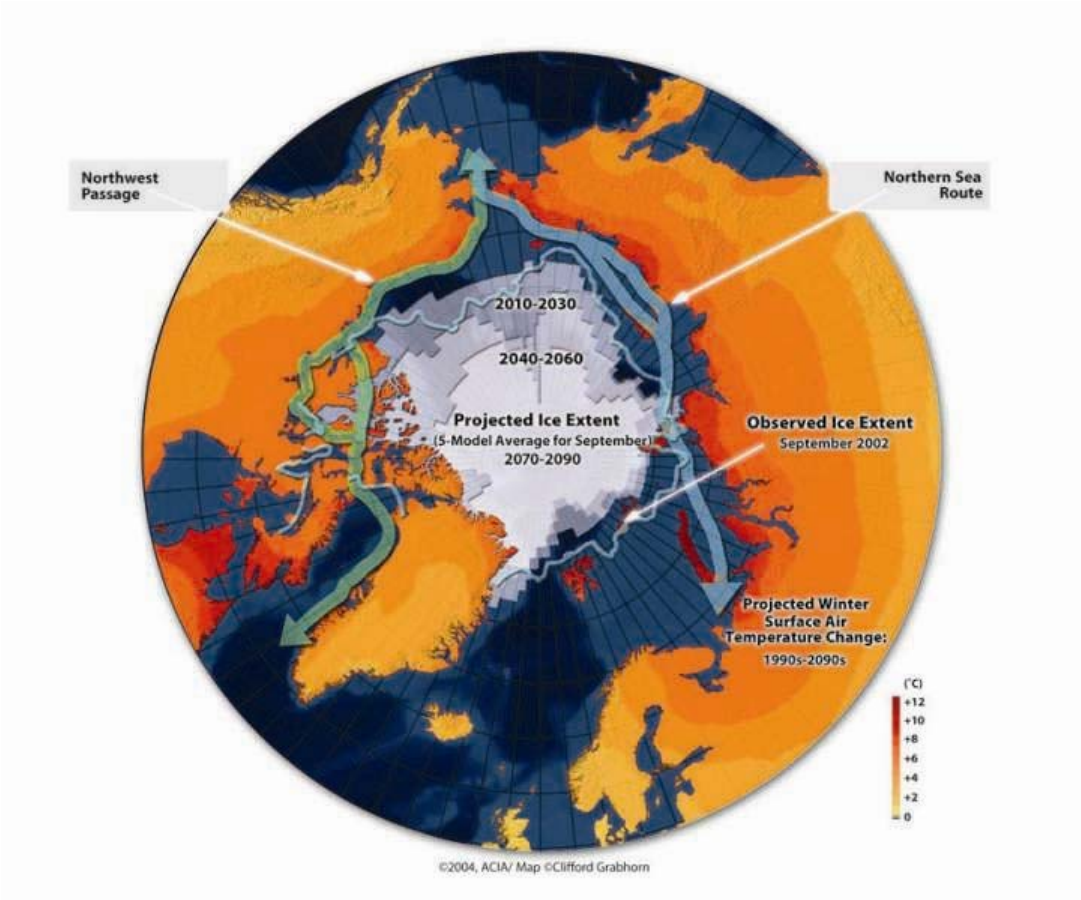


Figure 11. The Northwest Passage and the Northern Sea Routes[64]

95. **Governance.** In this scenario, most ISR in the Arctic is accomplished by space and near-space assets. Aside from routine fishery patrols and the occasional sovereignty patrols, the Air Force has little requirement to deploy in the Arctic. Although the government cancelled its plans to develop the port of Nanisivik in 2011, there are still requirements for the Air Force to support the logistical re-supply of Canadian Forces Station (CFS) Alert and the Canadian Forces Arctic Training Centre in Resolute Bay.

96. Furthermore, the Government of Canada has few reasons to deploy its Air Force north since cooperation by Arctic states has increased significantly in recent years as states realized that there was much more to gain by cooperating instead of competing when it came time to filing their respective UNCLOS claims (See figure 12). In fact, due to the resurgence of particularly harsh winters, the Northwest Passage has been essentially impracticable since 2016. Consequently, there have been very few challenges to our sovereignty, although there have been rumours of under-sea patrols by US, Russian, and Chinese nuclear submarines and unmanned underwater vehicles (UUVs).

[64] ©1994, ACIA, map ©Clifford Grabhorn.

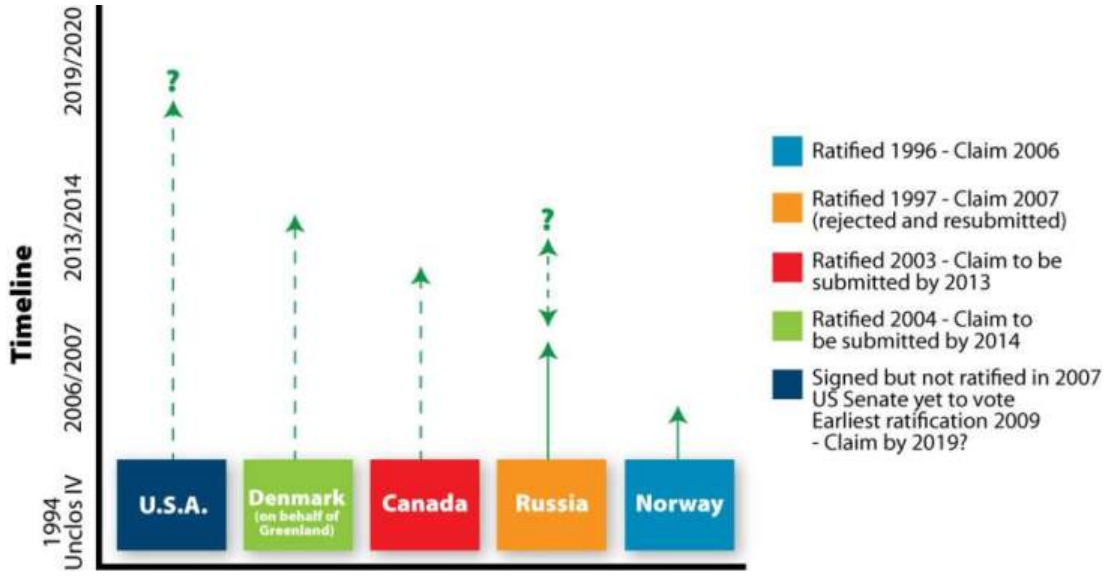


Figure 12. Arctic UNCLOS Timelines[65]

97. Lastly, the region as a whole has declined as a priority for the last few federal governments and has gone back to being almost ignored by an Ottawa that has been preoccupied by more urgent matters. Pressed to balance budgets, the government has invested little to improve the Canadian Forces and Air Force capabilities to operate in the North. In conformity with the lack of commercial development and popular interest in the Arctic, the government has relied on increased space assets as well as long endurance, near-space UAS for surveillance of the Arctic instead of boots on the ground and new aircraft.

98. **Resources.** Although the price of commodities has steadily increased since the end of the Great Recession of 2008, the costs to extract those resources in the Arctic have continued to make them economically unviable. Aside from diamond, gold, and uranium mines (all located near Yellowknife), there has been little commercial appetite to explore and open new mines much farther away. Despite desperate attempts by provincial, territorial, and municipal governments to promote the region for business, the return of extremely harsh weather conditions has hampered any potential development. Even oil, which recently touched $200 per barrel, is still considered too cheap to warrant the staggering costs and difficulty of extracting it from the Arctic.

Worst Case Scenario – Arctic Gold Rush

99. **General.** The worst case scenario from an Air Force point of view is one in which the Air Force is ill prepared to operate in the Arctic. In this alternative future, global warming is making the region more accessible, and a plethora of human activities to include tourism, mining, and criminal activities put enormous strain on the infrastructure and to the governance of the region. Furthermore, Arctic states are not cooperating, and various overlapping claims are creating tensions in this gold rush to Arctic resources.

[65] Data attributed to United Kingdom, *The DCDC Strategic Trends Programme, the Arctic out to 2040*, 52.

100. **Climate.** In 2020, the continuous melting of sea ice that started several decades ago is not showing any signs of reversal. In fact, in September 2019, the extent of the summer Arctic ice cap was at a near-record low, only six per cent greater than the record low of 2017, and 47.6 per cent below the average extent of sea ice from 1980 to 2000. As a consequence of melting Greenland and Arctic glaciers, sea levels around the globe have risen by an average of 3.5 centimetres in the last 15 years, significantly affecting weather patterns in unprecedented ways. The most active hurricane season ever recorded was in 2018, with 32 tropical cyclones formed, of which a record 19 became hurricanes (including the massive category 1 Hurricanes *Erika* and *Michael* that both devastated the Yucatan Peninsula only three months apart).

101. **Governance.** In this scenario, there is minimum (if any) cooperation amongst the Arctic nations and many territorial disputes[66] are taxing the International Courts. In 2016, Russia ceased to participate in Arctic Council[67] affairs to protest against North Atlantic Treaty Organization (NATO) threats of retaliation after the Svalbard[68] Crisis earlier that year. In fact, military analysts are now referring to the current crisis between Russia and the West as Cold War II. NORAD assets (especially Canadian assets) are constantly being tested by Russian manned and unmanned vehicles. As well, numerous Russian submarines and nuclear powered icebreakers have been violating Canadian and American territorial waters. In 2017, a Canadian Arctic surveillance UAS took pictures of an artificial iceberg just north of Inuvik with what appeared to be an encampment of Russian scientists. In the time it took NORAD to despatch several aircraft to investigate, the mysterious iceberg and its occupants had vanished.

102. Virtually ice-free since the summer of 2016, the Northwest Passage is fast becoming a preferred shipping route between Asia and Europe. Even though the Canadian government has declared the Northwest Passage part of our territorial waters, with very little capability to enforce our sovereignty, it is not uncommon to find American, Asian, and European vessels operating within the Canadian Arctic Archipelago. In 2016, a Polish tanker hit a small iceberg and spilled millions of litres of crude oil into Baffin Bay. Canada was severely criticized by the international press (and especially by Danish politicians) for its inability to respond to the emergency. Consequently, most of the oil spill washed out onto the western shores of Greenland. In 2018, a German tourist died as a result of an accident near

[66] Canada is currently disputing sovereignty over Hans Island with Denmark, and the ownership of the undersea Lomonosov Ridge with Russia and Denmark, as well as the location of its maritime boundary in the Beaufort Sea with the US, and the status of the Northwest Passage with the international community. These disputes will not be easily resolved and are expected to continue over the next decade. See also note 73.

[67] The **Arctic Council** is an Intergovernmental forum for Arctic governments and people. The member states are: Canada, Denmark, Finland, Iceland, Norway, Sweden, Russia, and the US.

[68] The **Spitsbergen Treaty** (which came into force in 1925) recognizes the full and absolute sovereignty of Norway over the Arctic archipelago of Spitsbergen (now called Svalbard). There has been a long-running dispute, primarily between Norway and the Soviet Union (and now Russia) over fishing rights in the region. Note that Norway also claims that the archipelago is a part of mainland Norway's continental shelf, a position that Russia is also disputing.

Cambridge Bay on board a small cruise ship. Again, the government was embarrassed as SAR assets took well over 30 hours to respond to the emergency.[69]

103. The Russian mafia is also widely rumoured to be trafficking Canadian diamonds using mini-unmanned submarines and aircraft. Organized crime may also be involved in the illegal traffic of oil by tapping into pipelines on-shore and off-shore in the Beaufort Sea. In 2015, the American government formally called on the Canadian government to do more to stop the flow of illegal immigrants and Russian criminals into Alaska.[70]

104. **Resources.** Warmer climates are highly favourable to human activity, and by 2020 the Arctic is booming with activities ranging from exploration and tourism to fishing and mining. Accelerated by the impact of global warming and unprecedented high commodity prices, we are witnessing a "no-holds-barred" rush among nations for oil, fish, diamonds, and access to shipping routes.[71] As peak oil occurred earlier than expected in 2012, oil companies are now furiously engaged in active competition to secure rights to lucrative petroleum and natural gas reserves below the sea floor (see figure 13). Unfortunately, in their rush to extract the oil, many have shown a complete disregard for Canadian laws and environmental concerns. Due to its limited capabilities, Canada has been unable to enforce meaningful sanctions. Many fish stocks are also showing grave signs of stress due to overfishing and resource mismanagement. By 2016, stocks of Arctic Char have been depleted so much that it is doubtful that the specie will be able to support commercial fishing activities again.

[69] SAR in the Arctic is a grave concern for the Air Force as the region is lacking even the most basic infrastructure of road networks, airfields, staging/supply bases, or medical facilities. The potential for a major air disaster in the High Arctic is far more likely now and in the future than at any time in the past. More than 100,000 people fly over the Canadian Arctic each day on high-latitude routes to Europe and Asia. Because a sparse population creates a statistically low risk, it would be inefficient to locate SAR assets in the Arctic, but in case of a Major Air Disaster (MAJAID), it would take at least six hours for a Hercules aircraft based in Southern Canada to reach the Arctic, and much longer for helicopters (even if they were shipped by C17).

[70] The former US ambassador to Canada, Paul Celluci, has warned that terrorists might use an ice-free Northwest Passage to traffic in weapons of mass destruction. See Michael Byers, "Wanted: Mid-sized Icebreakers, Long-range Choppers, Perspective" *Globe and Mail* (12 June 2009).

[71] Unexploited resources in the Arctic account for about 22 per cent of the undiscovered, technically recoverable resources in the world. It accounts for about 13 per cent of the undiscovered oil, 30 per cent of the undiscovered natural gas, and 20 per cent of the undiscovered natural gas liquids in the world. About 84 per cent of the estimated resources are expected to occur offshore. Continued warming of the Arctic implies that the accessibility and profitability of these resources will increase significantly. See United States Geological Survey "90 Billion Barrels of Oil and 1,670 Trillion Cubic Feet of Natural Gas Assessed in the Arctic." Available online at http://www.usgs.gov/newsroom/article.asp?ID=1980 (accessed January 14, 2010).

Figure 13. Main Areas of Hydrocarbon Reserves in the Arctic[72]

105. UNCLOS has reached an impasse as almost every single Arctic nation filed overlapping and conflicting claims. Note that claims in the Arctic already overlap even as many countries have yet to establish their official position on claimed areas (see figure 14). Furthermore, Canada, Denmark, and Russia have all used the outer edge of ice formations in drawing their Arctic baselines. As ice recedes, revealing new coastal geography, questions over the legitimacy of existing baselines will add further complexity to claims over seaward jurisdiction.[73]

106. By 2020, most nations have filed appeals with the International Court and it will be many years before any rulings are expected. Meanwhile, the Russian Navy and the U.S. Navy have deployed large task forces in the contested zone in the Beaufort Sea near the Lomonosov Ridge[74] even though the contested zone straddles into mostly Canadian waters.

[72] Philippe Rekacewicz and Hugo Ahlenius, UNEP/Grid-Arendal. Available online at http://maps.grida.no/go/graphic/fossil-fuel-resources-and-oil-and-gas-production-in-the-arctic (accessed March 30, 2010).

[73] United Kingdom, *The DCDC Global Strategic Trends Programme 2007-2036*, 51.

[74] The **Lomonosov Ridge** is an unusual underwater ridge of continental crust in the Arctic Ocean. It spans 1,800 km from the New Siberian Islands over the central part of the ocean to Ellesmere Island of the Canadian Arctic islands. As part

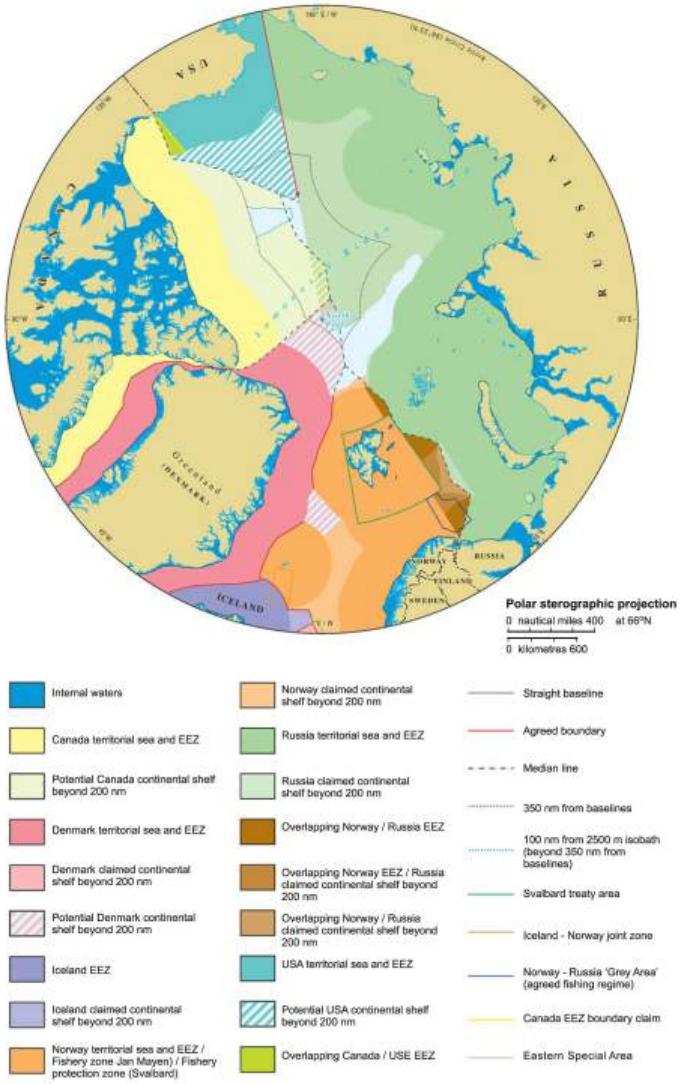


Figure 14. Claims of Ownership Map[75]

Take Away – Air Force Operations in the Arctic

107. **Climate change.** On the one hand, climate change will dictate Air Force involvement in the Arctic, as a warmer climate will translate into increased activities in the North. On the other hand, a

of their respective UNCLOS submissions, Russia claims that the Lomonosov Ridge is an extension of the Eurasian continent. Canada asserts that the ridge is an extension of its continental shelf. Danish scientists also hope to prove that the ridge is an extension of Greenland, which would make Denmark another claimant to the area. See also note 65.

[75] International Boundaries Research Unit, Durham University, United Kingdom. Available online at http://www.dur.ac.uk/ibru/resources/arctic (accessed March 30, 2010).

harsher climate may reduce human activities, but it will increase the difficulties to operate in that region should the Air Force be required to deploy into the Arctic.

108. **Arctic surveillance.** Upwards of 50 per cent of the world's undiscovered resources are estimated to lie in the Arctic. Should the Arctic experience an economic boom as a result of resource exploration and extraction, then governance, policing, and surveillance will be challenging given the sheer size of the region. As costly as this task will be, it will remain essential for the Air Force to consider the best possible options from HAA to tethered aerostats, UAS, and satellites. Note that, should a threat be detected, securing our remote Arctic border will be a monumental task.

109. **SAR requirement.** The Air Force will need to develop a more agile and robust response to SAR incidents in the Arctic. At the moment, SAR response time and capabilities in northern regions remain problematic. Clearly, increased permanent presence and economic activities in the Arctic as well as expanding trans-polar air routes will ultimately require greater SAR resources in the North and greater, Arctic hardened air mobility support. A permanent SAR capability may even become a future requirement.

110. **Increased requirement for Arctic operations.** The government's proposed Canadian Forces Arctic Training Centre in Resolute Bay is expected to house approximately 100 full-time personnel. It is logical to assume that the level of Air Force effort to sustain and support the new CFATC will be more or less on par with that of CFS Alert.[76] Likewise, the deepwater seaport at Nanisivik will require some level of airlift to sustain operations at the new base, albeit at a lesser level.

111. **Potential for conflicts.** Mineral extraction and shipping will likely be a source of tension and dispute in the future. New shipping routes may also reshape the global transport system. While these developments offer opportunities for growth, they are also potential sources of competition and conflict for access and natural resources. Currently, the CF has few capabilities to project hard power in our High Arctic. For the Air Force and Navy, and to a lesser degree the Army, the High Arctic may become a permanent theatre of deployment located at strategic range.

112. **CFAWC Arctic War Game.** In October 2009, CFAWC hosted a tabletop exercise to war-game the two alternative future Arctic scenarios described above. The tabletop war game was designed to use *Game Theory* as developed by Neumann and Morgenstern.[77] The results are presented in Annex A to this document.

[76] CFS Alert is the most northern permanently inhabited settlement in the world. It is situated on the northeastern tip of Ellesmere Island in the Canadian Arctic Archipelago. In 2008, CFS Alert housed approximately 70 full-time personnel. Twice a year, the station receives major replenishments. Operation BOXTOP is the name given to the biannual resupply of CFS Alert. Using USAF Base Thule in Greenland as a staging point, for two to three weeks every spring and fall, the Air Force operates day and night to fly fuel and supplies to the station. In the past several years, a typical BOXTOP operation moved over 950,000 pounds of freight and more than 305,000 imperial gallons of fuel into CFS Alert. To accomplish this level of activity, four CC130s, one CC150, and one CC177 aircraft flew in total more than 500 hours and moved more than 130 chalks of freight. In addition, CC130 aircraft regularly fly into and out of CFS Alert (approximately every week) to transport perishable supplies. These flights originate from 8 Wing Trenton, and they contain food, medical supplies, and CF personnel rotating through CFS Alert.

[77] Owen Guillermo, *Game Theory* (Philadelphia: W.B. Saunders Company, 1968).

CONCLUSION

113. The aim of this paper was to conduct an alternative futures analysis of four prominent future security trends that will be critical to Canada's Air Force in 2020. For each of the four trends, key factors were identified, and two scenarios were designed. These scenarios were built by taking the key factors to the extremes of what is deemed possible and arranging them in such a way as to produce a best- and worst-case scenario from the perspective of the Air Force. Note that neither of these scenarios is more likely than the other. In fact, a more probable scenario would likely fall somewhere between these two extremes. What is required now is to delve further into the analysis of these scenarios in order to deduce required Air Force capabilities and structure if these extreme cases were to come to pass.

114. The most significant findings are briefly summarized below.

Force Generation Issues:

115. Over the next 10 years, recruiting, training and retaining will become a serious challenge. Demographic trends indicate that novel strategies and methods for recruiting may have to be employed. The challenges associated with the changing nature of potential recruits in 2020 will be significant. Flexible enrolment plans as well as frequent, short-term contracts that do not attract long-term benefits may become the norm. In addition to updating policies, the Air Force will need to do better when reaching out to minority groups and especially women.

116. Efficient, relevant, and fast evolving training methods will also be required. As the pace of technological advance continues to accelerate, it will be challenging to produce and retain skilled individuals able to operate and manage both legacy and emerging systems. It is likely that by 2020, most training activities will be outsourced to private companies. Lastly, it is becoming obvious that the current CRA policy will need further modernization.

117. The Air Force must do more to appeal to visible minorities and women. Strategies must be broad-based and reach all elements of Canadian society. As competition increases in a dwindling labour pool and an increasingly immigrant-dependant population base, novel yet security-conscious approaches to recruiting will need to be adopted. Renewed efforts will be required in order to entice more women to join the CF and the Air Force.

118. The Air Force needs efficient, relevant, and fast evolving training. As the pace of technological advance continues to accelerate, it will be challenging to produce and retain skilled individuals able to operate and manage both legacy and emerging systems. Cooperative approaches with learning institutions and industry are likely to yield considerable mutual benefits. In fact, by 2020, most training activities should be outsourced to private companies.

Future of Simulators and Training:

119. In the future, the cost of flying operations is likely to be extremely expensive. Consequently, it will be particularly difficult for the Air Force to justify extensive hours of routine training. Due to forecasted exponential advances in computers, simulators will soon provide awesome display and sensorial effects. As such, simulators are poised to become an affordable alternative to replace a majority of the ab initio training curriculum as well as some recurrent training. Even at today's relatively cheap fuel prices, operating a simulator is far less expensive than actual flying. By 2020, this ratio will likely be even more tilted in favour of simulation.

120. Simulation provides not only real cost benefit but also operational advantages, such as the ability to simulate a hybrid reality, which will allow crews to operate under all weather conditions. Furthermore, complex missions, such as inserting an SOF squad at night in the middle of a foreign city, could be accurately simulated and rehearsed in a high fidelity environment.

Unmanned Aerial Systems Operations:

121. In general terms, the use of UAS is compelling where the need to avoid aircrew casualties is paramount, or the risk of having a manned platform shot down over hostile territory is unacceptable. UAS offer greater persistence over the operating area, and favour missions which fall into the dull, dirty, and dangerous category. UAS, however, are not the panacea to all problems. In fact, the Air Force of the near future is likely to be a hybrid force that employs the right weapon system for the task in question. Having said that, how best to utilize UAS vehicles is still a topic of debate. Although UAS might be cheaper than a manned aircraft, the UAS system as a whole is not always less expensive, and aside from a micro air vehicle, there is no such thing as an expendable UAS.

122. In the future, UAS will likely acquire greater autonomy, but first, political and military leaders will need to resolve the legal and ethical questions surrounding the autonomy of a military machine. Furthermore, as UAS become more prevalent, the question of integration into the commercial air traffic management system will also need to be tackled.

123. The need for Arctic surveillance will intensify in the years to come. The cost of a persistent and wide-area ISR capability provided solely by manned aircraft is likely to be prohibitive. By 2020, UAS, surveillance satellites, high altitude airships, and other persistent, semi-autonomous sensors will be highly matured and will likely offer significant cost savings over manned aircraft patrols.

Air Force Operations in the Arctic:

124. Climate change will dictate Air Force involvement in the Arctic. On the one hand, a warmer climate will translate into increased activities in the North. On the other hand, a harsher climate may reduce human activities, but it will increase the operational difficulties. It should be noted that, no matter what, upwards of 50 per cent of the world's undiscovered resources are estimated to lie in the Arctic. Should the Arctic experience an economic boom as a result of resource exploration and extraction, then governance, policing, and surveillance will be challenging given the sheer size of the region.

125. Since there is a high probability of increased activity, the Air Force will need to develop a more agile and robust response to SAR incidents in the Arctic. At the moment, SAR response time and capabilities in northern regions remain problematic, which may lead to the need for a permanent SAR capability.

126. Mineral extraction and shipping as well as UNCLOS claims will likely be a source of tension and dispute in the future. New shipping routes may also reshape the global transport system. While these developments offer opportunities for growth, they are also potential sources of competition and conflict for access and natural resources. Currently, the CF has few capabilities to project hard power in our High Arctic, a situation that also will likely have to change.

*** * ***

ANNEX A

CFAWC Arctic Strategic War Game

By Dr. Andrew Billyard

Introduction

In October 2009, CFAWC hosted a tabletop exercise[78] to war-game the two alternative future Arctic scenarios detailed in Part 4. The tabletop war game was designed to use Game Theory as developed by Neumann and Morgenstern. The results are presented in this Annex.

The following table captures the scenario themes for each of the key determining factors:

Key determining factors:	**Best Case scenario:** **Frozen hinterland**	**Worst Case scenario:** **Gold rush**
Climate	Mini-ice age	Increased global warming
Governance	Good governance, cooperation	Competition and confrontation
Resources	Lack of economic development	Rapid exploitation, pollution, organized crime

Table A 1. Key Determining Factors

Game Theory

For the war gaming exercise, *n*-person non-cooperative Game Theory was chosen as the multi-criteria decision support tool. Although a detailed discussion on Game Theory can easily fill an entire textbook, a brief outline of *n*-person non-cooperative Game Theory is summarized here. A game in the broad sense is the participation of two or more players in a defined scenario. Each player has one or more strategic actions that they will try to accomplish in order to satisfy their strategic goal. In Game Theory,

[78] The Participants were Dr. Andrew Billyard, Mrs. Irene Collin, Ms. Heather Hrychuk, LCol Dan Lachance, and Maj Tim Gushue.

all possible combinations of player actions are created and for every combination a score for each player is determined to reflect the preference of combinations from each player's perspective. For example, if there are three players and each player has four courses of action, then three sets of scores are created for the entire 4x4x4=64 combination set (one set of scores for each player).

The next step is to use these scores to assess the best course of action for a particular player when facing a certain combination of actions by the other players; the highest score within that subset indicates that player's best COA. For instance (carrying on with the example above), consider a specific action of player 2 combined with that of player 3. What is player 1's best COA against the combined actions of the other players? Because a scoring scheme for player 1 has already been completed for the entire 64 combinations, one simply looks for instances of this particular player 2 – player 3 combination within the larger list (there will be four of them since player 1 has four COA) and the highest score will represent player 1's best COA for that combination. It is considered the best (for that combination) because any other choice is at a lower score for player 1.

Finally, once the preferred COAs for each player against each combination of the other players' actions have been computed, one looks for Nash equilibrium.[79] These are the specific COA combinations in which each player's COA is the player's *best* COA. Simply put, in the equilibrium combination, any player would have to choose a less preferred action (lower score) to get out of that equilibrium.

It is important to understand what the equilibrium points represent. They do *not* represent the inevitable end-state of the game. What they represent is the state to which players will naturally tend towards due to their own selected preferences. Hence, Game Theory provides a way of estimating the consequence of players' preferences.

In this war game, there are three players: the Air Force, the Adversary (described below), and the Government. It is assumed that the three players are non-cooperative. This may appear too constraining considering that two players, the Air Force and the Government, would typically work in concert. However, the non-cooperation rule does reflect the disparity often seen in reality; this rule allows the Government in the game to act in ways contrary to the good of the Air Force and vice versa. An example would be for the Government to decrease Arctic funding when existing legislation may insist the Air Force maintain its current Arctic capabilities (status quo). Hence, the two are at odds; the strategic COA to maintain status quo for the Air Force is at odds with the Government's COA to reduce Arctic funding.

[79] In game theory, **Nash equilibrium** (named after John Forbes Nash, who proposed it) is a solution concept of a game involving two or more players, in which each player is assumed to know the equilibrium strategies of the other players, and no player has anything to gain by changing only his or her own strategy unilaterally.

Best Case Scenario

Scenario Particulars

In the best case scenario, the Arctic will be an area of decreased activity, articulated as a Frozen Hinterland. In this scenario, the Arctic climate remains very cold, with the potential for decreasing temperatures. Some research has even suggested a return to a mini-ice age, and since the Canadian Arctic's mean temperature has stabilized and begun to cool, this appears to be a plausible forecast. Given this climate, the Northwest Passage does not become a practical transport route, and very few challenges to Canadian sovereignty have occurred. Good governance and cooperation prevail, and accordingly, the Government has few reasons to deploy the Air Force in the North. Most Arctic ISR is accomplished by space and near-space assets; however, these requirements on the whole have been decreasing. While interest in Northern commodities such as oil and gas are still prevalent, the costs to extract them from a frozen Arctic have made extraction economically unfeasible. Costs, coupled with the harsh weather conditions, have resulted in a lack of economic development.

Variables

To apply game theory to this scenario, two players, each with a range of actions available to them, were determined: the Air Force and the Canadian Government. Unlike the worst case scenario (to follow), the particulars of this scenario do not result in the need for a third player. However, it is understood that adversaries may exist, but their only credible threat would be to build Arctic capabilities in their own sovereign state in anticipation of exploiting the Arctic (which leads the Government player to continue to engage in diplomatic talks; see below). As such, the game is two-dimensional in nature and lends itself easily to showing how the game theory was implemented.

Each player was then assigned realistic COAs in accordance with the details of the scenario. For the Air Force the first COA was to *Maintain the Status Quo*. In this case, the Air Force maintains the level of effort it currently devotes to its Arctic areas of interest, missions, and capabilities. The second COA was to *Decrease Situational Awareness*. The Air Force decreases its surveillance capabilities; whereas, information is collected to increase situational awareness, analysis does not necessarily occur to increase situational understanding. The decrease may entail the Air Force divesting itself of equipment or simply not undertaking as many missions as it has previously. In the third COA, the Air Force actually *Decrease Presence* in the Arctic. This COA includes decreasing a variety of possible options, such as sovereignty patrols or overt surveillance capabilities. Finally, for *Decrease Force Application*, the Air Force either divests itself of its Arctic force application capabilities, such as interception capabilities, or decreases the number of force application missions it undertakes.

Similarly, the Canadian Government in the game has been assigned three COAs. For the first of these COAs, *Maintain the Status Quo*, the Government's policies, actions, activities, and funding in the Arctic remain consistent with those of 2010.[80] For the COA *Decrease Arctic Funding*, the Government places less emphasis on the North, and, accordingly, has decreased funding. This could entail more limited

[80] Relative to other federal expenditures. This is not saying that the current dollar value for Arctic funding will be the same used in 2020.

military capabilities (not necessarily Air Force capabilities) or decreased funding and emphasis placed upon Northern inhabitation, as well as social and economic development. Lastly, for *Exercise Diplomacy*, the Government continues to engage in the international arena to resolve disputes. It should be noted that this COA does not achieve a specific goal of redefining boundaries. Rather, the Canadian Government is in the process of making diplomatic overtures, the outcome of which is not necessarily known. This COA is used to reflect the fact that if any adversaries were building Northern capabilities (e.g., Arctic mining capabilities) in their own sovereign state, they are not a direct threat to Canadian sovereignty, but would be the impetus for the Canadian Government to engage in the international arena to ensure that legal boundaries are set.

Scoring System

For this scenario, there are only 12 unique combinations of Air Force and Government COA; such a small number allows one to easily keep track of and validate the preferences of each player. As such, the scoring system was a simple scale of integers from -3 (worst) to 3 (best), 0 being neutral:

3 best (Best Case)	2 better	1 good	0 neutral	-1 bad	-2 worse	-3 worst (Worst Case)

Table A 2. Best Case Scenario Scoring System

For the Air Force, the best case would be characterized by the retention of capabilities that are relevant to the security environment or by the divestiture of those capabilities that are not required. Alternatively, the worst case would be characterized by decreasing those relevant capabilities or by retaining those which are not required considering the Arctic security environment. For the Government, the best case would be characterized as that in which the Government's response is the most appropriate in light of both the scenario and the other player's COA. This may mean decreasing Arctic funding in some situations, or engaging in diplomacy in others. The worst case scenario would be that in which the Government's response does not adequately meet the challenge posed by the scenario, or where the Government's response is too great. For example, in a case in which the Air Force maintains the status quo, it would be more preferential for the Government to decrease Arctic funding, therefore resulting in the Government being given a score of +2. The reasoning is that, in this scenario, engaging in diplomacy is unwarranted and maintaining the status quo entails unnecessary funds being spent. By comparing with the alternatives, the Government's preference would be to decrease Arctic funding.

Table A 3. *Results Matrix for the Best Case Scenario*

This depicts the game theory results for the Best Case Scenario. Each cell contains two numbers: the first is the Air Force's preference for this combination of actions, and the second is the Government's preference. For example, the first cell contains (1, -1), meaning that the Air Force would consider it good (+1) that the Air Force maintains Status Quo whilst the Government maintains Status Quo; whereas, the Government would consider this combination bad (-1). Light circles and dashes are shown to help aid the reader in demonstrating how the most preferred COA for each player (bold numbers in table) is determined against each combined COA of its opponents.

Note that the only blue cell in this table represents the only Nash equilibrium; this is the combination of Air Force decreasing force application capabilities while the Government pursues diplomacy. This example shows clearly why this is an equilibrium point. The Air Force preference is high for this option (+3) as is the Government's, albeit to a lesser extent (+1). However, for the Government's *Pursue Diplomacy* action, the Air Force would have a lesser score if it chooses any other COA for itself. Similarly, for the Air Force's *Decreased Force Application Capabilities*, the Government would have a lesser score if it chose any other COA for itself.

In order to demonstrate how this is an equilibrium point, consider the following. Suppose at some point in time the Air Force and Government are maintaining Status Quo (top left cell). If the Government chooses to change its COA, it would (in the table) move horizontally from "Status Quo" to "Decrease Arctic Funding" since it is preferable for the Government (scores a "+2" rather than Status Quo's "-1"). The situation is now the top middle cell. At this point, the Air Force would change its COA to "Decrease Presence" (+3) since that would be preferable to "Status Quo" (-1). Consequently, the scenario has moved to the second-last cell in the middle column. At this point, the Government would change its COA to "Diplomacy" since it is now preferable (+1) to "Decrease Arctic Funding" (-1), and so the scenario moves to the second last cell in the right-most column. Finally, the Air Force would change its COA to the preferable "Decrease Force Application Capabilities" (+3), and the scenario moves to the blue Nash equilibrium. At this point, neither player can move to a more preferable COA. The only way that they can do so is to move to a less preferable option and hope that the other player changes their COA. However, for this scenario, there is only one equilibrium; *regardless* of where they start in the table, if both players keep changing their COA to a more preferable one, they will inevitably end up in the blue cell of this table.

	Government: Maintain Status Quo	Government: Decrease Arctic Funding	Government: Pursue Diplomacy
AF: Maintain Status Quo	(1, -1)	(-1, **2**)	(0, 1)
AF: Decrease Sit. Aware. Capabilities	(-1, -2)	(-2, -1)	(1, 1)
AF: Decrease Presence Capabilities	(**3**, -2)	(**3**, -1)	(2, **1**)
AF: Decrease Force Application Capabilities	(2, -2)	(2, -1)	(**3**, **1**)

Legend:

Number pairs (x, y) represent the ranking preference of the Air Force and Government, respectively, for each combined COA.

Bold numbers indicate the player's most preferred COA in regards to the other player's COA. The direction of comparison for each (x, y) is indicated in this figure by dashed circles and lines

Blue cells represent the Nash equilibrium – either player would have to choose a less preferable COA to get out of this equilibrium

Table A 3. Results Matrix for the Best Case Scenario

Worst Case Scenario

Scenario Particulars
In the worst case scenario, the Arctic will be an area of increased activity, articulated as the Arctic Gold Rush. This scenario is characterized by increased global warming, which has led to continuous melting of sea ice and rising sea levels. In turn, the Arctic areas once deemed impassable are now appealing routes for international shipping, along with various illegal activities such as human trafficking. While the Canadian Government continually declares the Northwest Passage to be within its territorial waters, its limited capability to enforce its sovereignty has resulted in frequent intrusions into this sovereign territory. Cooperation between Arctic nations is limited, while tensions between Russia and the West over Arctic territory have developed into a serious crisis, referred to as Cold War II. NORAD assets are constantly tested by Russian manned and unmanned vehicles, while submarines and nuclear-powered icebreakers have violated Canada's territorial waters. Further, the warmer climate has increased human activities related to mineral and oil exploration, fishing, and tourism. Unfortunately, in their rush to extract oil and other lucrative resources, many corporations have shown complete disregard for Canadian laws and environmental concerns.

Variables
To apply game theory to this scenario, three players, in no particular order, each with a range of actions available to them, were determined: the Air Force, the Adversary (who could be a competing nation or a non-state entity such as a criminal organization or corporation) and the Canadian Government. While the environment has a large role to play in influencing the range of actions available to these players, it was not included as an independent actor, since although it may undertake various COAs, it does not exhibit any preferences of action, unlike the other actors.

Each player was then assigned four realistic COAs given the details of the scenario. In the case of the Air Force the first COA is *Maintain Status Quo*. Here, the Air Force maintains the level of effort it currently devotes to its Arctic areas of interest, missions, and capabilities. The second COA available to the Air Force is *Increase Situational Awareness.* In this case, the Air Force's surveillance capabilities are increased; however, this is limited to covert surveillance. Information is collected to increase situational awareness, although analysis does not necessarily occur to increase situational understanding. This increase may entail the acquisition of new equipment to provide increased capabilities or the deployment of current equipment on more missions to increase the capability. *Increase Presence* is the third Air Force COA. This COA includes a variety of possible options, such as increased sovereignty patrols, overt surveillance capabilities, or the establishment of an Air Force base in the North. However, these capabilities are limited in that they demonstrate an Air Force presence without interception or escort capacities. Finally, the fourth COA available to the Air Force is *Increase Interception and Engagement*. Here the Air Force increases its capabilities to intercept and engage with other actors (military or civilian) in the Arctic or it enhances its current capabilities. This is not limited solely to escort capabilities, but also includes kinetic capabilities.

The Adversary was also assigned a range of actions that it might undertake in the worst case Arctic scenario. The first of these is described as *Encroach on/Exploit Canadian Territory*. In this COA, non-state or state-sponsored actors encroach on Canadian territory or waterways to exploit resources, or utilize territory or waterways for transit during illicit activities. Non-state actors could be Canadian

nationals acting outside Canada's interests, or civilians from other nations. The second COA available to the Adversary is *Respect International Treaties Due to Canadian Actions*. Here, other nation states or non-state actors respect Canadian sovereignty, despite their Northern interests, due to the actions of the Air Force or Canadian Government. It assumes that others want to encroach on Canadian territory, but their freedom of action is constrained due to Canadian activities. The third COA entails *Legally Redefine Political Boundaries* (in the Adversary's Favour). In this case, other nation states attempt to end territorial disputes through international dialogue and are in the process of successfully redefining political boundaries in alignment with their desires. The final COA available to the Adversary is *Increase Northern Capabilities*. In this COA, other nations (whether they are friendly or hostile) are engaged in the building of military and non-military Arctic capabilities.

Like the Air Force and the Adversary, the Canadian Government has been assigned a range of actions that it may undertake. The first of these COAs is *Maintain the Status Quo*. Here the Government's policies, actions, activities, and funding in the Arctic remain consistent with those of 2010. The second COA available to the Government is *Threaten Actions/Posturing*, in which the Government increases its position in relation to the Adversary's activities. While this could be political posturing (rhetoric), it can also include increasing Arctic patrols or basing as well as funding military Arctic capabilities. These could be single service or joint capabilities, but are not necessarily Air Force capabilities. The third Government COA is *Increase Treaty Dialogue*. In this situation the Government increases its engagement in international dialogue as an attempt to resolve territorial disputes. It should be noted that unlike the Adversary's third COA, this COA is not defined as achieving a specific goal of redefining boundaries. Rather the Canadian Government is in the process of making diplomatic overtures, the outcome of which is not determined. The final COA available to the Government is *Increase Northern Immigration and Development*. In this situation, the Government is placing greater emphasis on and funding towards Northern inhabitation, and social and economic development. These developments are not related to military assets.

Scoring System

For this scenario, there are 64 unique combinations of Air Force, Adversary, and Government COAs. Therefore, the simple "worst" to "best" scoring scheme used in the previous scenario would prove to be hard to manage. For instance, there could be many combinations which the Air Force would consider "better", but some "better" could mean different things to different combinations. Effectively, one would have to do a pair-wise comparison of all the combinations to determine if one is better, the same, or worse than the other. This would entail 64x63=4,032 pair-wise comparisons for each player, which is unmanageable in a one-day workshop. Instead, it was determined that for each player a unique meaning would be assigned to the integer scores. Consequently, each combination could be assigned a score based on a logical argument, independent of how the other combinations scored. Descriptions of the scores, as applied to each player, are as follows:

Air Force

A positive ranking for the Air Force indicates that the situation is in its preference, achieving a favourable or desirable mission outcome. However, some situations, such as those with no or limited cost increases, are more desirable than others. For example, in a situation in which the Adversary respects international treaties and the Government maintains the Status Quo, the tabletop exercise

determined that it is preferable for the Air Force to have increased surveillance than to have increased interception. Whereas, both COAs achieve the desired result (the Adversary respecting Canadian sovereignty), the costs associated with increased surveillance (both in terms of level of effort and monetary costs) are limited when compared to those associated with increased interception. Further, increased interception capabilities are unnecessary when the Adversary respects the sovereign territory.

A negative value for a ranking implies that the situation does not achieve an outcome which is favourable to the Air Force. For example, in a situation in which the Adversary is encroaching on Canadian borders or exploiting Canadian resources, despite the Air Force's increased interception capabilities and the Government's increased diplomacy, the Air Force would receive a rank of -3. This is due to the fact that the Air Force's actions do not achieve a favourable mission outcome (forcing the encroachment to cease) at a large cost (the Adversary continues to engage in these actions despite the Air Force's increased capability). Therefore, such a situation would not be in the Air Force's favour. Table 3 below summarizes the Air Force COAs.

+4	Achieving mission/desired outcome without any increased costs, very appropriate capability increase given circumstances
+3	Increased surveillance/situational awareness, achieves favourable/desired mission outcome, limited costs, very appropriate capability increase given circumstances
+2	Increased presence, achieves favourable/desired mission outcome, medium costs, very appropriate capability increase given circumstances
+1	Increased interception, achieves favourable/desired mission outcome, large costs, appropriate capability increase given circumstances
0	Neutral impact/others' actions do not affect
-1	Increased surveillance/situational awareness, does not achieve favourable mission outcome and with limited costs, inappropriate capability increase given circumstances
-2	Increased presence, does not achieve favourable mission outcome, with medium costs, very inappropriate capability increase given circumstances
-3	Increased interception, does not achieve favourable mission outcome and with large costs, completely inappropriate capability increase given circumstances

Table A 4. Air Force COAs – Worst Case Scenario

Adversary

The Adversary has been assigned rankings which vary between -3 and +3. A positive ranking indicates that the Adversary is able to achieve its objective or mission, although its ability to do so may be hampered by the risks involved (in relation to the Air Force's or Canadian Government's actions). For example, in the case in which the Adversary continues to encroach or exploit despite the Air Force's increased interception capabilities and the Canadian Government's increased diplomatic efforts, the Adversary would be given a rank of +1. Here the Adversary can achieve its mission of encroachment, although it may be with loss, either by being intercepted or by facing repercussions in diplomatic circles. However, these risks and losses are insufficient levers to curtail the Adversary's ambitions.

A negative ranking indicates that the Adversary's freedom of action is limited or curtailed completely, and complemented with a range of potential repercussions. For example, in the case in which the Adversary desires to encroach, but is forced to respect international treaties, a negative ranking is appropriate. Table 4 summarizes the Adversary COAs.

+3	Mission success, unhampered
+2	Mission success, with impediment(s) or risks
+1	Mission success, with loss, future loss
0	Neutral impact/others' actions do not affect
-1	Actions limited, limited repercussions (slap on the wrist)
-2	Limited freedom of action, large scale/future repercussions
-3	Mission failure/ no freedom of action

Table A 5. Adversary COAs – Worst Case Scenario

Government

In the case of the Government, rankings are composed of two variables, the associated costs and the achievement of desired results. Costs for the Government are not only those monetary funds that are expended, but also intangible costs such as potential embarrassment or loss of votes. For the Government, a situation whereby the status quo is maintained and the Adversary respects international treaties would warrant a ranking of +3. Here there is no cost to the Government, and the desired result, maintenance of sovereign territory, is achieved.

Alternatively, in a situation in which the desired result is not achieved, a negative ranking is applied. This ranking is relative to the costs involved on the Government's behalf. For example, in a situation in which the Adversary is encroaching, the Air Force is increasing interception, and the Government has increased Northern immigration and development, a -3 is warranted due to the large monetary funds being expended. However, in a situation in which the other players pursue the same COA and the Government maintains the status quo, a -3 is also applicable. This is due to the fact that large costs, in terms of embarrassment and power projection, would be incurred if Canada's territory was being encroached upon and the Government did not respond.

+3	No cost, achieves desired results, most appropriate action given circumstances
+2	Limited costs, achieves desired result, very appropriate action given circumstances
+1	Large costs, achieves desired results, appropriate action given circumstances
0	Neutral impact/others' actions do not affect
-1	No costs, does not achieve desired results, inappropriate action given circumstances
-2	Limited costs, does not achieve desired results, very inappropriate action given circumstances
-3	Large costs, does not achieve desired results, most inappropriate action given circumstances

Table A 6. Adversary COAs – Worst Case Scenario

Results Matrix

Table 6 represents the results matrix for the Worst Case Scenario. Since this scenario's game is three-dimensional, a little creativity must go into displaying the entire dataset in a two-dimensional representation. Within this table, the unit cells contain three numbers in the format (*x*, *y*, *z*): the first is the Air Force's preference score for the combination of actions, the second is the Adversary's preference score, and the third is the Government's preference score. To deduce the course-of-action combination structure within this table, one starts with the heavy grey dividing lines. These are used to highlight the rows and columns denoting (respectively) the Air Force's COA and the Adversary's COA; the intersection of which yields a solid grey super cell. Within each super cell are four unit cells divided by lighter, dashed lines, which represent each of the Government's COA. The first super cell in Table 6 includes red footnotes that indicate in a legend below the table which unit cell corresponds to which Government COA.

	Adversary – Encroach on Canadian Terrritory		Adversary – Respecting International Treaties		Adversary – Legally Redefining Boundaries		Adversary – Increase Northern Capabilities	
AF - Maintain Status Quo	(**-1**, **3**, **-2**)†	(**-1**, 2, **-2**)‡	(**4**, -3, **3**)	(**4**, -3, 1)	(**0**, **3**, -3)	(**0**, **3**, -2)	(**-1**, **3**, -1)	(**0**, 2, -1)
	(**-1**, **2**, **-2**)*	(**-1**, 2, -3)§	(**4**, -3, 2)	(**4**, -3, -3)	(**0**, **2**, **-1**)	(**0**, 2, -3)	(**0**, **2**, **0**)	(**-1**, **3**, -3)
AF – Increase Situational Awareness Capabilities	(**-1**, 2, **-1**)	(**-1**, 2, -2)	(3, -3, **3**)	(3, -3, 1)	(-1, **3**, -3)	(-1, **3**, -2)	(-1, **3**, -1)	(**0**, 2, -1)
	(**-1**, **2**, **-1**)	(**-1**, 2, -3)	(3, -3, 2)	(3, -3, -3)	(-1, **2**, **-1**)	(-1, 2, -3)	(-1, **2**, **0**)	(**-1**, **3**, -3)
AF – Increase Presence Capabilities	(-2, 2, -2)	(-2, 1.5, -2.5)	(2, -3, **3**)	(2, -3, 1)	(-2, **3**, -3)	(-2, **3**, -2)	(-2, **3**, -1)	(-2, 2, -1)
	(-2, 1.5, **-1**)	(-2, 1.5, -3)	(2, -3, 2)	(2, -3, -3)	(-2, **2**, **-1**)	(-2, 2, -3)	(-2, **2**, **0**)	(-2, **3**, -3)
AF – Increase Force Application Capabilities	(-3, 1, -3)	(-3, 1, **-2**)	(1, -3, **3**)	(1, -3, 1)	(-3, **3**, -3)	(-3, **3**, -2)	(-3, **3**, -1)	(-3, 2, -1)
	(-3, 1, **-2**)	(-3, 1, -3)	(2, -3, 2)	(1, -3, -3)	(-3, **3**, **-1**)	(-3, 2, -3)	(-3, 2, **0**)	(-3, **3**, -3)

†Gov't – Maintains Status Quo	‡Gov't – Increase Posturing
*Gov't – Increase Treaty Dialogue	§Gov't – Increase North Imm. & Devel.

Legend:

Number triplets (x, y, z) represent the ranking preference of the Air Force, Adversary and Government, respectively, for each combined COA.

Bold numbers indicate the player's most preferred COA in regards to each combination of the other players' COA (the dash circles and lines indicate the direction along which each player considers their preferences).

Blue cells represent the Nash equilibrium – each player would have to choose a less preferable COA to get out of this equilibrium

Table A 7. Results Matrix for the Worst Case Scenario

Light circles and dashes are shown to help aid the reader in demonstrating how the most preferred COA for each player (bold numbers in table) is determined against each combined COA of its opponents. For example, in order to determine the Air Force's best COA for a unique combination of Adversary-Government COA, the first numbers of triplets must be compared along a column (fixed Adversary COA), skipping every other row (so that it is always in the same relative unit cell representing a fixed Government COA). Similarly, in order to determine the Adversary's best COA for a unique combination of Air Force-Government COA, the second numbers of the triplets must be compared along a row (fixed Air Force COA), skipping every other column (so that it is always in the same relative unit cell representing a fixed Government COA. Finally, in order to determine the Government's best COA, the third numbers in the triplets within a super cell (the intersection of the Air Force COA and the Adversary COA) are compared.

Note that there are five Nash equilibria to this table, as summarized below:

1. Air Force Maintains Status Quo, Government Increases Treaty Dialogue, Adversary Building Northern Capability outside Canadian sovereignty.

2. Air Force Maintains Status Quo, Government Increases Treaty Dialogue, Adversary Appears to be Successfully Redefining Political Boundaries.

3. Air Force Increases Situational Awareness, Government Increases Treaty Dialogue, Adversary is encroaching on Canadian Borders.

4. Air Force Maintains Status Quo, Government Increases Treaty Dialogue, Adversary is encroaching on Canadian Borders.

5. Air Force Maintains Status Quo, Government Maintains Status Quo, Adversary is encroaching on Canadian Borders.

Bifurcation Example

Again, all equilibrium points represent an end state that the players tend to move towards. Which equilibrium point that they tend towards depends on how the game is played. Consider Table 7 below. Suppose that the players are at the bottom left unit cell (circled in green). Here, the Air Force has increased its force application in the North, the Adversary is encroaching on Canadian borders, and the Government is increasing its international treaty dialogue. This is the best COA for the Government, so it would not likely change its stance. However, this is not the best COA for the Air Force or the Adversary, and so they will tend to choose another COA that better suits them.

If the Adversary moves first (they are taking a loss at encroachment and the Air Force does not seem to be letting up on its force application), then its best COA is to go about legally redefining boundaries in its favour (dashed blue line in Table). Treaty dialogue is still the Government's best COA, but now the Air Force would choose a better COA (investing in force application with no threat is costly). As a result, maintaining 2010 Status Quo would seem the best COA for the Air Force, and the game has reached equilibrium.

If the Air Force moves first because their force application does not seem to be deterring encroachment (dashed red line in Table), then their best COA is either to increase situational awareness or revert to maintaining the 2010 Status Quo (cheapest option). For either choice, this is the best COA for the other two players, and so the game has reached equilibrium.

	Adversary – Encroach on Canadian Terrritory		Adversary – Respecting International Treaties		Adversary – Legally Redefining Boundaries		Adversary – Increase Northern Capabilities	
AF - Maintain Status Quo	(**-1**, **3**, **-2**)†	(**-1**, 2, **-2**)‡	(**4**, -3, **3**)	(**4**, -3, 1)	(**0**, **3**, -3)	(**0**, **3**, -2)	(**-1**, **3**, -1)	(**0**, 2, -1)
	(**-1**, **2**, **-2**)*	(**-1**, 2, -3)§	(**4**, -3, 2)	(**4**, -3, -3)	(**0**, **2**, **-1**)	(**0**, 2, -3)	(**0**, **2**, **0**)	(**-1**, **3**, -3)
AF – Increase Situational Awareness Capabilities	(**-1**, 2, **-1**)	(**-1**, 2, -2)	(3, -3, **3**)	(3, -3, 1)	(-1, **3**, -3)	(-1, **3**, -2)	(-1, **3**, -1)	(**0**, 2, -1)
	(**-1**, 2, **-1**)	(**-1**, 2, -3)	(3, -3, 2)	(3, -3, -3)	(-1, **2**, **-1**)	(-1, 2, -3)	(-1, **2**, **0**)	(**-1**, **3**, -3)
AF – Increase Presence Capabilities	(-2, 2, -2)	(-2, 1.5, -2.5)	(2, -3, **3**)	(2, -3, 1)	(-2, **3**, -3)	(-2, **3**, -2)	(-2, **3**, -1)	(-2, 2, -1)
	(-2, 1.5, **-1**)	(-2, 1.5, -3)	(2, -3, 2)	(2, -3, -3)	(-2, **2**, **-1**)	(-2, 2, -3)	(-2, **2**, **0**)	(-2, **3**, -3)
AF – Increase Force Application Capabilities	(-3, 1, -3)	(-3, 1, **-2**)	(1, -3, **3**)	(1, -3, 1)	(-3, **3**, -3)	(-3, **3**, -2)	(-3, **3**, -1)	(-3, 2, -1)
	(-3, 1, **-2**)	(-3, 1, -3)	(2, -3, 2)	(1, -3, -3)	(-3, **3**, **-1**)	(-3, 2, -3)	(-3, 2, **0**)	(-3, **3**, -3)

†Gov't – Maintains Status Quo	‡Gov't – Increase Posturing
*Gov't – Increase Treaty Dialogue	§Gov't – Increase North Imm. & Devel.

Legend:

Number triplets (x, y, z) represent the ranking preference of the Air Force, Adversary and Government, respectively, for each combined COA.

Bold numbers indicate the player's most preferred COA in regards to each combination of the other players' COA (the dash circles and lines indicate the direction along which each player considers their preferences).

Blue cells represent the Nash equilibrium – each player would have to choose a less preferable COA to get out of this equilibrium

Table A 8. Results Matrix for the Worst Case Scenario with Bifurcation example

Conclusions

As shown in the results matrices, every situation has many possibilities, and no particular COA is best in every circumstance. The worst case matrix shows five different equilibrium states. However, as previously stated, an equilibrium does not necessarily represent the end state of the whole scenario. Although the equilibrium state may define the best COA for all of the players, it should be remembered that not all players will always act in their own best interest, especially if this results in another player

gaining an equal or greater benefit. However, in the absence of more robust analysis of whether player 1 (for instance) would strategically choose not to pursue its best COA, the analysis here clearly demonstrates what the end state would typically be if every player chose their most preferred COA.

Best Case. In this case, the system tends towards the solution that the Government will continue to engage in treaty dialogues to ensure other nations and non-state players continue to respect Canada's border claim, while the Air Force divests in its force application capabilities due to its lack of use and deemed unnecessary expenditure.

Worst Case. In this scenario, there are five potential end states:

1. The Adversary does not encroach on Canadian claimed boundaries, but is building northern capabilities outside of Canadian sovereignty, which causes the Government to increase its treaty dialogue. Because there is no imminent threat to Canadian sovereignty, the Air Force maintains its 2010 status quo.

2. The Adversary appears to be successfully redefining political boundaries, which causes the Government to increase its treaty dialogue. Because there is no imminent threat to Canadian sovereignty, the Air Force maintains its 2010 status quo.

3. The Adversary continues to successfully encroach on Canadian borders and the Air Force increases its situational awareness capability in the North. The Government continues to increase its treaty dialogue.

4. The Adversary continues to successfully encroach on Canadian borders, which causes the Government to increase its treaty dialogue. The Air Force maintains status quo.

5. The Adversary continues to successfully encroach on Canadian borders, and both the Government and Air Force maintain status quo, most likely due to limited success and budgetary constraints.

GLOSSARY

alternative future

An alternative future is a possible future that occurs when certain events or other influences cause a deviation from the general direction in which a trend is moving. Alternative futures can be caused by revolutionary breakthroughs and also by a s**trategic shock** or a **wild card event**.

comprehensive approach

The broad scope of actions undertaken in a coordinated and collaborative manner by national and multinational military forces, civilian government agencies, international and intergovernmental organizations, non-governmental organizations, or the private sector to achieve greater harmonization in analysing, planning, managing, and evaluating coalition interventions in complex contingencies and emergencies.

digital native

A digital native is a person for whom digital technologies already existed when they were born, and, hence, has grown up with widely available digital technology, such as computers, the Internet, mobile phones, and MP3s. These young people study, work, write, and interact with each other in ways that are sometimes hard for the older generation to imagine.

driver

An event or human activity that provides impetus or motivation to fuel or sustain a trend.

hybrid reality

Hybrid reality integrates a simulator database with actual flying.

key factors

Key factors are thought to be the most important contributing features of a future security trend. The key factors are used to create the scenarios. They are made to have either extremely positive or negative effects (while remaining plausible), which create a best (utopian) and a worst case (dystopian) scenario—the alternative futures.

Nash equilibrium

In game theory, Nash equilibrium (named after John Forbes Nash, who proposed it) is a solution concept of a game involving two or more players, in which each player is assumed to know the equilibrium strategies of the other players, and no player has anything to gain by changing only his or her own strategy unilaterally.

operational training systems provider (OTSP)

Under this program, a prime contractor will provide comprehensive aircrew training services (to include instructors, courseware, simulators, trainers and facilities) for Canada's C130J and CH47 fleets, and potentially other aircraft platforms in the future. The OTSP program will allow for the development of training systems and processes that are flexible and can be integrated with existing and future aircrew training programs.

peak oil

Peak oil refers to the point in time when oil production has peaked and only half of proven reserves remain. The significance in this lies in the fact that the remaining known quantity is finite and the laws of supply and demand indicate greater demands for dwindling supplies, which ultimately translates into higher prices. The date when the world reaches global peak oil production cannot be pegged exactly. The projected dates vary between the most pessimistic in 2010 and the most optimistic in 2035.

strategic shock

A sudden and/or unexpected and often powerful event or driver that causes the trajectory of a trend to significantly deviate from its existing course.

trend

A tendency or a movement towards something or in a particular direction.

wild card event (sometimes called a black swan event)

A wild card event is a high impact, low probability event that would have dramatic consequences if it actually occurred. Wild cards are rare events, beyond the realm of normal expectations, which makes them almost impossible to predict. *9-11* is often cited as being a black swan event because of the impact it had on all our lives.

LIST OF ABBREVIATIONS

ADM (HR-Mil)	Assistant Deputy Minister (Human Resources-Military)
AI	artificial intelligence
AVS	Augmented Visionics System
CAE	computer-aided engineering
CAS	Chief of the Air Staff
CDB	common database
CF	Canadian Forces
CFATC	Canadian Forces Arctic Training Centre
CFAWC	Canadian Forces Aerospace Warfare Centre
CFS	Canadian Forces Station
COA	course of action
CRA	compulsory retirement age
DARPA	US Department of Defense Advanced Research Projects Agency
DND	Department of National Defence
HAA	high altitude airship
HALE	high altitude long endurance
iUAS	intelligent unmanned aerial system
ICAO	International Civil Aviation Organization
ISR	intelligence, surveillance and reconnaissance
MAV	micro air vehicle
NATO	North Atlantic Treaty Organization
NORAD	North American Aerospace Defence Command
OTSP	Operational Training Systems Provider

SAR	search and rescue
SE	synthetic environment
SOF	special operations forces
UAS	unmanned aerial system
UAV	unmanned aerial vehicle
UNCLOS	United Nations Convention on the Laws of the Sea
US	United States
USAF	United States Air Force
YFR	yearly flying rate

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