ROYAL CANADIAN AIR FORCE JOURNAL

WINTER 2017 • VOL.6, NO.1

ATTACK ON CAMP BASTION

IMAGING TECHNOLOGY FOR SEARCH AND RESCUE

RCAF C4ISR: AT A TURNING POINT

AND MORE!

CANADIAN ARMED FORCES
FORCES ARMÉES CANADIENNES

National Defence Défense nationale

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The *ROYAL CANADIAN AIR FORCE JOURNAL* is an official publication of the Commander Royal Canadian Air Force (RCAF) and is published quarterly. It is a forum for discussing concepts, issues and ideas that are both crucial and central to air and space power. The *Journal* is dedicated to disseminating the ideas and opinions of not only RCAF personnel, but also those civilians who have an interest in issues of air and space power. Articles may cover the scope of air-force doctrine, training, leadership, lessons learned and air-force operations: past, present or future. Submissions on related subjects such as ethics, technology and air-force history are also invited. This journal is therefore dedicated to the expression of mature professional thought on the art and science of air warfare and is central to the intellectual health of the RCAF. It serves as a vehicle for the continuing education and professional development of all ranks and personnel in the RCAF as well as members from other environments, employees of government agencies and academia concerned with air-force affairs.

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Published by Canadian Forces Aerospace Warfare Centre
ISSN 1927-7601

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http://w08-ttn-vmweb01/CFAWC/en/elibrary/journal/current-issue.asp

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ROYAL CANADIAN AIR FORCE
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For the Winter issue: **30 October**

For the Spring issue: **30 January**

For the Summer issue: **30 April**

For the Fall issue: **30 July**

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CONTENTS

WINTER 2017

VOLUME 6 • NUMBER 1

EDITOR'S **MESSAGE**

This winter issue of the *Royal Canadian Air Force Journal (RCAFJ)* provides an opportunity for all to peruse award-winning articles from bright minds advancing airpower thought in Canada. The Commander Royal Canadian Air Force (RCAF) has initiated an awards programme that is expected to serve as motivation for innovators to put pen to paper and produce thoughtful analyses of airpower issues, and this journal is happy to publish these articles to the wider RCAF to support the Commander. This year's Manson Award recipient, Captain D. A. S. Lavoie, provides some insights into the possible uses of advanced imaging technologies to assist in the conduct of search and rescue missions. This year's recipient of the Leckie Award, Lieutenant-Colonel J. C. J. P. Gagnon, offers an interesting way forward in the area of command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR). The winners of these two awards invite us to explore airpower options for the future and set the standard for future academic writers to follow.

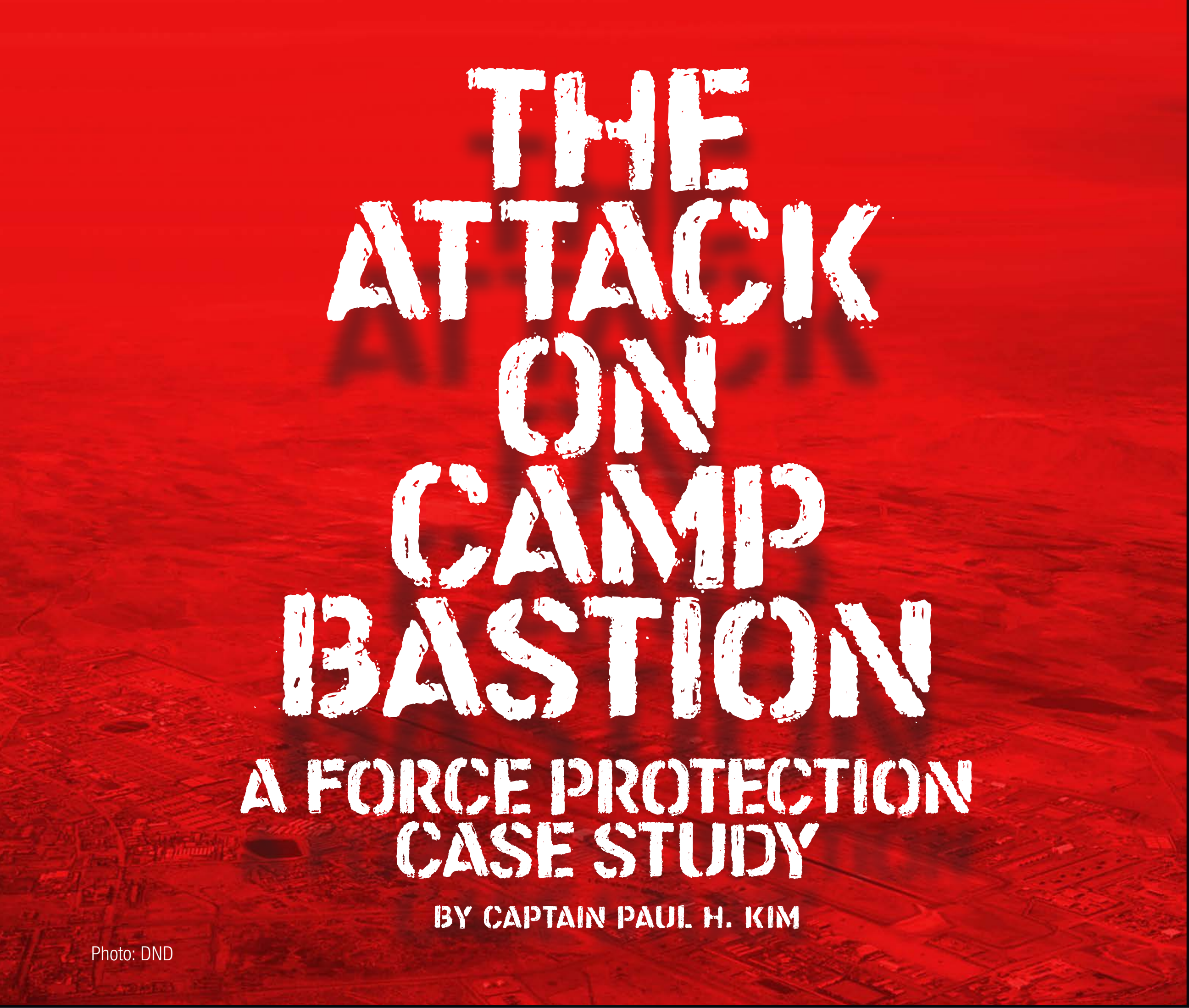
In addition to award-winning papers, the RCAFJ will be including other interesting works from students of the Joint Command and Staff Programme to provide better visibility on the airpower-related work coming out of the Canadian Forces College. Tapping into the work of our post-graduate airpower experts is but one change we are making at the *RCAFJ*. Another change for future instalments of the *Journal* will be the introduction of guest editors, who will bring different perspectives and expertise to the issues they are assigned to produce. Selected editors can provide expertise in commemorative issues, bringing to light our fascinating history, or they can focus on specific areas of interest in the hopes of sparking discussion. The aim is to provide you, the reader, with multiple viewpoints and a wide range of interesting subjects, both historical and contemporary.

Enjoy the read.

Sic Itur Ad Astra

Lieutenant-Colonel Doug Moulton, CD, MBA
Senior Editor

A CC130J Hercules tail number 130612, doing flybys, landings and take-offs during Ex MOUNTAIN STAR. Photo: DND



THE ATTACK ON CAMP BASTION

A FORCE PROTECTION CASE STUDY

BY CAPTAIN PAUL H. KIM

Photo: DND

It is easier and more effective to destroy the enemy's aerial power by destroying his nest and eggs on the ground than to hunt his flying birds in the air.[1]

– General Giulio Douhet

It is doubtful if the Taliban had ever heard of Giulio Douhet, but they didn't need the pioneering airpower theorist to teach them to know to strike air power at its most vulnerable point: on the ground.

On the night of September 12, 2012, 15 well-trained Taliban fighters disguised in stolen United States (US) Army uniforms penetrated the perimeter of the Camp Bastion complex in Helmand province, Afghanistan, and inflicted devastating losses on the 3rd Marine Air Wing (3rd MAW). By dawn of the next day, they succeeded in inflicting the "worst loss of US air power in a single incident since Vietnam."[2] The most significant materiel damage the Taliban inflicted was the destruction of six Marine Harrier jets; two more Harriers were so badly damaged that they were scrapped; and six other US and British aircraft were damaged to various degrees, including several state-of-the-art MV22 Ospreys. During the attack, two Marines were killed and 17 other International Security Assistance Force (ISAF) coalition troops were wounded while fighting off the Taliban on the Bastion flight line.[3]

The relevance of the Camp Bastion attack for the Royal Canadian Air Force (RCAF) is that a future air task force (ATF) may very well find itself in a similar situation to the 3rd MAW on Bastion: reliant on exterior and perimeter force protection (FP) by an allied force or host nation. Indeed, given the lack of its own organic, air-base defence units, this expectation is explicitly stated in both the RCAF's doctrine and expeditionary capability concept of operations.[4]

While it is beyond the scope of this case study to advocate for a dedicated air-base defence force, the Camp Bastion attack does provide a useful example to prepare any future ATF for the extreme threats they might face.[5] To understand why the Bastion attack is such an illustrative FP case study, a brief recounting of the events is necessary to see what went wrong and what went right for the base defenders.

THE ATTACKERS

> *Let your plans be dark and impenetrable as night, and when you move, fall like a thunderbolt.*[6]
>
> – Sun Tzu

Like most successful special operations raids, the Taliban planned their attack meticulously and based it on solid intelligence.[7] Details gleaned from the only surviving enemy raider and verified by propaganda videos and photos released by the Taliban showed that they had conducted detailed reconnaissance on Camp Bastion over a period of months. Using sources on the base itself and observations from exterior reconnaissance, they were able to build a detailed map of the Bastion layout. Their reconnaissance had been aided by the policy of the Bastion-complex commanders to allow opium plants to be harvested unmolested by local farmers right outside the wire of the Bastion perimeter. By either infiltrating these farmers or interrogating them, the Taliban discovered that while occasional patrols were carried out, they were often spotty from a stretched-thin security force. More significantly, they discovered that while the perimeter had a network of 24 observation towers, not every one of them was manned continuously, due to personnel shortages. By allowing the Taliban to get so close to the fence line, they were able to find "dead space," unobservable hollows in the ground where they could form up and penetrate the perimeter with a minimal chance of being seen.[8]

Screenshot from Taliban-released video, showing the Bastion attackers being briefed[9]

To prepare for their raid, the Taliban carefully planned and rehearsed in their sanctuary in the Pakistani tribal territories, which were off-limits to ISAF coalition forces. According to the only surviving attacker, the Taliban specifically recruited volunteers for the attack, and none of them knew each other before being brought together for training in Pakistan. The attackers' training encompassed small-unit tactics—weapons handling, communications and manoeuvring.[10] They trained and rehearsed their attack for four months prior to the attack; the intention was that one section would target the jets; another, the helicopters; and the last section, the coalition personnel in their sheltered tent lines.

To maximize their chances, they waited for a moonless night and donned US Army digital camouflage fatigues to further confuse any defenders. On the night of the attack, it was exactly such a time and place—a very dark night through terrain criss-crossed with wadis, passing by a vacant tower and shielded from view of the more distant manned posts—that the Taliban infiltrated Bastion.[11]

THE BASE

> *We live in a world that has walls and those walls need to be guarded by men with guns.*[12]
>
> – *A Few Good Men*

Camp Bastion had been carved out of the Helmand desert when the British arrived in 2006 to assume command of what eventually became Regional Command South West. From the desert floor, they built a 3,500 metre runway and made it into the hub of ISAF operations in south-western Afghanistan.[13] In 2008, a surge of Marines arrived, and Camp Bastion was split into three separate camps for the US, United Kingdom and Afghan National Security Forces (ANSF) within the overall complex. The headquarters of the 3rd MAW located themselves with their higher headquarters in the new Marine section, Camp Leatherneck, but the flying squadrons were positioned on the only flight line, which was located in the remaining British section of the expanded complex and continued to be called Camp Bastion.

With the Marines on the ground and an expanded ANSF presence, the British were no longer solely responsible for FP. Instead, the Marines agreed to provide foot patrols around the Bastion complex, backed by occasional British patrols in the immediate vicinity of Camp Bastion itself. However, due to a drawdown of forces, the Marines steadily reduced the number of patrols, as their designated FP unit, an artillery battalion, was reduced to battery size of 110 personnel of all ranks. This reduced unit was also responsible for security duties on Camp Leatherneck, manning a forward patrol base, providing troops for two quick reaction force (QRF) missions and their original role of providing indirect fire support. At the time of the attack, there was only one squad of Marines on patrol outside the wire, and they were several kilometres south of Bastion.

On Camp Bastion itself, the Royal Air Force's (RAF's) 5 FP Wing was responsible for security and operated foot patrols outside the wire with their organic ground combat defence unit, the RAF Regiment, to supplement the Marines. The RAF Regiment was also responsible for gate guard duties, interior patrols and providing a QRF to respond to any incursions. However, due to personnel shortfalls, the RAF Regiment did not man the observation towers. Instead, 5 FP Wing had to task various British units on Bastion to provide personnel to man the towers and also used troops from the Pacific island nation of Tonga. This ad hoc security force was still not able to provide enough troops to man all the towers. The British never asked the Marines to provide troops for the towers on Bastion because of the ISAF agreement to split security responsibilities. In any event, there was really no one the British could have appealed to in order to have the Marines tasked to provide troops for the towers because there was no single FP commander for the entire complex. (It should also be noted that the Marines also only manned half of the towers on the Leatherneck side of the complex.) On the night of the attack, only 11 of the 24 towers that ringed Camp Bastion were manned.[14]

The Marine squadrons that operated from the Bastion flight line had also not considered the possibility of a ground attack. One of the attack survivors recounted that the only scenario they had been trained and prepared for was to react to indirect fire into the camp. "The type of training we received whenever, if we did get attacked, was to get inside the bunkers. So we weren't really prepared for it."[15]

THE ATTACK

> *Every Marine is, first and foremost, a rifleman. All other conditions are secondary.*[16]
>
> – General Alfred M. Gray, 29th Commandant,
> United States Marine Corps

At least two days before the attack, the Taliban raiders infiltrated back into Afghanistan and were picked up in Kandahar and driven to a safe house where they donned the stolen US Army uniforms; received a last-minute briefing, using a map drawn on a white board; and then made "martyrdom videos."[17] Sometime around 10 p.m., the Taliban cut through Bastion's 30 foot [9.1 metre] high chain-link fence and entered the camp. Their entry did set off motion detector alarms to alert the RAF Regiment's QRF unit. However, they would not arrive until at least 12 minutes after the Taliban broke through.

Unchallenged, the Taliban split into three sections, as they had rehearsed. Almost immediately, they started firing on groups of Marines they saw working on the flight line. The gunfire attracted the attention of Marines working in various offices and aircraft shelters. Other Marines were only alerted when they heard the sound of explosions caused by the Taliban firing rocket launchers and throwing hand grenades at the parked Harriers and fuel pumps. Many Marines followed their pre-deployment training and started heading for the indirect fire bunkers until informed of the true situation.[18]

Details from the US Department of the Army investigation into the Camp Bastion attack[19]

Universally, none of the Marines had more than a pistol or a rifle and a few rounds to defend themselves. However, US Marine training for both officers and non-commissioned members (NCMs) includes mandatory courses in infantry weapons handling and small-unit tactics. All Marine officers after commissioning undergo a six-month course in squad and platoon tactics; NCMs take a month of weapons handling and squad tactics after boot camp. It was this training that the Marines on Bastion fell back on to hold back the Taliban while awaiting the QRF. Some aircraft technicians stripped machine guns from parked helicopters to use on the ground. Marine officers and sergeants began organizing impromptu squads to defend their local areas and lead counterattacks. It was while leading one of those counterattacks that the commanding officer of Marine Fighter Attack Squadron 211 (VMA-211) and a maintenance-technician sergeant were killed.[20]

While the troops fought to hold back the enemy, the Bastion defenders were able to launch several British and American helicopter gunships to provide support. The British and Marine flight crews of the gunships aloft had the "surreal" experience of firing on their own flight line in support of their comrades on the ground. Even with the airborne fire support, the arrival of the RAF Regiment and reinforcements from units across the complex, it still took approximately six hours and the expenditure of thousands of rounds to eliminate the Taliban from their seized hiding places.[21] The intense nature of the fighting was characterized by the expenditure of 10,000 rounds of ammunition by the RAF Regiment alone.[22]

The remnants of a US Marine Harrier and aircraft shelter, both destroyed in the Camp Bastion attack[23]

THE AFTERMATH

Nothing except a battle lost can be half as melancholy as a battle won.[24]

– Sir Arthur Wellesley, Duke of Wellington, June 1815

The Camp Bastion attack sent shockwaves through the ISAF command and reverberated around the world. In addition to the casualties and materiel destruction they inflicted, the Taliban won a huge propaganda victory, as the attack displayed the depth of their reach and further added to their reputation and credibility as cunning fighters. The attack was the subject of hearings by both the US Congress and British Parliament. On an operational level, the attack forced ISAF to make new arrangements for close air support and tactical transport due to the loss of the aircraft and infrastructure on Bastion. It also forced ISAF to focus more on FP on all their bases in theatre instead of other priorities. Strategically, the Marines lost 6 per cent of their worldwide Harrier fleet, and they were forced to send replacements from the US to reconstitute VMA-211.[25] Separate investigations were conducted by the US Marines, ISAF and the US Army, the latter at the direction of the United States Central Command. The US Army investigation found the two senior US Marine generals on Camp Leatherneck shared command culpability for the attack. Both generals were censured and forced into early retirement.[26]

CONCLUSION

The wise man learns from the mistakes of others.[27]

– Chancellor Otto Von Bismarck

The events of the Camp Bastion attack make an excellent case study of the importance of protecting air bases on the ground. As multiple post-attack investigations and hearings revealed, the attack was the result of an adaptive, resilient enemy taking advantage of weaknesses caused primarily by a complacent attitude towards FP.[28] It clearly shows what can happen when FP is outsourced and becomes "someone else's problem." At the very least, it reinforces the need for individual weapons training by all members prior to a deployment. The quick and dogged defence by the Marines on the flight line during the first minutes of the attack limited the damage done by the Taliban. However, the Taliban should never have gotten as far as they did, which required ground crew and aircrew to have to fight in extremis as infantry.

Captain Paul H. Kim is currently serving as platoon commander of the Integrated Personnel Support Centre, Winnipeg. As an RCAF Logistics officer, he has supported fighter and tactical helicopter operations as well as the Joint Task Force – Afghanistan Air Wing. He has served as a recruiting officer and as the J9 Civil-Military Cooperation for JOINTEX 13. As an infantry NCM, he served in Charlie Company, 2 Princess Patricia's Canadian Light Infantry Battle Group in the Medak Pocket operation.

ABBREVIATIONS

ANSF	Afghan National Security Forces
ATF	air task force
FP	force protection
ISAF	International Security Assistance Force
MAW	Marine Air Wing
VMA-211	Marine Fighter Attack Squadron 211
NCM	non-commissioned member
QRF	quick reaction force
RAF	Royal Air Force
RCAF	Royal Canadian Air Force
US	United States

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MANSON AWARD

Commander 2 Canadian Air Division, Brigadier-General D. Cochrane, presents Captain David Lavoie with the inaugural Manson Award for his project "Imaging Technology for Search and Rescue," which follows.

In order to promote vital airpower research within the Royal Canadian Air Force (RCAF), the RCAF Commander has instituted a series of awards that will recognize individuals who contribute first-class papers that address airpower-related issues.

Five research awards have been established, and the second to be awarded in the series is the Manson Award, which is presented to the best individual project on the Aerospace Studies Program.

The Manson Award is so-named in recognition of General Paul Manson, Order of Canada, Commander of the Order of Military Merit, Canadian Forces Decoration; he is a retired Canadian Forces officer, fighter pilot and businessman. Manson joined the RCAF in 1952 and graduated from the Royal Military College in 1956. He received his wings in 1957 and, as a junior officer, served as a fighter pilot in Germany and Canada. He served as Commanding Officer of 441 Tactical Fighter Squadron before becoming programme manager of the New Fighter Aircraft project (which led to the selection of the CF188 Hornet) in 1977. He went on to be Commander 1 Canadian Air Group in 1980; Commander, Air Command in 1983; and Assistant Deputy Minister in the Department of National Defence in 1985. His last appointment was as Chief of the Defence Staff in 1986, before retiring in 1989.

Following military service he was the president of Paramax, a Montreal-based aerospace company. He retired from business as chairman of Lockheed Martin Canada in 1997.

IMAGING TECHNOLOGY FOR SEARCH AND RESCUE

BY CAPTAIN DAVID LAVOIE, CD, BSC, PMP, PPHYS

Photo: DND

ABSTRACT

This article gives an overview of imaging technologies that have the potential to improve the efficiency of search and rescue (SAR) missions by augmenting the capabilities of the search and rescue technician (SAR Tech) and reducing the degree of vigilance decrement. The study establishes the human physiology as a baseline of the capabilities potentially available to a SAR Tech for an aerial visual search. The specifications of hyperspectral and active range-gated (ARG) imaging technologies are compared to this baseline. Through this comparison, the research explains the principles behind each technology, while highlighting the strengths and weaknesses of each system. The article recommends hyperspectral sensors as well as integrated ARG and thermal infrared (IR) sensors as viable options for use on Royal Canadian Air Force (RCAF) SAR assets.

PART I - INTRODUCTION

"I could see so many helicopters flying over me, but they could not see me!"[1] This statement is extracted from the true tales of survivors of Hurricane Ike in Texas, but it is all too familiar to many Canadians as well. SAR in Canada is primarily executed by SAR Techs working from airborne platforms. It is conducted in two phases: the search phase and the rescue phase. The search phase consists of a visual search for the victims, using aircraft such as the CC115 Buffalo, the CC130 Hercules, the CC138 Twin Otter, the CH146 Griffon and the CH149 Cormorant. Furthermore, the CH124 Sea King and the CP140 Aurora act as secondary assets when needed.[2] These assets are currently ill-equipped to ensure an efficient search phase in all flight and meteorological conditions. This is partially due to the limitations inherent to human physiology, such as data collection and the processing of high amounts of data.

The Visual Short Term Memory[3] is involved in processing the information collected during visual searches. The visual memory's pre-attentive processing[4] is the most effective process for detection in a scene with multiple colours and multiple textures.[5] However, this processing ability is finite and does not increase with practice.[6] Furthermore, the eye sees only the visible spectrum and cannot perceive IR signatures,[7] in contrast to thermal IR sensors which can detect heat. Moreover, compared to a sensor, the eye also requires a significant contrast, as theorized by Ernst Heinrich Weber, to detect differences in colours or luminance. Hence, more subtle contrasts do not draw attention and can be missed by the SAR Tech. Sensors would have the ability to highlight these subtle contrasts, promoting detection by the pre-attentive processes of the visual memory and potentially increasing the detection rate of victims.

In addition to the limitations inherent to human physiology, other general factors increase the possibility of missing information during a visual search. For example, SAR assets are authorized to fly in challenging meteorological conditions beyond visual flight rules (VFR) as per the *Royal Canadian Air Force Flight Operations Manual*.[8] During these missions, the visibility can be as low as one nautical mile and can be aggravated by particulates in the atmosphere such as rain, fog, smoke and blowing snow over the search area. A sensor working outside the visible range can provide the ability, which the eye does not have, to see through a semi-opaque atmosphere.

As will be demonstrated, most of the limitations of the human could be overcome by using existing sensor technologies. It is undeniably beneficial to explore ways in which these technologies can help increase the efficiency of Canadian SAR missions.

AIM

The aim of this article is to identify existing technologies that can help detect, recognize and identify a SAR target during flightworthy weather conditions.

OUTLINE

In order to objectively compare the capabilities of the technologies, this article will use the SAR scenarios of searching for a person in a forest and in water as standards of comparison. The former, being affected by the changing background and the surrounding distractions, is mainly used to compare spatial resolution and processing advantages of sensors over the brain. The latter is known to be a challenging SAR mission due to the relatively high threshold required for the eye to discriminate contrasts between similar colours and the smaller proportion of blue cones, compared to other cones, leading to a reduced sensitivity in that colour scheme.[9] Consequently, searching for a person in water is a relevant scenario to compare the spectral resolution of sensors with that of humans. Although there are other existing technologies that could be used, this article focuses on hyperspectral and ARG sensors. The topics this article discusses are:

a. human physiology as a basis of comparison for other sensor technologies;

b. hyperspectral technology for detection and recognition from long range to close range;

c. ARG imaging technology for detection, recognition and identification in inclement weather from medium range to close range; and

d. lessons learned from testing the Advanced Integrated Multi-Sensing Surveillance (AIMS) system.

PART II - HUMAN PHYSIOLOGY

Like a sensor, the human body also possesses sensing capabilities. Those capabilities can be enhanced by using hyperspectral and ARG sensors. To demonstrate their advantages, a comparison of performances will be done between the capabilities inherent to human physiology and those inherent to each technology. The following paragraphs explain the characteristics of the average SAR Tech that will be used in this comparison. The characteristics of interest are:

a. electromagnetic sensitivity band;

b. field of view (FOV);

c. spatial resolution;

d. processing;

e. radiometric resolution;

f. chromatic resolution (spectral resolution); and

g. reliability.

ELECTROMAGNETIC SENSITIVITY BAND

The human eye is sensitive to the light reflected from the scene in wavelengths ranging from 380 nanometres (nm) to 700 nm (the visible spectrum). This is achieved with four separate types of sensor cells in the eye. First, the rods, which make up the bulk of the sensors covering the entire surface of the retina, have a sensitivity of 380 nm to 650 nm[10] but peak around 505 nm. The rods are responsible for scotopic[11] vision as well as peripheral information. However, it can take up to 30 minutes for the eye to fully adapt to darkness. Secondly, there are three types of cones, each is sensitive to a different wavelength. Cones are concentrated where the intensity of light is greatest on the retina and are aligned with the pupil. The cones account for photopic[12] vision and respond to wavelengths from 400 to 700 nm.[13] Due to the three types of cones (blue, green and red), the human eye is not equally sensitive to all wavelengths (see Figure 1). Although the absorptivity of cell types varies for each person, the human eye is generally more sensitive to green, followed by red and then blue wavelengths. This results in a significant reduction in the eye's ability to perceive some colours or distinguish between them, mainly in the blue spectrum.

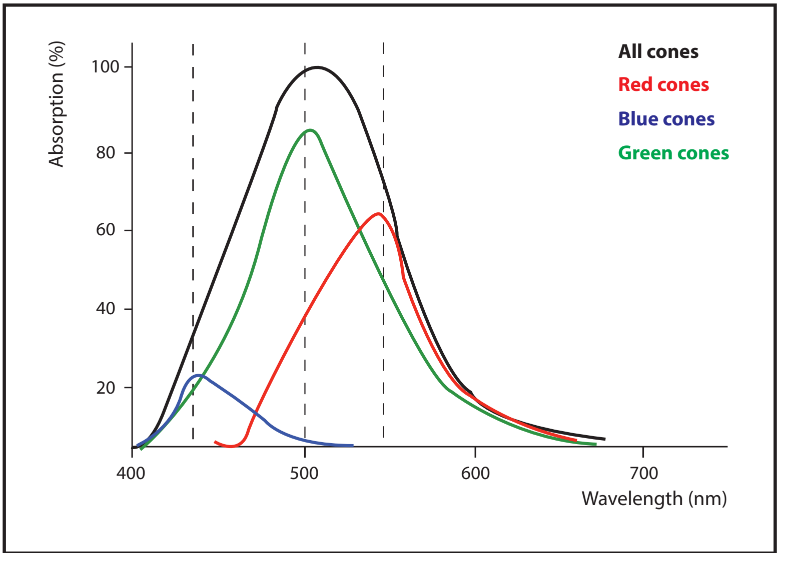

Figure 1. Absorptivity of cone cells[14]

While limited to the visible spectrum, the human eye is very sensitive to light in the green colours but is much less sensitive to blue colours. In a similar environment, a victim wearing blue clothes will not be detected by the SAR Tech as easily as a victim wearing green clothes, assuming that the background is not green.

FIELD OF VIEW

The average FOV of humans spans 200 degrees (°) horizontally and 135° vertically. But most of the FOV provides low resolution peripheral vision except for a region of 8°–10° diameter called the central vision.[15] Due to the higher density of cone cells, the resolution increases towards the centre of the retina until a maximum is reached. Referred to as the foveal vision, this region is at most 3° in diameter. The combined FOV of both eyes is represented in Figure 2 for peripheral, central and foveal vision. The left image illustrates the FOV extending on both sides of the head. The right image demonstrates the scaled regions aligned straight ahead.

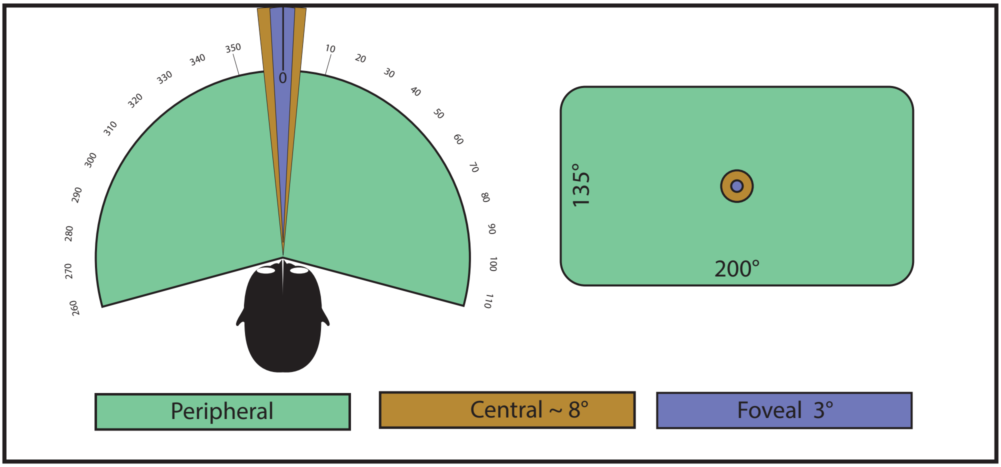

Figure 2. FOV of the human eyes

Based on this information, studies have identified the portions of the FOV involved in a visual search. The conclusion was that both central and peripheral information are required to conduct a search,[16] and a two-step process was isolated. During a visual search, the brain first identifies a point of interest based on low resolution information collected in the peripheral vision. Secondly, to access high spatial-resolution information, the brain commands the eye to rapidly align the fovea to the point of interest, called fixation point. In addition, George Geri conducted an experiment in 2010 and measured the average angular distance between two fixation points to be 7º. He referred to this measurement as the useful FOV.[17] Similarly, his experiment demonstrated that search speed and accuracy of detections were not improved with a FOV greater than 7° when the targets were stationary.[18]

Although the movement of an object in the peripheral vision of a SAR Tech will attract attention, a victim will regularly be incapacitated and/or immobile. Consequently, the peripheral information will not be contributing as much to the search, and the SAR Tech's useful FOV will be similar in size to that of a sensor.

SPATIAL RESOLUTION

Spatial resolution is defined as the ability of a sensor to resolve two objects in close proximity. The smaller and closer the distinguishable objects are, the higher the resolution. The range capability of a sensor is directly related to its resolution. Those ranges could be approximated using Johnson's criteria and the associated requirements as defined in Table 1.[19] In order to compare a sensor to the capabilities of a human, the ranges associated with Johnson's criteria need to be identified for the human eye. They can be estimated using the visual acuity of the SAR Tech and the height of the victim. The normal human visual acuity is expressed as 20/20 by optometrists. This is representative of a spatial resolution of 30 cycles/degree or 1 arcminute.[20] Assuming a clear visibility and that the Earth's curvature is negligible, the frame of reference can be represented by a right triangle (Figure 3) with the adjacent side being the maximum distance and the opposite size being the height of the victim. Therefore, the ranges of the human eye for detection, recognition and identification can be estimated by changing the angle representing the number of cycles required as per Johnson's criteria. Table 1 tabulates the results based on both the observer and the target located on the ground.

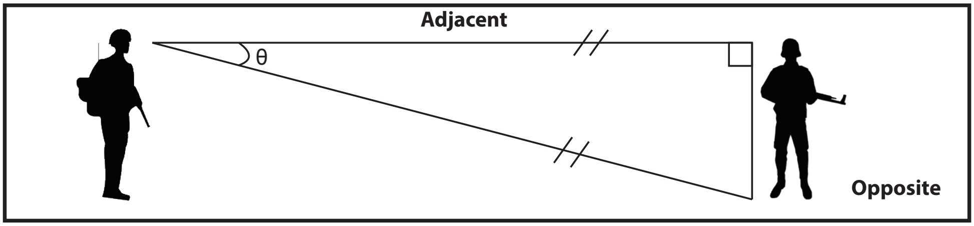

Figure 3. Frame of reference of a distant observer—assuming a right triangle

Capability	Required Cycles as per Johnson's Criteria	Associated Angle (Θ)	Estimated Maximum Distance from Target (km)
Detection	1 ± 0.25 cycle	2 arcminutes = $\frac{2}{60}$ degree	3.14
Recognition	4 ± 0.8 cycle	8 arcminutes = $\frac{2}{60}$ degree	0.786
Identification	6.4 ± 1.5 cycle	12.8 arcminutes = $\frac{12.8}{60}$ degree	0.491

Table 1. Estimated range capability of the human eye using a human target of 182.88 cm

The ranges in Table 1 are the optimal ranges of the unaided human eye. As the observer climbs in altitude, the area of the target visible to the observer will decrease and the calculated distances also decrease. In all SAR aerial visual searches, the ranges for detection, recognition and identification of the unaided human eye will be smaller than the aforementioned and will be further reduced as visibility decreases.

PROCESSING

As the information in a scene is collected, it is processed by the part of the brain involved with visual information: the visual memory. The SAR Tech will always have a preconceived idea of the intended target and will search for specific shapes and colours. Other elements in the FOV that do not contain the expected characteristics will be filtered. This is an attention-based, top-down approach[21] as described by Jeremy Wolfe in his guided-search theory. The SAR Tech's attention will be drawn to the characteristics expected of the target. The visual memory will then determine if it is indeed the feature of interest. This process requires a high level of attention, as the visual memory retrieves the stored knowledge in the long-term memory to compare to the visual data being collected.[22] Since attention needs to be dedicated to the task, it is a post-attentive process[23] of the visual memory. The concern with this approach is that objects appear different when seen from an aircraft compared to when seen from the ground. Although practice increases the image database stored in the brain's long-term memory,[24] it does not improve one's ability to detect a SAR target from the air.[25] Actively searching for characteristics requires too much processing and post-attentive processes filter key information.

Since the processing capacity of the visual memory is finite, a bottom-up approach requiring low-level processes called pre-attentive processing provides better results in a visual search.[26] The visual memory assesses the information contained in the FOV, including the search area in central vision and the peripheral vision, instead of actively seeking specific characteristics. A target requires at least one unique feature that is different from the textured background for pre-attentive processing of the visual memory to detect it. Once detected, attention can be drawn to the area for further analysis. Hence, pre-attentive processing reduces the overall processing required to assess a scene. Unavoidably, distractions will also draw attention. For example, a variation in luminance[27] will be detected over colours, and a variation in colours will be detected over texture.[28] Furthermore, the SAR Tech will experience a phenomenon that Duncan and Humphreys call similarity theory. If the target and non-target (distraction) in the FOV share many characteristics, the search efficiency will decrease, as both elements will compete for the brain's attention and limited visual memory. If the non-targets are dissimilar to each other, the search efficiency will also decrease, as the pre-attentive processes cannot immediately ignore the information collected.[29]

The ability to detect a victim in pre-attentive processes of the visual memory yields a quicker detection and potentially a greater detection rate than the use of post-attentive processes. The human does not have this ability without computers, but using algorithms to highlight information and filter distractions in real time would promote detection through pre-attentive processes.[30]

RADIOMETRIC RESOLUTION

A theory applicable to a myriad of sensory variations detected through pre-attentive processes is Weber–Fechner's Law.[31] This law states that to be immediately detected, a variation needs to exceed a certain threshold. This threshold, represented in Equation (1), consists of the Weber fraction multiplied by the initial quantity. The Weber fraction varies depending on the stimulus being measured. This stimulus can be a property detectable through all senses. However, for sight, the property can only be size, shape, colour or luminance.

$$\Delta \mathrm{I} = K_w I \tag{1}$$

Where:

$\Delta \mathrm{I}$ = threshold required for immediate detection

K_w = Weber fraction

I = initial quantity

The sensitivity of the human eye to luminance, also called radiometric resolution,[32] follows Weber–Fechner's Law over most of the daylight luminance range. The dotted line in Figure 4 represents the logarithmic value of the threshold to detect a change in luminance. The full line represents the Weber fraction, which is also the slope of the dotted line. The Weber fraction, or slope of the dotted line, value between 1 millilambert (mL) and 100 mL is constant and thus follows Weber–Fechner's Law. In most daylight conditions, the unaided SAR Tech would have a radiometric resolution of approximately 14 per cent (%).[33] In other words, to be instantly detected, an object must have at least 14% less or more intensity than the background. Otherwise, pre-attentive processing will not perceive the object.

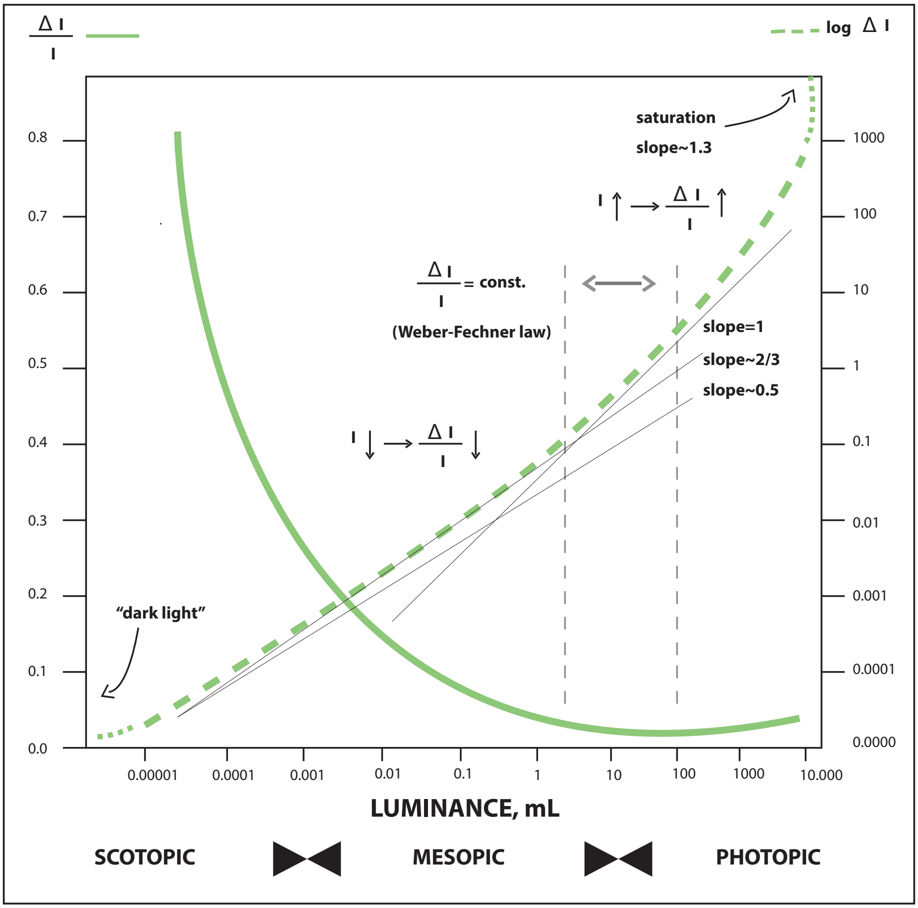

Figure 4. Radiometric sensitivity of the human eye[34]

As opposed to the constant radiometric resolution of a sensor, the human eye is greatly affected by the ambient luminance. During unusually dark nights, the radiometric resolution improves as the surrounding luminance decreases. Inversely, during unusually bright days, the radiometric resolution will decline as the surrounding luminance increases.

CHROMATIC RESOLUTION (SPECTRAL RESOLUTION)

The radiometric resolution of the rod or cone cells determines the chromatic resolution of the human eye. As demonstrated in Figure 1, the human eye is not equally sensitive to all wavelengths. The amplitudes of the stimulation of each cell type are compiled by the brain and interpreted as a colour. Generally, the human eye can differentiate between 16 and 32 shades of black and white and between approximately 100 colours.[35] However, for detection in pre-attentive processes of the visual memory, the chromatic resolution of the human eye follows Weber–Fechner's Law, as it is intrinsically related to the radiometric resolution of the eye.[36] As determined by Hansen, Giesel and Gegenfurtner's experiment, the chromatic resolution of the human eye for natural objects varies in the Weber fraction from 0.06 to 0.21 in an isoluminant plane. The smaller Weber fraction was only achieved with an adaptation time of 8 seconds to the colour surrounding the area of interest.[37] Consequently, the chromatic resolution will be lesser in an environment in motion, such as an airborne SAR platform, than in a steady environment.

During a SAR visual search, the colours and textures in and around the useful FOV will rarely remain constant for more than eight seconds. The eye may not adapt to the background. Therefore, objects with less than 21% chromatic difference with the background may not be detected in pre-attentive processing. In addition, it was determined through experiments that the Weber fraction is at its peak when detecting a contrast between similar wavelengths.[38] A SAR Tech could encounter this situation when searching for a blue target in the ocean. An example is a sailor falling in the water wearing their Royal Canadian Navy Naval Combat dress. To aid with understanding, five fictitious chromatic resolution thresholds of 20% are drawn on the International Commission on Illumination (CIE) chromaticity diagram in Figure 5. This threshold was selected for being representative of a worst-case scenario. The axes represent a percentage value of the stimulus received by the visual memory from green and red cones. The figure demonstrates that the differentiation of the colours inside a black circle is unlikely to be achieved by pre-attentive processes of the visual memory but is possible with a conscious effort.

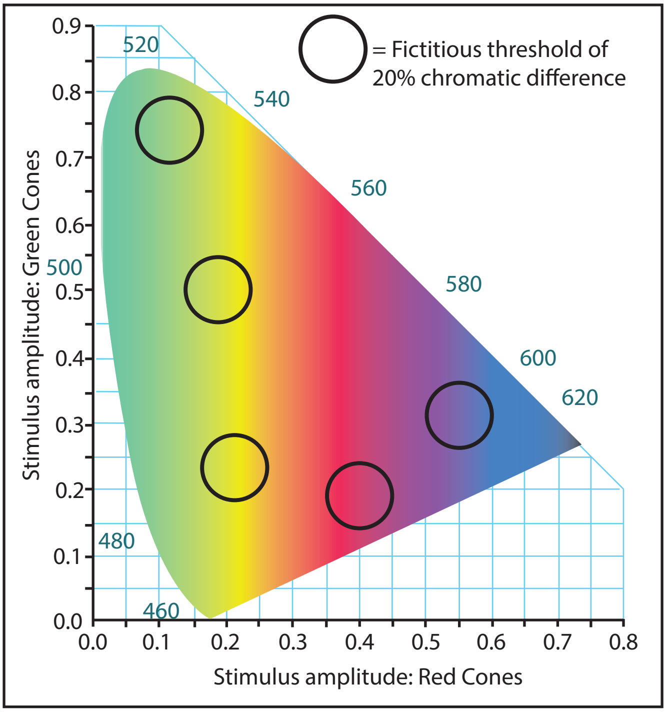

Figure 5. Fictitious chromatic resolution threshold example[39]

The human eye, when fully adapted to the background, can differentiate between approximately 100 colours. During a SAR visual search, due to the lack of adaptation time, the SAR Tech will differentiate between fewer colours in the pre-attentive processes of the visual memory, as a higher threshold of chromatic difference will be required.

RELIABILITY

While on a search, the SAR Tech uses active search techniques that require remaining still and concentrated for extended periods of time. However, performance declines over time when an individual conducts a task requiring sustained attention. This is called vigilance decrement. The average individual will exhibit vigilance decrement within 15 minutes of beginning sustained attention, but it can occur within 5 minutes if the stress level or workload is elevated.[40] Experienced and junior SAR Techs will all exhibit vigilance decrement at a similar rate, and it is mainly related to the demand for visual memory.[41] Therefore, the reliability of the SAR Tech's focus and effectiveness will naturally decrease during the search, whereas a sensor's performance will remain consistent.

RESULTS

In brief, the SAR Tech is a sensor with specifications dictated by human physiology. In the next parts of this article, the specifications summarized in Table 2 will be compared with those of imaging sensor technology to assess the value of using these sensors to replace or complement the SAR Tech.

Specification	Human Physiology
Electromagnetic Sensitivity Band	• 380–700 nm (visible spectrum)
FOV	• 7° useful FOV • 200° x 135° total
Spatial Resolution	• 30 cycle/degree • for a human target: ◦ detection – 3.14 km ◦ recognition – 0.786 km ◦ identification – 0.491 km
Processing	• visual memory • pre-attentive processing (unconscious) • post-attentive processing (conscious)
Radiometric Resolution	• > 14% variation required
Chromatic Resolution (Spectral Resolution)	• > 21% variation required
Reliability	• vigilance decrement ◦ 15 minutes for normal workload and normal stress ◦ 5 minutes for heavy workload or high stress level

Table 2. Specifications of the "SAR Tech sensor"

PART III - HYPERSPECTRAL TECHNOLOGY

Within its spectral sensitivity band, the eye is the best hyperspectral instrument available to humans. Nonetheless, this part will argue that a hyperspectral sensor is a valuable capability to add to a SAR platform.

PRINCIPLE OF OPERATION

Hyperspectral sensors evolved from multispectral sensors. However, both are very different. A multispectral sensor provides the ability to gather information from tens of discrete non-contiguous spectral bands, using filters or instruments sensitive to particular wavelengths, from ultraviolet (UV) to IR. However, multispectral sensors have low spectral resolution with bandwidths ranging between 70 nm and 400 nm.[42] Valuable information remains hidden within those wide bands. Multispectral imaging is generally used to create patterns. For example, the data is collected to discriminate areas of vegetation from areas of minerals. Although analogous to multispectral sensors, a hyperspectral sensor provides hundreds of contiguous narrow bandwidths ranging between 5 nm and 10 nm.[43] The data collected is in the form of a spectral signature for a given pixel. The compiled information is typically represented as a data cube with the image on top as a two-dimensional plane. The spectral radiance information of each pixel is included underneath the image, as a third dimension. As opposed to multispectral imaging, hyperspectral imaging is most often target based and aimed at detection, discrimination, classification, identification, recognition and quantification. Therefore, the hyperspectral data exploitation is better suited for SAR if focused on detecting pre-planned bands instead of displaying all the information that can be collected.

A hyperspectral sensor acquires information in two general ways: spectral scanning and spatial scanning. Both are shown in Figure 6, where the x and y axes represent the area and the wavelength is represented by the λ axis. The acquisition technique is designed in the sensor and is highly dependent on how it will be used. Spectral scanning consists of cycling through the filters to acquire data from all the wavelengths of interests. It requires the sensor to be stationary and, therefore, is not suitable for airborne operations. Similarly to the human eye, spatial scanning consists of acquiring all the wavelengths of interest in a pixel at once. The FOV is moved relative to the ground to acquire information from different locations. It requires stabilization and computing power to reconstruct the image. Although it must know precisely where it was looking in order to produce a quality image, it is suitable for airborne operations.

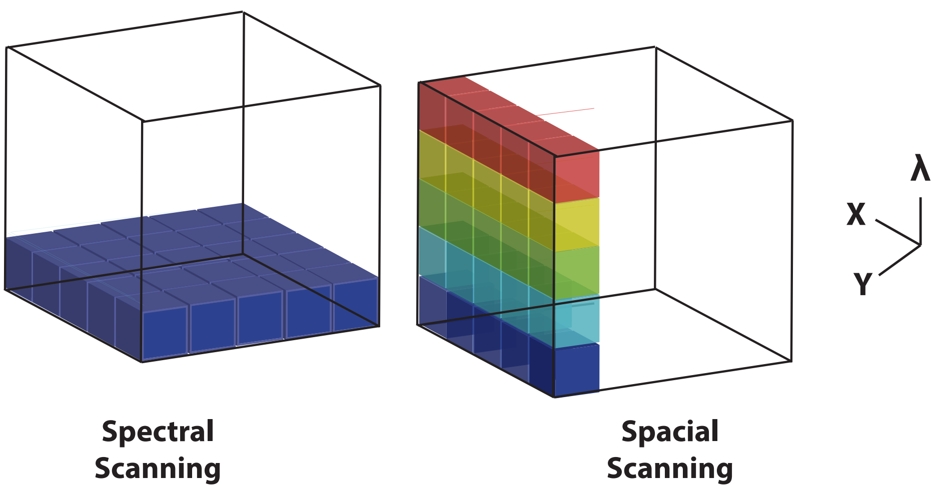

Figure 6. Hyperspectral acquisition techniques[44]

Spatial scanning relates to the acquisition of the data and its conversion into a two-dimensional array. The image is produced by correlating the information gathered through time from a pixel. However, various acquisition techniques provide different image quality and applications for hyperspectral imaging. Generally, the longer the dwell time over an area on the Earth's surface, the better the signal-to-noise ratio (SNR) will be. The dwell time can be increased by arranging the pixels in a line which covers a width called *ground swath*. The ground swath moves with the aircraft, permitting the acquisition of information from an area. This first configuration, named pushbroom scanning, eliminates the need for moving parts and ensures a uniform spacing between pixels. Secondly, the framing-camera spatial-scanning method uses a two-dimensional detector array comparable to the eye's retina. The need for movement is removed and an image is collected like a picture. This technique is more expensive but removes any issues associated with the stability of the platform. Although legacy techniques are still used in new products, these two techniques are preferable for airborne SAR platforms. Moreover, these techniques have previously been used for airborne SAR on platforms such as the Airborne Real-time Cueing Hyperspectral Enhanced Reconnaissance (ARCHER) which uses pushbroom scanning.[45] Acquisition techniques are shown in Figure 7.

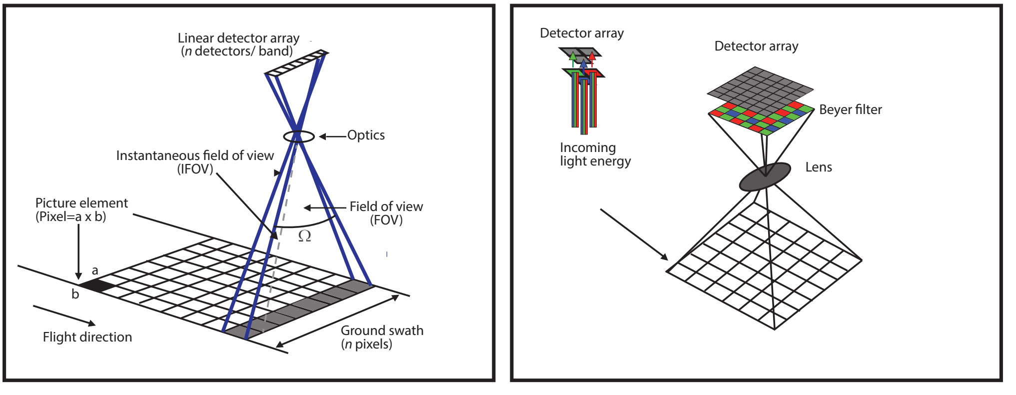

Figure 7. Left: pushbroom scanning; right: framing camera[46]

Using only spatial scanning, an airborne hyperspectral system for SAR would provide complete and relevant information of the scene. And although multiple spatial-scanning techniques exist, those providing more dwell time decrease the noise and maximize the detection rate. Therefore, only two spatial-scanning techniques are appropriate for this role: pushbroom scanning and framing camera.

SPECTRAL RESOLUTION

Within its narrow bandwidths (5 nm to 10 nm), the hyperspectral sensor is suitable for detecting, discriminating, classifying, identifying, recognizing and quantifying the acquired information. It is possible to differentiate between minerals, foliage and man-made materials by comparing the arrangement of wavelengths collected with a spectral signature database. Although the term *spectral signature* is used in this article and in referenced documentations, the concept of spectral signature is only true for pure materials isolated in laboratory.[47] In the natural environment, the angle at which the material is viewed and the angle of reflection will affect the reflectance collected. As well, the composition of a material will vary in nature compared to a pure material, which also changes its spectral reflectance. Therefore, the proper use of spectral data for SAR is not to seek an exact spectral signature match but instead to search for unique characteristics that match those within the spectral signature of the referenced material. The high spectral resolution of a hyperspectral sensor provides this capability.

The most important purpose of a hyperspectral sensor on a SAR mission is to detect and recognize a crash site, wreckage or human victim. A hyperspectral sensor can search for spectral characteristics of interest, such as those of human skin. The skin's spectral signature is defined mostly by the strong absorption of water, hemoglobin and melanin. With those characteristics, the Normalized Difference Skin Index (NDSI) was created in 2008 based on the proven concept for detecting vegetation. The NDSI uses two near-IR wavelengths, 1080 nm and 1580 nm, selected for being a local maximum and a local minimum on a spectral signature of the human skin, as seen in Figure 8.[48] The NDSI is calculated with Equation 2 using the intensity received for those specific wavelengths. A given pixel is highlighted if its index falls within a lower and upper limit. Of course, the high detection rate and the reduction of false detections are related to the proper determination of those limits. As a result, the use of the NDSI algorithm promotes the detection of a victim in pre-attentive processes.

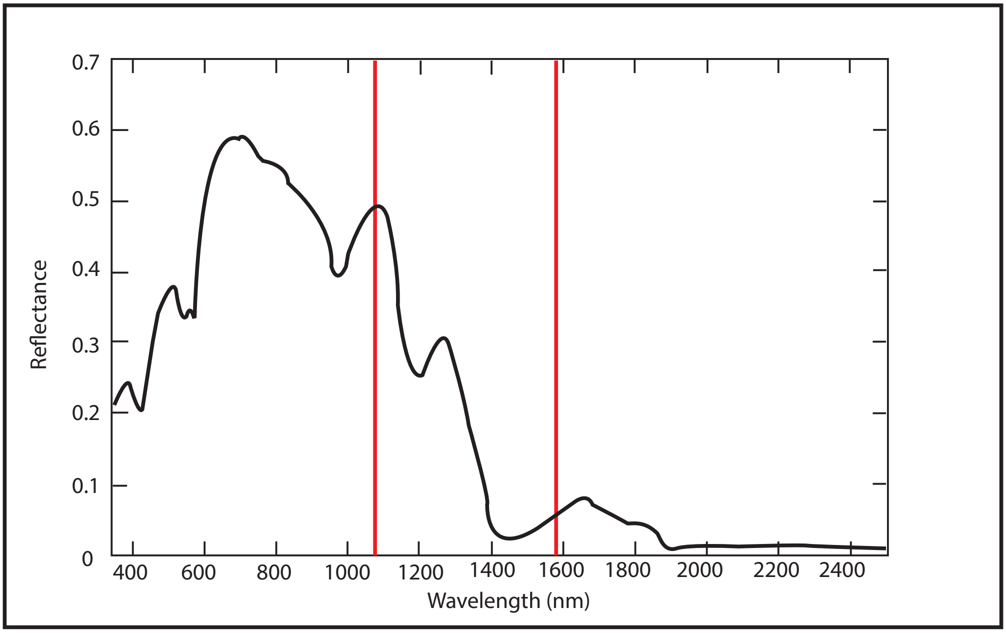

Figure 8. Spectral signature of the human skin with NDSI wavelength (1080 nm and 1580 nm)[49]

$$NDSI = \frac{\lambda(1080) - \lambda(1580)}{\lambda(1080) + \lambda(1580)} \tag{2}$$

Where:

$\lambda(1080)$ = received intensity of the 1080 nm wavelength
$\lambda(1580)$ = received intensity of the 1580 nm wavelength

Based on the premise that some portion of skin will not be covered, such as hands or face, the NDSI has demonstrated the ability to detect a human target in an urban environment, as shown in Figure 9. Although successful, the reliability of NDSI is affected by the background in two ways. First, to be detected in a given pixel, skin needs to fill a proportion of the pixel which varies with the background (see Table 3). Secondly, NDSI failed to detect skin submerged in as little as 5 millimetres of water.[50] Nonetheless, as long as there is skin visible, a hyperspectral system using the NDSI can increase the detection rate of victims while requiring minimal attention from the SAR Tech.

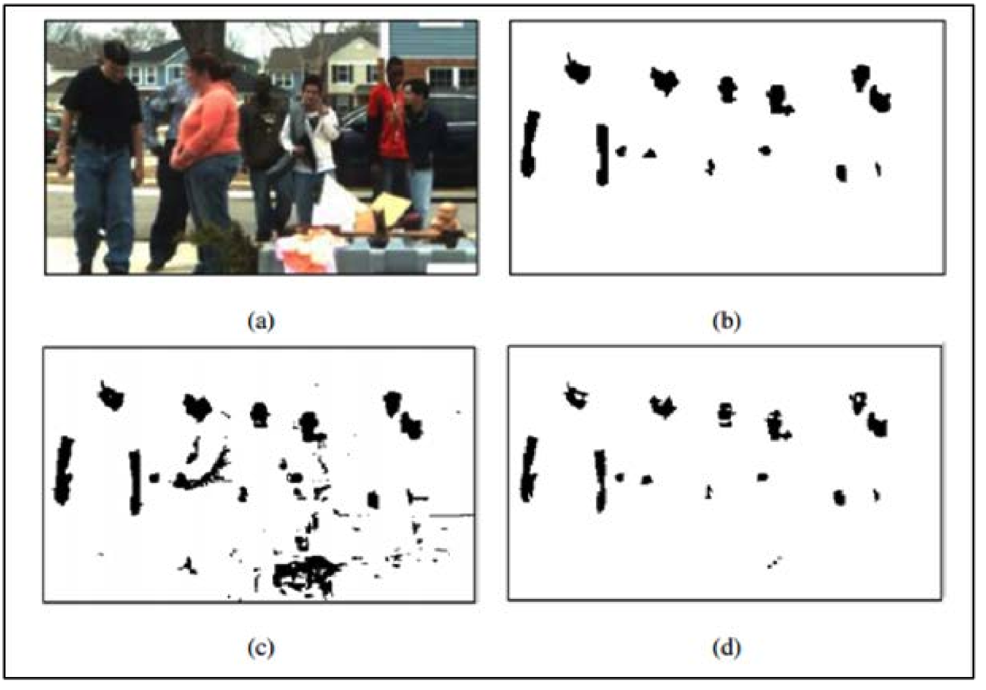

Figure 9. NDSI processed image: (a) Hyperspectral image featuring people with various skin colour; (b) Truth mask for the skin pixels; (c) A large NDSI threshold results in higher probability of detection and false detection; (d) A small NDSI threshold results in lower probability of detection and false detection[51]

Background	Minimum Proportion of Skin Required in a Pixel for Detection
Water	64%
Grass	70%
Sand	72%
Cloth	78%
Paint/Camouflage	Unknown

Table 3. Minimum proportion of skin required in a given pixel for detection[52]

Hyperspectral sensors have a high spectral resolution that can be used to search for specific characteristics in the spectral signature of targets of interest. Additionally, some algorithms have been proven successful at detecting specific characteristics and highlighting the pixel containing the characteristics. Those tools would promote detecting victims using pre-attentive processes of the visual memory of the SAR Tech and, consequently, would increase detection rate and range.

SPATIAL RESOLUTION

Based on the values in Table 3, the spatial resolution of the hyperspectral sensor is a key factor to determine if this is a viable option and an improvement over the capabilities of the unaided eye. The determinant scenario involves a victim in the water. The assumption is made that only the skin from the face is uncovered. Assuming a right triangle geometry as per Figure 3, the detection range of a 20 centimetre (cm) long face for the unaided eye is calculated at 343.77 metres (m). The TELOPS Airborne Hyper–Cam, which was used as a reference for spatial resolution, has a pixel size of 35 cm at 1000 m.[53] Therefore, the distance at which a 20 cm long face would be 64% of one pixel is calculated at 892.86 m by Equation 3. Hypothetically, using this hyperspectral sensor in conjunction with the NDSI would increase the detection range of a victim by more than 2½ times than that of the unaided eye. As demonstrated, the detection range varies with the spatial resolution of the hyperspectral sensor, but this system improves the detection rate and range.

$$\textit{Detection distance of skin using Hyper-Cam} = 1{,}000\ m * \frac{20\ cm}{64\% * 35\text{cm}} = 892.86\ m \qquad (3)$$

Not only does a hyperspectral sensor increase the type of information that can be detected, it can also increase the range of detection farther than aforementioned. Depending on the size of a target or the distance from which it is being looked at, there may be multiple materials in one pixel. Nonetheless, hyperspectral sensors can detect individual materials with as little as 1/10th of a pixel.[54] Therefore, with 1/10th of a pixel of the TELOPS Hyper–Cam, a 182.88 cm tall human with 50% of their body covered by clothing can be detected at 26.126 kilometres (km), as shown in Equation 4. Comparatively, the unaided eye can detect a 182.88 cm tall human at 3.14 km as shown in Table 1.

$$\textit{Detection distance of skin using Hyper-Cam} = 1 km * \frac{182.88\ cm * 50\%}{10\% * 35\text{cm}} = 26.126\ km \qquad (4)$$

The spatial resolution of a hyperspectral sensor varies with its applications and the algorithm used but is an improvement over the naked eye in most cases.

RADIOMETRIC RESOLUTION

The radiometric resolution of a sensor is dependent on two variables: the SNR at the detector and the "number of quantization levels used to digitize the continuous intensity value."[55] The most common quantization levels are 8-bit/pixel, 10-bit/pixel, 12-bit/pixel, 14-bit/pixel and 16-bit/pixel. These represent, respectively, 256 levels/pixel, 1,024 levels/pixel, 4,096 levels/pixel, 16,384 levels/pixel and 65,536 levels/pixel.[56] In comparison, the human eye—with a spectral resolution highly dependent on the radiometric resolution—can resolve approximately 132 levels in pre-attentive processes.[57] Although a higher quantization level provides greater details, the main drawback is the processing power required by the sensor.

PROCESSING

A hyperspectral sensor requires a superior processing capacity than most types of sensors, as it acquires significantly more data. Even more processing capacity is required to extract information from the acquired data, as it must suitably display information to promote detection by the pre-attentive processes of the visual memory. Two examples include an uncluttered display with symbols to highlight relevant information or, as shown in Figure 9(b), a blank image displaying only the potential targets. Moreover, to be efficient for a SAR mission, the image must be in real time with geolocation, enabling the SAR Tech to confirm the presence of a victim. Fortunately, the real-time processing of hyperspectral images is available as the computing power continues to follow Moore's Law.[58] In addition, the use of parallel architecture increases speed, decreases power consumption and decreases the weight of the system.[59] Hyperspectral sensors can now be used on airborne platforms for real-time searches as opposed to previous systems which needed to be processed post-mission.

This processing requirement can be made transparent to the SAR Tech by using software. Hence, a system could be designed for the SAR Tech to select an effective algorithm for the upcoming mission. Alerts could trigger when potential targets are detected by the hyperspectral system, while the SAR Tech performs their usual duties, promoting detection in pre-attentive processes.

RESULTS

Although the eye senses all visible wavelengths, it is feasible to search for specific colours in the FOV with a conscious effort. Likewise, a hyperspectral sensor can be geared towards specific spectral bands, conducting the conscious effort on behalf of the SAR Tech. And, unlike the human brain's processing, algorithms can be used to trigger pixels only when the information represents predetermined criteria. Displaying the pertinent information in real time promotes detection by the SAR Tech through pre-attentive processes of the visual memory. While a hyperspectral sensor allows the collection of multiple wavelengths, it is limited to its original design. Undeniably, a hyperspectral sensor complements the capabilities of a SAR Tech as summarized in Table 4.

Specification	Human Physiology	Hyperspectral Sensor
Electromagnetic Sensitivity Band	• 380–700 nm (visible spectrum)	• 10 nm to 1 mm (UV to IR)
FOV	• 7° useful FOV • 200° x 135° total	• variable depending on the system • TELOPS Hyper–Cam has: ◦ 6.4° x 5.1°
Spatial Resolution	• 30 cycle/degree • for a human target: ◦ detection – 3.14 km ◦ recognition – 0.786 km ◦ identification – 0.491 km	• variable depending on the optic and detector • 1/10th of a pixel (any wavelength) • 64% of a pixel (NDSI) • for a human target: ◦ detection – estimated as 26.126 km ◦ recognition – variable ◦ identification – not applicable to hyperspectral sensor
Processing	• visual memory • pre-attentive processing (unconscious) • post-attentive processing (conscious)	• promoting detection in pre-attentive processing: ◦ real time ◦ parallel architecture ◦ use of algorithms (i.e., NDSI)

Specification	Human Physiology	Hyperspectral Sensor
Radiometric Resolution	• > 14% variation required • approximately 132 levels (see Spectral Resolution)	• depends on the SNR ◦ improved with dwell time • depends on the number of quantization levels (bits) ◦ 8-bit (or 256 levels)/px ◦ 10-bit (1,024 levels)/px ◦ 12-bit (4,096 levels)/px ◦ 14-bit (16,384 levels)/px ◦ 16-bit (65,536 levels)/px
Spectral Resolution	• > 21% variation required • approximately 100 colours • between 16 and 32 shades of black and white	• 5–10 nm bandwidth
Reliability	• vigilance decrement ◦ 15 minutes for normal workload and normal stress ◦ 5 minutes for heavy workload or high stress level	• stable performance over the course of a SAR mission • promotes a decrease in SAR Tech vigilance decrement rate

Table 4. Human and hyperspectral sensor specifications

PART IV – ARG IMAGING TECHNOLOGY

The range at which sensors, operating in the UV to IR spectrums, can resolve objects is greatly diminished by inclement weather compared to those sensitive to longer wavelengths. As the electromagnetic energy travels in the atmosphere, it collides with particles of various sizes, causing scattering. The more scattering there is, the less energy that the sensor's aperture receives. As well, the energy received is obstructed by the scattered light, resulting in a low SNR. As shown in Figure 10, longer wavelengths such as radar waves are only impacted by bigger particles, but visible and IR wavelengths are affected by almost all sizes of particles. Most of the particles listed are water based and exist in atmospheric conditions encountered regularly during SAR missions. To search for a victim in those conditions, the SAR Tech requires a sensor that maximizes the SNR. ARG sensors provide the ability to see through inclement weather by filtering the noise, hence increasing the SNR.[60] Figure 11 shows the effect of ARG technology at a range of 400 m through snow.

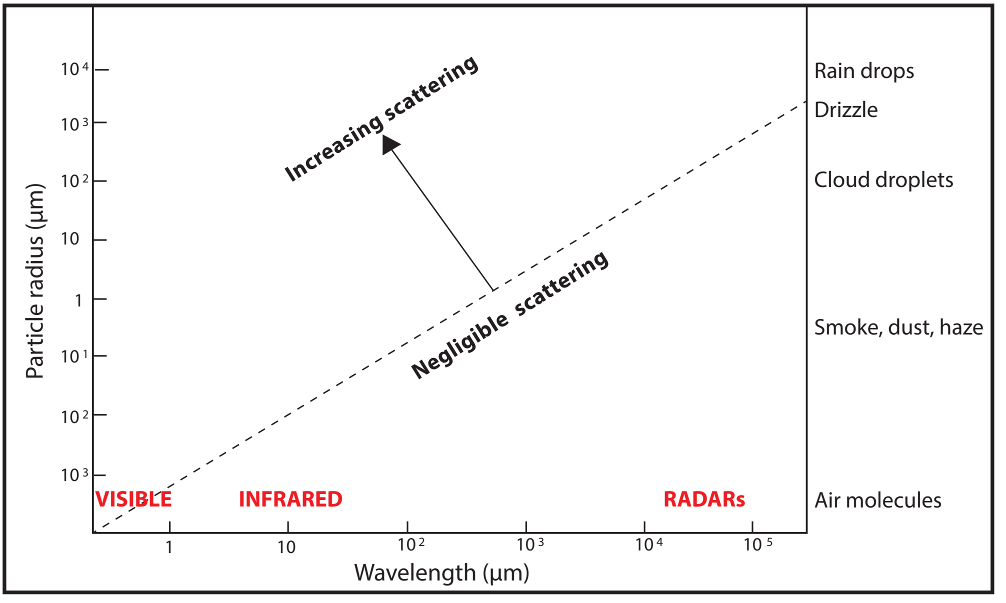

Figure 10. Effect of particles size on scattering relative to wavelengths[61]

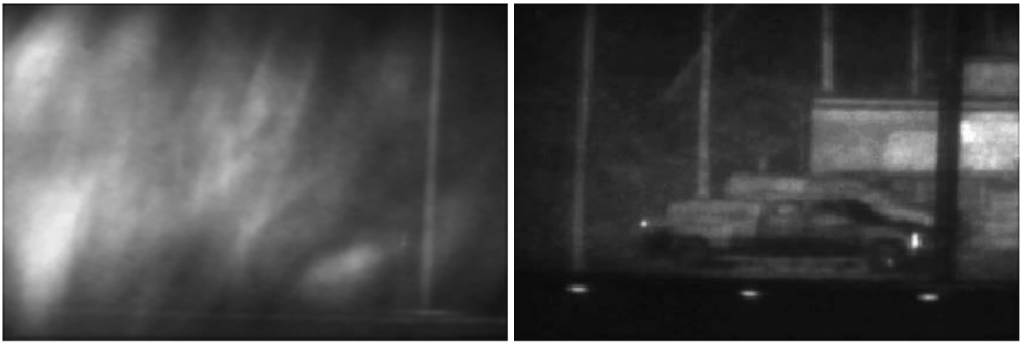

Figure 11. Left: 400 m through snow without ARG. Right: 400 m through snow with ARG

ELECTROMAGNETIC SENSITIVITY BAND

ARG sensors consist of three main components: a gated camera, an illuminator and a controller. A gated camera is one that has a short exposure time and has a shutter system to collect information at specific delays. The illuminator consists of a wide-beam pulsed laser that illuminates the scene. As shown in Figure 10, particles in the atmosphere have less of an impact on IR than they do on visible light. Since the illumination will be directed at victims, the laser should be eye safe. Therefore, the short-wave infrared (SWIR) wavelengths (0.9 to 1.7 micrometres [µm]) are ideal in an ARG sensor for SAR.[62] Similar to visible light, SWIR light is reflected, creating shadows and contrast in the image.

As with a hyperspectral sensor, an ARG sensor will be sensitive to the electromagnetic band towards which it was designed. Additionally, the hyperspectral sensor does not need to be sensitive to any wavelengths other than the wavelength of its laser to be effective. Practically, the SWIR wavelengths contribute to optimizing the sensor's safety and performance.

PRINCIPLE OF OPERATION

The principle of operation of the ARG imaging technology is shown in Figure 12. The illuminator sends a pulse of precise width. The controller calculates the travel time of the pulse to the desired range based on the speed of light. Once this calculated time has passed, the controller commands the camera to open the gate and collect information for the same duration as the laser pulse width was emitted by the illuminator. This is called the gate width. The shorter the pulse width and the gate width, the less ambient and scattered light that can enter the system. Only the light reflected at the desired location, during the pulse width, is displayed. Therefore, the system can see through obscurants—as long as enough laser pulse energy penetrates the obscurants in both directions—and does not display the light reflected by objects behind the target. The image is a slice in space and excludes everything else, as shown in Figure 13 and Figure 14. By reducing the noise, the SNR is increased.

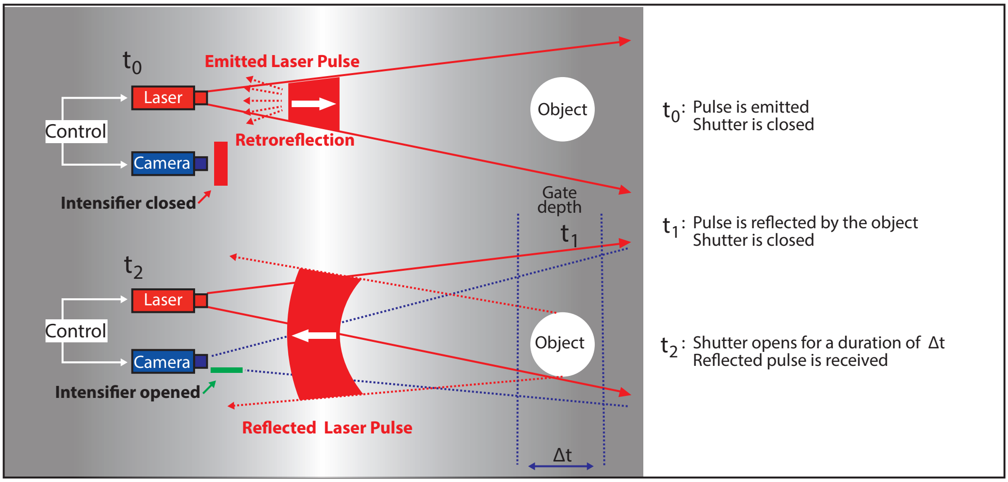

Figure 12. ARG imaging technology principle of operation[63]

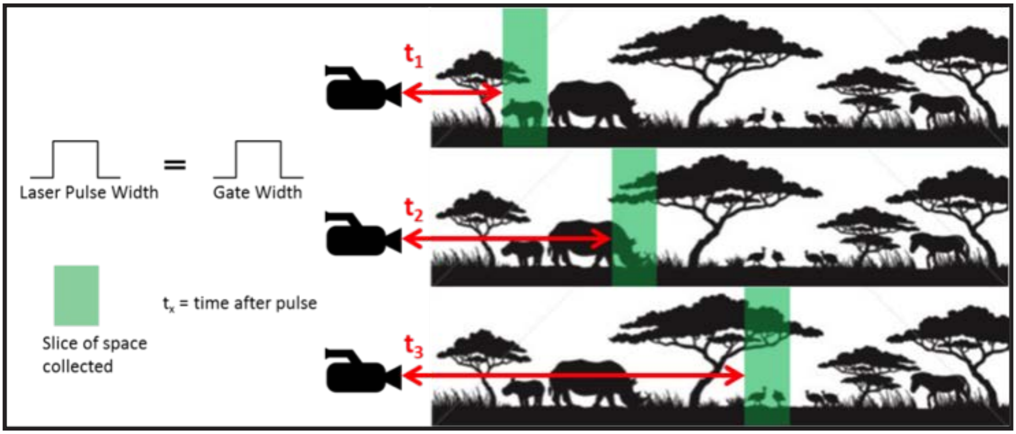

Figure 13. Slice of space collected when the ARG camera shutter opens after t_x time

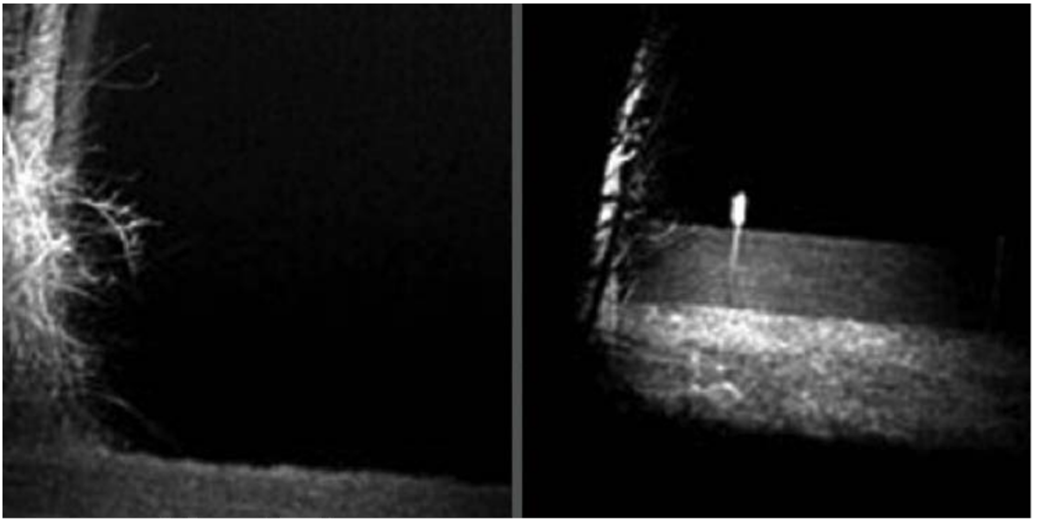

Figure 14. Image of different slice of space[64]

SPATIAL RESOLUTION

Assuming that the pulsed laser illuminator is sufficiently powerful, the spatial resolution of an ARG sensor is mainly dependent on the detector and the optics of the camera. The reflected pulsed laser light is focused on the detector by the optic of the camera. Assuming an ARG sensor similar to the one used by Steinvall in its image quality experiment, a resolution of 7 microradians (μrad) would result in the detection of a 182.88 cm human at 13.062 km, recognition at 3.27 km and identification at 2.04 km,[65] which is over four times the spatial resolution of the human eye.

In addition to the sensor's hardware, the laser pulse width and the gate width also influence the spatial resolution. A system with shorter pulse and gate width will collect less ambient and scattered light while trying to collect the desired reflection. The noise from scattered light—as well as the noise created by turbulence in the atmosphere between the sensor and the scene—will create scintillation speckle in the image, reducing the spatial resolution. An ARG sensor will generally use the information received during multiple frames to remove some noise from the image. But since the ARG sensor for SAR will be airborne, the displacement in space of the sensor between each frame will affect the extent of the noise reduction.[66] An image with a high SNR will contribute to a better spatial resolution, and the spatial resolution will improve as more frames are received. For an airborne system, stabilization is required, and the software needs to account for the aircraft's movement.

Based on the technical specifications, a SAR Tech could detect a human, using an ARG sensor, at up to 13.062 km. However, this is only true for the better images with multiple frames received. As well, as per the human eye, clutter in the image may prevent detection. If there are other objects near the human, the location is still detected, but it is impossible to know that it could be a human until the range is close enough for recognition. Since the image is monochrome, a green tree and a human wearing an orange suit appear as grey dots at the detection range. Therefore, even though an ARG sensor can be used for detection, it is better suited for recognition and identification.

RADIOMETRIC RESOLUTION

The radiometric resolution of an ARG sensor is crucial for creating a detailed image. Since the data is digitized into an image, using a similar principle as a hyperspectral sensor, the radiometric resolution is also dependent on SNR at the collector and the number of quantization levels used to digitize the signal. The most common quantization levels are the same as used on hyperspectral sensors.[67]

PROCESSING

The active involvement of the SAR Tech is required to operate an ARG sensor and assess the image. Consequently, it adds to the workload of the SAR Tech. ARG sensors display the image in real time and could provide geolocation as would a forward looking infrared sensor. But, as opposed to hyperspectral imaging, ARG sensors do not provide the ability to automatically detect a potential target based on the reflected wavelength received by the sensor and do not remove superfluous information from the image. Although, as per any surveillance camera, an image processing algorithm for pattern, shape or movement recognition could be applied to the system to assist in assessing the image. By providing an improved image to the SAR Tech, compared to conditions of a visual search in inclement weather, it is expected that an ARG sensor would reduce fatigue and increase detection range.

RESULTS

An ARG sensor allows a SAR Tech to see through inclement weather. It can be used to detect a 182.88 cm tall victim at ranges up to 13.062 km on land but is best used for recognition and identification at ranges up to 3.27 km and 2.04 km respectively. To improve performance and ensure safety, an ARG sensor for SAR should be using the SWIR wavelengths, which are eye safe. The ARG sensor's spectral resolution is high for the pulse laser wavelength, which improves the SNR. The data collected by the camera is digitized, and depending on the quantization levels designed into the system, the ARG sensor can provide a high radiometric resolution of up to 65,536 levels. Although the FOV can be similar to or greater than the useful FOV of the human eye, the information displayed still requires the SAR Tech, who has a useful FOV of 7°, to scan the image to detect the target. The constant involvement required of the SAR Tech to operate the sensor and scan the image leads to a heavy reliance on post-attentive processes of the visual memory and does not help to reduce the vigilance decrement. This is the main disadvantage of an ARG sensor. Nonetheless, the capabilities of an ARG sensor complement those of the SAR Tech as summarized in Table 5.

Specification	Human Physiology	Hyperspectral Sensor	Active Range-Gated
Electromagnetic Sensitivity Band	• 380–700 nm (visible spectrum)	• 10 nm to 1 mm (UV to IR)	• SWIR (0.9–1.7 µm)
FOV	• 7° useful FOV • 200° x 135° total	• variable depending on the system • TELOPS Hyper–Cam has: ◦ 6.4° x 5.1°	• variable depending on the system • Obzerv's Modular Active Range-Gated Camera68 has a variable wide FOV of 1.2° to 47°
Spatial Resolution	• 30 cycle/degree • for a human target: ◦ detection – 3.14 km ◦ recognition – 0.786 km ◦ identification – 0.491 km	• variable depending on the optic and detector • 1/10th of a pixel (any wavelength) • 64% of a pixel (NDSI) • for a human target: ◦ detection – estimated as 26.126 km ◦ recognition – variable ◦ identification – not applicable to hyperspectral sensor	• variable depending on the optic and detector • affected by the SNR • for a human target: ◦ detection – 13.062 km ◦ recognition – 3.27 km ◦ identification – 2.04 km
Processing	• visual memory • pre-attentive processing (unconscious) • post-attentive processing (conscious)	• promoting detection in pre-attentive processing: ◦ real time ◦ parallel architecture ◦ use of algorithms (i.e., NDSI)	• promoting detection in pre-attentive processing: ◦ if using pattern-recognition software ◦ otherwise, it requires conscious effort from the SAR Tech
Radiometric Resolution	• > 14% variation required • approximately 132 levels (see Spectral Resolution)	• depends on the SNR • improved with dwell time • depends on the number of quantization levels (bits) ◦ 8-bit (or 256 levels)/px ◦ 10-bit (1,024 levels)/px ◦ 12-bit (4,096 levels)/px ◦ 14-bit (16,384 levels)/px ◦ 16-bit (65,536 levels)/px	• depends on the SNR • improved with dwell time. • depends on the number of quantization levels (bits) ◦ 8-bit (or 256 levels)/px ◦ 10-bit (1,024 levels)/px ◦ 12-bit (4,096 levels)/px ◦ 14-bit (16,384 levels)/px ◦ 16-bit (65,536 levels)/px
Spectral Resolution	• > 21% variation required • approximately 100 colours • between 16 and 32 shades of black and white	• 5–10 nm bandwidth	• focused on the wavelength of the pulse laser
Reliability	• vigilance decrement ◦ 15 minutes for normal workload and normal stress ◦ 5 minutes for heavy workload or high stress level	• stable performance over the course of a SAR mission • promotes a decrease in SAR Tech vigilance decrement rate	• stable performance over the course of a SAR mission • requires dedicated attention from the SAR Tech ◦ although the image is better than the outside visibility, the vigilance decrement is most likely similar

Table 5. Human, hyperspectral sensor and ARG sensor specifications

PART V – ADVANCED INTEGRATED MULTI-SENSING SURVEILLANCE

PURPOSE OF ARG SENSORS

The Canadian Armed Forces (CAF) was involved with ARG imaging technology as early as 2004. A prototype sensor was built by Defence Research and Development Canada (DRDC) and was tested airborne in 2011.[69] The AIMS system consisted of an ARG sensor and a thermal IR sensor mounted in a Wescam MX-20 turret. The AIMS system was designed for medium ranges. In the future, the ARG sensor could be tested at ranges up to 20 km by increasing the power of the pulsed laser. During a snowing night, a SAR Tech using the ARG sensor detected a human at 5.4 km,[70] but this range was increased to 8.3 km if the victim wore a life jacket with retro-reflectors.[71] Reflective bands return a particularly bright reflection. The report concluded that an ARG sensor is effective for recognition and identification at ranges up to 10 km. Notwithstanding an operational situation, the small FOV of the ARG sensor—although similar to the useful FOV of the human eye—would make it difficult to search a realistic area. Consequently, the ARG sensor alone was not recommended for detection if other tools could be used.

THERMAL IMAGER AND ARG SENSOR SYSTEM

DRDC AIMS also included a cooled far infrared (FIR) thermal imager, as both systems offer complementary attributes. Thermal IR energy penetrates fog better than pulsed laser energy. Recalling Figure 10, the longer the wavelength, the less it is impacted by particles in the atmosphere. Therefore, if searching for a warm vehicle or a human being, the thermal signature can be detected using the thermal imager. However, the level of emissivity in contrast with the background had a significant impact on the detection ability.[72] The main advantage of a thermal imager is its contribution to detection by pre-attentive processes of the visual memory. As the aircraft flies over the area of interest, the scene in the FOV moves relatively rapidly. It was observed during testing that unless the SAR Tech was actively keeping the sensor on a location on the ground, it took 23 seconds for the Twin Otter to fly over the ground FOV length of 1,422 m. Hence, the victim was visible in the display for only 23 seconds.[73] With a contrasting IR signature, the SAR Tech could detect the target immediately. Whereas when using the monochrome ARG sensor, a conscious effort from the SAR Tech may be required unless the outline of the target has a unique feature compared to the background. Although the thermal imager may provide a higher detection rate, in the right conditions, both sensors have similar ranges for detection. Since the ARG sensor provides more details of the scene viewed through fog, it is effective for recognition and identification. Hence, both systems are complementary to one another and would be more effective if used together.

OPERATOR-MACHINE INTERFACE

Of interest, the last lesson learned for the ARG sensor is the requirement for a simple operator-machine interface (OMI). CAE Professional Services assessed the AIMS system for human factors and conducted a task workload analysis on the CP140 Aurora. The conclusion mentioned the suitability of the current implementation but recommended a reduction of the workload for a future variant.[74]

PART VI – CONCLUDING MATERIAL

SUMMARY

Current RCAF SAR assets are not equipped with the latest technologies, such as hyperspectral and ARG imaging, which would increase the effectiveness and efficiency of SAR missions. Consequently, SAR Techs in Canada conduct searches from airborne platforms relying mainly on the capabilities inherent to human physiology. The primary objective for using a sensor is to promote detecting victims without a conscious effort from the SAR Tech. Detection in pre-attentive processes of the visual memory requires less effort and increases mission effectiveness. Inversely, using post-attentive processes of the visual memory will promote vigilance decrement in the SAR Tech, affect the reliability and reduce the effectiveness of the mission.

Naturally, the human eye is limited to the visible spectrum, and the brain does not have the ability to completely filter some information in order to highlight other. Valuable information is contained in other parts of the electromagnetic spectrum, and crucial knowledge can be gained by removing clutter in the information. This is possible by using a hyperspectral sensor, as it can be designed for sensitivity to a wider selection of bands within the electromagnetic spectrum, from UV to IR, and its high spectral resolution of hundreds of bandwidths from 5 nm to 10 nm removes clutter. A hyperspectral sensor can collect information from thousands of narrow bandwidths almost instantly while a human is limited, during a short glance, to approximately 100 colours and 16 to 32 shades of black and white. This chromatic resolution is also greatly affected by the radiometric resolution of the eye, which requires at least 14% difference in intensity to perceive a contrast. The radiometric resolution of a digital sensor reaches up to 65,536 levels that can be differentiated from one another, while the human eye can instantly discriminate only 132 hues.

In addition, the human eye cannot see through obscurants in the atmosphere. Hence, when searching for a victim in inclement weather, the SAR Tech experiences a greater vigilance decrement due to the heavy workload and stress. It could be expected to begin within as little as 5 minutes vice within 15 minutes for normal operations. This can be alleviated by using an ARG sensor which uses a pulsed laser to illuminate the scene and only collects the reflected light from the laser pulse, filtering the noise and consequently increasing the SNR. This sensor can detect a victim on land at an estimated range of up to 13.062 km as opposed to the human eye which is limited to the atmospheric visibility.

Nonetheless, a commonly reported disadvantage of the use of sensors is the small FOV displayed to the operator. Although humans have a wide FOV, the peripheral vision will not contribute to a visual search if the victim is seemingly immobile. This leaves the SAR Tech with a useful FOV of 7°, within which the maximal spatial resolution permits the detection of a victim on land at ranges up to 3.14 km. In comparison, this FOV is similar in size to the one of a hyperspectral sensor or an ARG sensor. However, both sensors provide the ability to detect a victim from at least twice and up to eight times the range of the human eye.

CONCLUSION

With the increase in processing capability of computers, a hyperspectral sensor can now be used on airborne platforms to provide real-time information. With the use of algorithms, alerts could be triggered when potential targets are detected, and the relevant information can be highlighted on the display. This would promote detecting victims at a greater range while using only pre-attentive processes of the visual memory. For the RCAF SAR role, the hyperspectral imaging technology is a valuable addition and is better suited for detection of pre-planned bandwidths, to be used in algorithms such as the NDSI, instead of displaying all the information that can be collected.

In addition, using ARG imaging technology onboard RCAF SAR assets would enable a SAR Tech to see through inclement weather. The high spatial resolution provides in excess of four times the detection, recognition and identification ranges of the human eye. However, the image is monochrome, and this impedes detection of the human in contrast with surrounding items. Hence, ARG imaging technology is better suited for recognition and identification. Furthermore, an ARG sensor would help reduce vigilance decrement in the SAR Tech by providing a clear image vice searching through fog. However, the constant involvement of the SAR Tech required to operate the sensor and search the display would increase the workload unless pattern-recognition software is used. The vigilance decrement is, therefore, expected to remain the same with or without the use of an ARG sensor, but the detection rate and range would be increased.

RECOMMENDATION

All the imaging technologies covered in this article (hyperspectral, ARG and thermal) are commercially available for airborne sensors. The RCAF SAR assets should be equipped with a hyperspectral sensor designed to conduct spatial scanning using either pushbroom-scanning or framing-camera methods, as others are less reliable and effective on airborne platforms. The system should use algorithms to search for relevant narrow bandwidths and alert the SAR Tech when points of interest are detected while highlighting the relevant information. Moreover, tools such as the NDSI should be used on all missions to detect skin. This has the potential to significantly increase detection rate and range.

In addition, the use of an ARG imaging technology on SAR missions was proven to be effective during the testing of AIMS in 2011. However, it is recommended to use the SWIR wavelengths in the illuminator to optimize performance and the system's safety. Furthermore, it is recommended to integrate a thermal imager in the ARG sensor, as both systems are complementary. The thermal imager would facilitate detection, as it indicates that the point on the display has a temperature contrast with the background, whereas the ARG sensor would enable identifying the victim.

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ABBREVIATIONS

°	degree
%	per cent
λ	lambda
AIMS	Advanced Integrated Multi-Sensing Surveillance
ARG	active range-gated
CAF	Canadian Armed Forces
cm	centimetre
DRDC	Defence Research and Development Canada
FOV	field of view
IR	infrared
km	kilometre
m	metres
mL	millilambert
NDSI	Normalized Difference Skin Index
nm	nanometre

px	pixel
RCAF	Royal Canadian Air Force
SAR	search and rescue
SAR Tech	search and rescue technician
SNR	signal-to-noise ratio
SWIR	short-wave infrared
UV	ultraviolet
µm	micrometre

NOTES

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3. *Visual Short Term Memory* will be referred to as *visual memory* in this document.

4. Pre-attentive processing: Subconscious accumulation of information from the environment. It is done quickly, effortlessly and in parallel, without any attention being focused on the image. From J. T. Enns, "Attention and Visual Memory in Visualization and Computer Graphics," *Transactions on Visualization and Computer Graphics* 18, no. 7 (July 2012).

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11. Scotopic: Denoting vision in dim light.

12. Photopic: Denoting vision in bright light.

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17. Useful field of view (UFOV): Visual area over which information can be extracted at a brief glance, in a single fixation, without eye or head movements.

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21. Top-down activation: user-driven attempt to verify hypotheses or answer questions by glancing about an image, searching for the necessary visual information. Enns, "Attention and Visual Memory."

22. Enns, "Attention and Visual Memory."

23. Post-attentive processing: Conscious processing of the visual information.

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25. Enns, "Attention and Visual Memory."

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27. Luminance: Intensity of the light.

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The main argument for improving the use of imaging technology for SAR missions is to help SAR Technicians, like Sergeant Bruno Lapointe (pictured), ensure That Others May Live. Photo: DND

Overview of Precision Strike Capability for CP140 and CC130J

by Major D. G. Jamont, CD, MDS

Photo: DND

Editor's note: This paper was written by a candidate attending the Canadian Forces College in fulfilment of one of the requirements of the course of studies.

Aim

The aim of this article is to provide an overview of possible options for the addition of a precision strike capability to either the Royal Canadian Air Force (RCAF) CP140 Aurora or CC130J Hercules airframe. This article discusses the operating environment that such a strike capability could be employed in, the capabilities that should be considered for a project, the potential of the CP140 and/or CC130J as growth platforms, the new roles and missions these platforms could perform and the possible barriers that could disrupt the implementation of such a capability. Future areas of investigation should include studying the technical feasibility and engineering impact of installing a precision guided munition (PGM) capability on these aircraft.

Introduction

This article was written in response to the Commander (Comd) RCAF's list of research topics for 2016, specifically F-11: Investigate the advantages of providing a precision-strike capability to manned, long-range/high-endurance intelligence, surveillance and reconnaissance (ISR) platforms. The use of PGMs in conventional, asymmetric and hybrid warfare has seen a significant rise since Operation (Op) DESERT STORM in 1991. PGM use is expected to continue to rise in the coming years, with the focus on air strikes as the primary delivery method.[1] By leveraging existing technology for targeting and weapons systems and applying lessons learned from our allies, the RCAF has the opportunity to build upon its existing strike capability that is currently resident only within the CF188 Hornet fleet.

Discussion

Theory/Assumptions

It should be acknowledged immediately that the implementation of an ISR precision strike capability should be expected to take a minimum of 5 years, with a likely 5–10 year window to see delivery or installation. RCAF Shape doctrine states that armed ISR platforms provide advantage and flexibility: "A platform that is both capable of collecting information and acting upon it blurs the lines between intelligence collection (Sense) and operations (Shape), emphasizing the flexibility, versatility, and responsiveness of aerospace power."[2] It is expected that this platform would only be used in permissive and semi-permissive environments. The assumed survivability of these aircraft in a non-permissive environment—where air superiority or supremacy is not guaranteed and area defence weapons are present—is assumed to be low.[3] Equipping another fleet with precision strike capability will build upon the RCAF doctrinal tenets of flexibility and versatility, which are "key to the effective employment of aerospace power. Inherently flexible and uniquely versatile, aerospace resources can be quickly and decisively shifted from one objective to another across a broad spectrum at the strategic, operational, or tactical levels of conflict."[4] The platform and associated PGM capability should be oriented towards being useful in a near-peer, hostile-force engagement. To avoid the pitfall of "re-fighting the last war," any future capability should be employable in such a campaign. If we prepare for a near-peer engagement, counter-insurgency (COIN), asymmetric and hybrid warfare conflicts capabilities will already exist. The lessons learned in Afghanistan, those of a COIN campaign with a permissive air environment, could be incorrect in this respect, where air power was able to be concentrated and operate at will without a credible threat from opposition forces.[5]

Platforms

The CP140 Aurora is the only dedicated ISR aircraft in the RCAF. It has grown from being an antisubmarine warfare (ASW)-centric asset into a multirole ISR platform, operating over land, in the littorals and in open ocean areas. The fleet continues to develop proficiency in the over-land role—conducting littoral and over-land ISR as well as strike coordination and reconnaissance coordination (SCAR-C) during Op MOBILE—and is involved in over-land operations in Op IMPACT in Iraq. It is in the midst of a midlife refit which will result in a total fleet of 14 aircraft, each receiving wing and empennage structural upgrades as well as avionics upgrades delivered in several blocks. Block 3 is scheduled to be at full operational capability (FOC) in mid-2019, with Block 4 reaching initial operational capability (IOC) around the same time period. The aircraft has a 14-hour endurance, enabling long on-station periods, and a bomb bay that is capable of carrying eight Mk-46 ASW torpedoes. Physically, the bomb bay has the space to carry a similar number of PGMs of similar size, up to approximately 500 pounds [227 kilograms] each, using Mk-46 specifications. Internally stored sonobuoys are only marginally smaller and lighter than some PGMs and are deployed in a similar manner. The aircraft is capable of being fitted with 10 external hard points, but the recent wing upgrade does not currently have hard points installed, and the supporting ordnance wiring is unconfirmed to still be in place. The MX-20 electro-optic/infrared (EO/IR) turret is able to image targets from overt and covert profiles, day or night. No laser devices are mounted in the turret. Current statements of life cycle place the CP140 in service until 2030.

The CC130J Hercules is a new fleet to the RCAF; the last CC130J was delivered in 2012 for a total of 17 airframes. It is currently employed as a transport aircraft, with an endurance of 12 hours, and is able to deliver troops and cargo to austere landing strips. Its cargo area represents a configurable area for roll-on roll-off (ro-ro) mission equipment that could see it used in a variety of roles, for example, ISR and aerial fire support. The RCAF CC130J does not possess integral weapons storage or any type of imaging or targeting sensor, but the flexibility of the configurable cargo area allows fitment of the required mission equipment. The Canadian Special Operations Forces Command (CANSOFCOM)-sponsored Special Airborne Mission Installation and Response (SABIR) project to equip the CC130J with a ro-ro EO/IR turret and crew console has been shelved at present.

Capabilities for Consideration

USMC Harvest HAWK

The United States Marine Corps (USMC) has modified several KC-130J tankers as dual-purpose refuellers with ISR/gunship capability by installing the ro-ro Hercules Airborne Weapons Kit (HAWK). The Harvest HAWK is specifically designed around the C-130J airframe, with installation taking approximately 6 months for the wiring fitment and approximately 8 hours for the roll-on installation.[6] Open-source defence websites place the cost of a HAWK at approximately US$6.2M each, but this value is unconfirmed, and any level of service support is unclear.[7] The kit delivers precision strike to a high-endurance platform and provides precision targeting, video downlink, Blue Force Tracker and multiple PGM options. A USMC report cited the long loiter time and pinpoint accuracy of the KC-130J as key enablers in providing effective close air support (CAS) to land operations in Afghanistan.[8] The HAWK kit allows internally stored PGMs to be deployed through a Derringer door in place of a paratroop door, similar to internal sonobuoy launches aboard the CP140. This allows the aircraft to remain pressurized during weapon drops, decreasing response time to calls for fire support while allowing it to remain at a higher altitude, increasing effective weapons ranges and allowing greater stand-off from targets. Currently, the kit replaces a refuelling pod with four AGM-114 Hellfire missiles, and internally, it carries a mix of up to 10 AGM-176A Griffin glide bombs or GBU-44 Viper Strike glide bombs that are manually loaded into the Derringer door. A 30 millimetre canon is scheduled to be integrated in future updates. The two-person crew console is palletized and rolls on for installation, allowing quick reconfiguration. The EO/IR targeting sensor turret includes EO/IR sensors, plus laser designation and range finding. This kit represents a proven, plug-and-play hardware solution to the option of arming a C-130J.

Choice of Weapons

The selection of available PGMs is broad. To maintain agility across a variety of mission sets, a munition, or set of munitions, should be selected to be multipurpose, sustainable and interoperable. The purpose of this analysis is not to propose a specific solution but to identify the characteristics of existing PGMs that could satisfy the Comd's request. The required effects must be determined for the weapons. Should it be able to precisely strike and destroy a building or strike an apartment in that building without destroying the building? It should be capable of day/night operation and of striking fixed and moving targets. The Griffin and Viper Strike PGMs used in Harvest HAWK are proven to engage fixed and moving targets by employing global positioning system / inertial navigation system guidance plus terminal laser guidance. Laser guidance is critical to engaging moving targets using existing PGM technology. This capability would permit the prosecution of time sensitive targets (TST) that could be in motion. Laser guidance should be able to be self-designated, "buddy-designated" by other aircraft or designated by ground forces. Multiple warhead options could be a desired attribute, allowing different target sets to be serviced by one munition using different warheads. Interoperability should also be considered as new fleets and capabilities are procured. Procuring a PGM that is used across fleets—for example the CP140, CC130J, Joint Unmanned Surveillance and Target Acquisition System (JUSTAS) and next-generation fighter—would considerably enhance the Sustain function in the provision of munitions to a deployed air task force by reducing the variety of munitions required.

At a higher level, interoperability with allies, using the United States for example, could gain purchasing, development and upgrade advantages with the defence industry. However, the counterargument to that advantage is that American forces could likely have priority in the delivery of munitions ahead of foreign military sales to Canada. Interoperability of munitions with coalition partners could allow leveraging of their supply lines and have the desired effect of reducing the dependence on receiving supplies directly from Canada, a key lesson identified during Ops MOBILE and IMPACT.[9] Multiple types of PGMs should be considered for high-endurance ISR platforms in order to allow flexibility in the delivery of the desired kinetic effect from a single platform. With an appropriately armed CP140, it could transition between multiple roles: ASW attack using Mk-46 torpedoes; antisurface warfare (ASuW) attack using a Harpoon or similar PGM; land attack against hardened structures using a munition similar to GBU-39/53 Small Diameter Bomb; and finally, engage a mobile TST in a crowded environment using something similar to GBU-44 Viper Strike with a precise, low-collateral-damage warhead.

CP140 Aurora and CC130J Hercules – Common Requirements

Both platforms would benefit greatly from a signals intelligence (SIGINT) capability, which would enable greater information fidelity by providing definition and context to the visual image that is presented on EO/IR sensor displays. CANSOFCOM operations would be enhanced if a SIGINT capability was aboard long-range, high-endurance ISR platforms, as it would provide more utility and greater integration. Options of fitting aircraft "for, but not with" would provide supported commanders with greater flexibility, depending on mission sets that involve dynamic targeting, as "accurate and timely intelligence is critical to maximizing the inherent offensive advantages of aerospace power."[10] Furthermore, "during the Finish phase of a Find-Fix-Finish [special operations forces (SOF)] direct action mission, manned ISR assets are considered critical to success."[11] RCAF Sense doctrine states, "surveillance and reconnaissance activities are normally conducted by units that have significant self-protection or stand-off capabilities. They are often assigned to support other combat tasks by providing combat information."[12] Enhanced countermeasures would be mandatory if these platforms were to be employed as part of a package in a non-permissive environment that includes hostile air forces or area defence systems like radar-guided surface-to-air missiles (SAMs). It is critical that a variety of options for kinetic and non-kinetic aerospace effects is provided to supported commanders.

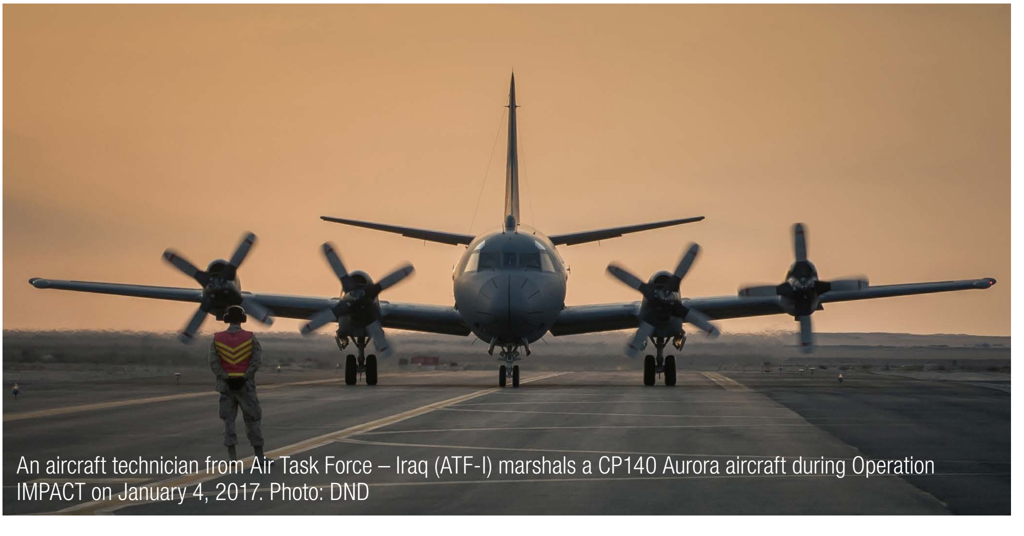
Expansion of Roles

If furnished with a PGM strike capability, the CP140 or CC130J or their manned/unmanned replacements would be capable of employing kinetic effects across a greater spectrum of missions. Doctrinally, these would include support to SOF (aerial fire support and armed overwatch) and support to counter-land missions (air interdiction, aerial fire support, CAS, tactical security as well as direction and control of fires).[13] This represents a significant growth from the predominantly over-land/over-water ISR role that the CP140 fills and the tactical-transport role that CC130J fills. This growth would reduce pressure on the CF188 fleet to provide strike effects and would also provide commanders at the joint-, air- and land-component levels with additional options for both ISR and kinetic effects.

Barriers to Development

Personnel

Significant frictions from both communities will likely delay the development and implementation of a precision strike capability to either the CP140 or CC130J. The author contends that a capability is a combination of correctly trained personnel and appropriate hardware. Both fleets would need to either source additional personnel trained as forward air controllers or joint terminal attack controllers to crew the aircraft or establish an appropriate training programme to qualify aircrew to employ the weapons system. In this environment of person year (PY) neutral establishment changes, the availability of correctly trained personnel and positions will be a barrier to establishing IOC of the PGM capability, regardless of fleet.



An aircraft technician from Air Task Force – Iraq (ATF-I) marshals a CP140 Aurora aircraft during Operation IMPACT on January 4, 2017. Photo: DND

CP140 Aurora

The CP140 is in the midst of a phased upgrade that is not set to reach IOC of its final phase, Block 4, until 2019.[14] Inserting a weapons requirement into this process will not be possible until IOC is declared, as it will delay the upgrade programme at great cost and delay to the overall Aurora Incremental Modernization Project (AIMP).[15] From an airframe standpoint, given enough time, funding and priority, anything is possible if the requirement is supported and funding is available: the bomb bay could be configured for PGMs; hard points could be installed and wired; internal drop chutes, like the Derringer door, could be installed; and capabilities like countermeasures, a laser designator and SIGINT could be added. Significant flight testing would be required for the external carriage of munitions.[16] The limiting factors in this case are PY levels, capital-project funding, amount of aircraft engineering required and the political will to develop an armed ISR capability in an aircraft that is slated to be removed from service in 2030. The Aurora's lifespan may require that the RCAF take the long-term view of integrating a PGM strike capability into the CP140 replacement. Spending the time, money and engineering to install a weapons suite on the CP140 may only yield 6–8 years of service life. Conversely, developing this capability now may firmly establish PGM strike capability in the fleet, making its transition to the CP140 replacement straightforward.

CC130J Hercules

The Hercules fleet is new and is not slated for retirement in the near future. The major limiting factor is that Lockheed Martin (LM) is the prime contractor for the interim-service-support contract, meaning that any design change or engineering test must be run by LM at cost to the Government of Canada, as "this ensures proper transition to their in-service management role … ."[17] Normally, integral engineering units, like the Aerospace Engineering Test Establishment, perform such roles for RCAF fleets, but this has been outsourced for the time being to LM. Training personnel will require significant effort to convert aircrews from a transport-oriented community into one that is proficient in ISR, targeting and weapons employment, a skill set that the CP140 community already has and is continuing to develop.

Conclusion

The future operating environment will continue to be dynamic, and the RCAF should be prepared to provide additional kinetic and non-kinetic effects to supported commanders in upcoming campaigns. Developing and implementing a precision strike capability on high-endurance platforms will provide such agility. PGMs should be selected to be interoperable, sustainable and effective across RCAF fleets and, potentially, across allied fleets as well. Leveraging existing engineering testing and development, such as the USMC Harvest HAWK, could enable a more rapid technical and operational approval process with RCAF fleets. Establishing a strike capability within the CP140 and/or CC130J fleets will require significant effort to overcome multiple barriers to implementation, including personnel, funding and the development of political will. However, establishing this capability in the near future will enable an easier transition to precision strike for future airframes within the RCAF, bringing depth to kinetic options for future operations, be they against a near-peer adversary or in a hybrid context.

Major Jamont is currently the Commandant of the Canadian Forces School of Survival and Aeromedical Training located at 17 Wing Winnipeg. He has flown operationally at both 407 Demon Squadron and 405 Pathfinder Squadron and instructed at the CP140 Operational Training Unit,

404 Squadron. Operational deployments include Op SIRIUS 2004, Op SAFARI 2007, Summit of the Americas 2009 and Op MOBILE 2011. Major Jamont served as an air liaison officer with CANSOFCOM and completed Joint Command and Staff Programme 42 in June 2016.

Abbreviations

ASW	antisubmarine warfare
CANSOFCOM	Canadian Special Operations Forces Command
CAS	close air support
COIN	counter-insurgency
comd	commander
DND	Department of National Defence
EO	electro-optic
HAWK	Hercules Airborne Weapons Kit
IOC	initial operational capability
IR	infrared
ISR	intelligence, surveillance and reconnaissance
LM	Lockheed Martin
Op	operation
PGM	precision guided munition
PY	person year
RCAF	Royal Canadian Air Force
ro-ro	roll-on roll-off
SIGINT	signals intelligence
SOF	special operations forces
TST	time sensitive targets
USMC	United States Marine Corps

Notes

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LECKIE AWARD

Commander RCAF, Lieutenant-General M. J. Hood and RCAF Command Chief Warrant Officer, Chief Warrant Officer Gérard Poitras, present Lieutenant-Colonel Jean-Philippe Gagnon with the inaugural Leckie Award for his paper "RCAF C4ISR: At a Turning Point," which follows.

In order to promote vital airpower research within the Royal Canadian Air Force (RCAF), the RCAF Commander has instituted a series of awards that will recognize individuals who contribute first-class papers that address airpower-related issues.

Five research awards have been established, and the third to be awarded in the series is the Leckie Award, which is presented annually to a Joint Command and Staff Programme student (either distance learning or residential) and equivalent allied programmes for a pre-eminent (non-directed research project) paper on a capability-focused airpower topic.

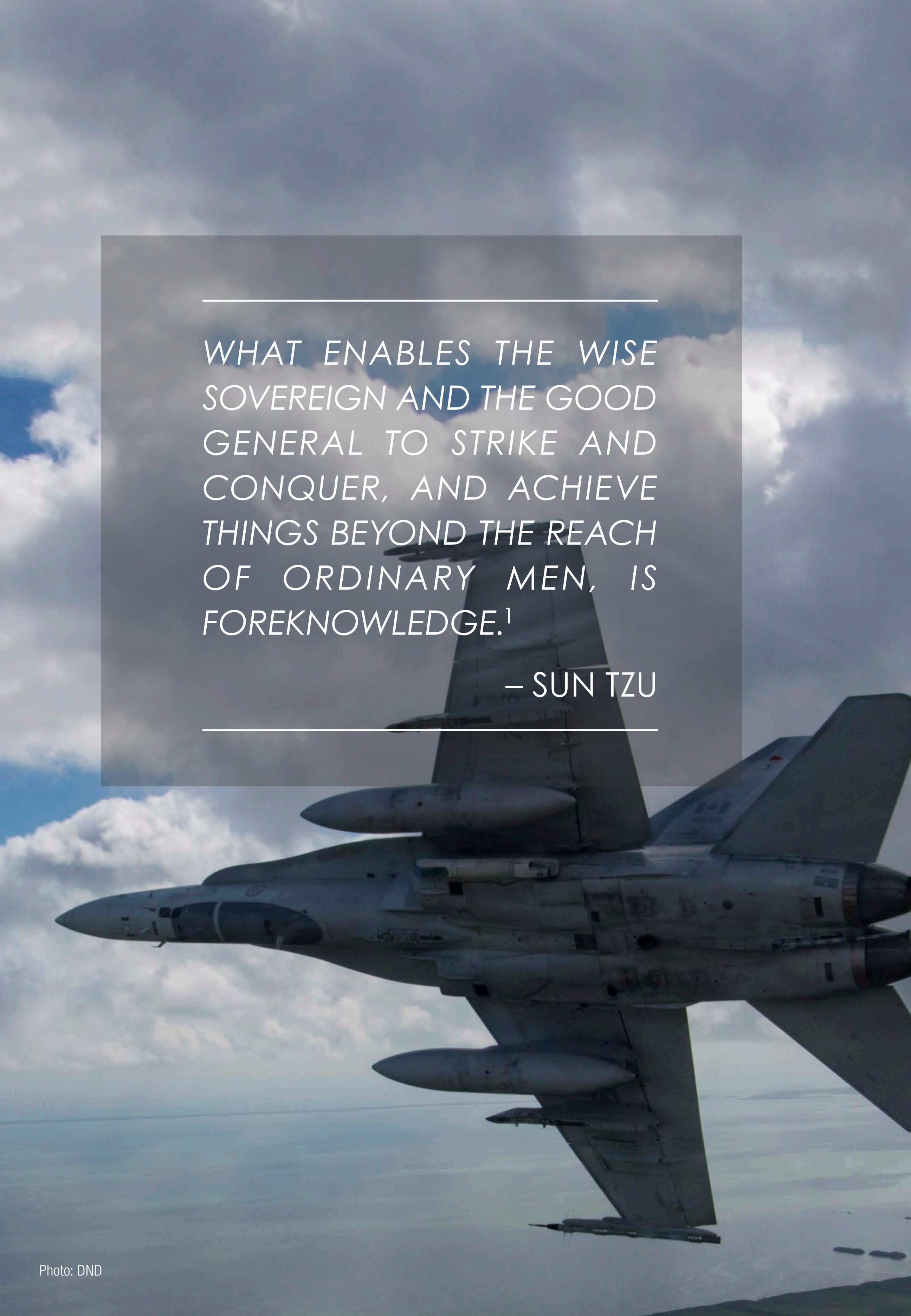
The Leckie Award is so-named in recognition of Air Marshal Robert Leckie, Companion of the Order of the Bath, Distinguished Service Order for Gallantry, Distinguished Service Cross, Distinguished Flying Cross and Canadian Forces Decoration. Leckie joined Britain's Royal Naval Air Service in 1915 after learning to fly at the Curtiss Aviation School in Toronto. He flew HS-2L Curtiss flying boats for the duration of the Great War and accepted a permanent commission in the Royal Air Force as a wing commander in 1919. He transferred to the RCAF in 1942 as an air vice-marshal and, upon promotion to air marshal, became the RCAF's Chief of the Air Staff from 1944 until his retirement on 1 September 1947. He was known for dedicated service and unmatched leadership qualities that were demonstrated during both World Wars.

Following military service, he was appointed special consultant to the Air Cadet League; he passed away 31 March 1975.

RCAF C4ISR | AT A TURNING POINT

By Lieutenant-Colonel J. C. J. P. Gagnon, CD, MDS, MBA

Photo: DND



WHAT ENABLES THE WISE SOVEREIGN AND THE GOOD GENERAL TO STRIKE AND CONQUER, AND ACHIEVE THINGS BEYOND THE REACH OF ORDINARY MEN, IS FOREKNOWLEDGE.[1]

– SUN TZU

Photo: DND

INTRODUCTION

In the last 20 years, exponential growth in computing power has changed how modern society interacts. This technological revolution has also affected military forces, which have needed to adapt to this leap into the information age. Nowhere has this been more evident than in the C4ISR (command, control, communications, computers, intelligence, surveillance and reconnaissance) domain because of its heavy reliance on technology. The Canadian Armed Forces (CAF) recognizes the need to adapt its approach to C4ISR, and it has charted a course with *The CAF C4ISR Strategic Vision, Goals and Objectives*,[2] which provides the intent for the organization to meet this challenge. The Royal Canadian Air Force (RCAF) is at a technological crossroad, and it must decide how it will embrace this opportunity for change in its C4ISR enterprise. Since much research has been done in the field of organizational change, it can be useful to examine how these principles can be applied to the dilemma faced by the RCAF today. This article will, thus, use organizational-change theory as a backdrop to examine how the RCAF can embrace the required change effort in the C4ISR enterprise.

First, the concept of C4ISR will be explained to provide the reader with an understanding of what it entails for military operations. Then the world of C4ISR will be examined to explore the various aspects that pose significant challenges to effective integration on the modern battlefield. After introducing organizational-change theory, the next section will explore what two of Canada's closest allied air forces, the United States (US) and Australia, have done to progress their C4ISR enterprise. To bring this analysis to the Canadian context, the article will then examine what has been done to date in the C4ISR domain in CAF and the RCAF.

Finally, by using organizational-change models as a tool and by drawing on recent lessons from our closest allies, the final section will make high-level recommendations on how the RCAF can chart a course to move its C4ISR enterprise forward in the rapidly evolving technological environment.

C4ISR DEFINED

The basic premise of C4ISR is to leverage the synergy and interconnection of people, technology and processes to provide the commander with accurate and timely information to achieve decision superiority.[3] To provide an understanding of C4ISR, it is useful to isolate and analyse its separate components, while keeping in mind that C4ISR is only effective when all components are working tightly together. The first two *C*s represent the command and control (C2) aspect of the process and relate to the commander's ability to understand the information provided to make informed decisions and then to communicate their intent to direct operations. The next two *C*s are communications and computers; they relate to the communication and information systems (CIS) used to get the gathered information from the sensors to the commander or warfighter. This is the backbone of C4ISR; it comprises all communication links across various systems and the exploitation systems themselves. The *I* stands for intelligence, the process of analysing collected data to make deductions and interpretations, which result in information products for the commander to enable their decision-making process. Finally, *S* and *R* entail the activities of surveillance and reconnaissance of enemy forces to gather data and observe their actions. Reconnaissance implies a wide "search for data and information about a target or area of interest,"[4] while surveillance translates into a more persistent monitoring function akin to a police stakeout.

Another concept that is often used while talking about C4ISR is the processing, exploitation and dissemination (PED) function. PED is the activity where data and information provided by the sensors are processed and exploited and then disseminated to decision makers at all levels. Through the PED process, the intelligence product must arrive at the appropriate time and with enough interpretation to be useful to the commander or warfighter.

C4ISR is, therefore, the all-encompassing grouping of a system of systems that must work seamlessly to enable decision superiority by providing the right information, at the right time, to the right person. When we relate C4ISR to the kill-chain concept of "find, fix, track, target, engage and assess," it is obvious that C4ISR is part of most of these steps, and hence, C4ISR activities are operations in themselves, not just supporting operations as was previously conceptually accepted.[5]

THE PROBLEM WITH C4ISR

Before the advent of modern computers, the collection of information and its transformation into an intelligence product was a slow, methodical process. Until recently, the intelligence environment was a very specific domain with dedicated resources, such as the U-2 aircraft, being used to collect specific information about an area or a designated target. As computing power increased and sensors miniaturized, new systems were developed that could be used on a variety of non-traditional intelligence platforms and that could relay their information to the commander or even directly to the warfighter in real time or near real time. As those capabilities were fielded, individual militaries and services within them acquired their own systems to suit their individual needs. These systems were not designed with a common architecture, and therefore, present-day armed forces, such as CAF, are left with a variety of disparate systems that are not easily interoperable. A compelling RCAF example of this phenomenon can be observed in the various incompatible tactical data link (TDL) systems fitted to RCAF aircraft that have traditionally not worked together:

> The RCAF currently operates only three air assets capable of TDL: the CF-188 has Link 16 while the CP-140 operates Link 11. The CH-124 Sea King has a locally created ad hoc TDL capable of linking with select RCN [Royal Canadian Navy] assets. Both Link 16 and Link 11 standards are not compatible unless a common interface is remotely used to fuse the information and create a recognized air picture (RAP). The Hornet cannot exchange Link 16 data with the Aurora and neither of them can exchange TDL data with the army. The Sea King can only link with a few RCN assets. Even the CF-18's version of Link 16 is not fully interoperable with coalition partners, since the Link 16 message format was not fully implemented.[6]

What makes this challenge even more daunting is that the technological gap is not limited to different platforms; it also extends to different sensors installed on the same platform. The information collected by the myriad of sensors is not always formatted in a way that can be distributed and easily used across a networked architecture. The CIS network, itself, must be robust enough to handle a growing volume of data, which requires a tremendous bandwidth capacity to cope with multiple sources of imagery and other data-intensive products.

Because C4ISR interactions require the participation of many organizations, it does not align well with the traditional boundaries of the separate air, sea and land environments. This affects a variety of facets, such as the procurement system where each environment is typically defending its own projects that are competing for a limited funding envelope. This often leaves C4ISR with no clear leading organization that can champion C4ISR initiatives. Also, since C4ISR links the traditionally separate worlds of intelligence and flying operations, there is still a perceived division within the C4ISR enterprise; the Vice Chief of the Defence Staff (VCDS) observed that the "lack of integration between the intelligence and operations process is one area where C4ISR capability is particularly weak."[7]

Finally, another problem with C4ISR is the many, and often conflicting, uses of the term by its various players. Often the acronym is broken down in its subcomponents or components are added such as target acquisition (TA), which yields new acronyms—like intelligence, surveillance and reconnaissance (ISR); joint intelligence, surveillance and reconnaissance (JISR); command, control, communications, computers and intelligence (C4I); reconnaissance, surveillance and target acquisition (RSTA); and intelligence, surveillance, target acquisition and reconnaissance (ISTAR)—that are used interchangeably, thus leading to confusion.[8] The Canadian Army, for example, uses the term ISTAR in its doctrine, even though its definition more closely resembles that of C4ISR.[9] The RCAF refers to ISR in its Sense doctrine, yet it links ISR to command and networks; the more appropriate term is C4ISR because that is exactly what the C4 portion of the term implies.[10] Without agreeing on which term should be used across the environments, it is difficult to define a way ahead that is inclusive for all players. To this end, it would be useful if all stakeholders in CAF would agree to use the term C4ISR when talking about any part of the enterprise.

Within this context, C4ISR must evolve into a better-optimized system, where all components of the organization must adapt to take advantage of the opportunity from the paradigm shift of the information age. Adapting the C4ISR enterprise can be the catalyst that will force the RCAF to fully embrace this technological shift. Using change-management principles to frame the challenge of moving C4ISR forward in the RCAF can be useful to evaluate and adjust the approach taken by its senior leadership. Using this framework to explore what other countries and their air forces are doing as well as to determine what approach is favoured in each instance provides insights into how the RCAF could instigate and sustain a C4ISR transformation.

CHANGE THEORY

Because the challenge (and opportunity) for the RCAF—caused by the required adaptation to the new C4ISR reality—will affect it as a whole, it is an organizational change. *Leadership in the Canadian Forces: Conceptual Foundations* has identified a theoretical model that can be used to guide the examination of the direction the RCAF is taking for this organizational-change effort.[11] In this volume, the seminal work of Harvard Business School professor John P. Kotter identifies eight critical success factors that can determine if an organizational-change effort will succeed. These eight steps are:

1. establishing a sense of urgency;
2. forming a powerful guiding coalition;
3. creating a vision;
4. communicating the vision;
5. empowering others to act on the vision;

6. planning for and creating short-term wins;

7. consolidating improvements and producing still more change; and

8. institutionalizing new approaches.[12]

Further research by organizational-consultants William Bridges and Susan Mitchell have broken down the change process into three distinct phases: endings, neutral zone and new beginnings.[13] In the ending phase, Bridges and Mitchell point out that it is important to identify why the status quo is no longer acceptable and to help the organization and its members understand that they must let go of the past.[14] The neutral zone is the transition phase where the leadership must listen to concerns emanating from the organization, delineate clear expectations and provide resources to help the transition to the next phase.[15] The new-beginnings phase is characterized by accepting that things will be done differently and that these new ways are becoming the new normal. Every member of the organization will not transition through these phases at the same pace; therefore, care must be taken to ensure that in the neutral zone, short-term wins are celebrated to facilitate the transition to the next phase.[16]

Finally, an area that cannot be overlooked in organizational change is the political behaviour of various stakeholders when they are struggling for power. David Buchanan, professor of organizational behaviour at De Montfort University in Leicester, conducted extensive research in organizational-change politics, and in an article written with Richard Badham, he observed that political manoeuvring must be acknowledged and addressed.[17] Power brokers in the change effort yield significant influence that can help or hinder the successful outcome of the desired change. It is, therefore, important to exert influence early on the opinions of various stakeholders to ensure that political behaviour is controlled from the onset of the change effort.

CLOSE ALLIES' CHANGES TO C4ISR

Although the context of US and Australian air forces is slightly different than in Canada, many parallels can be drawn with respect to the challenge of adapting their C4ISR enterprise to the changing technological environment. By doing so, lessons can be identified to help frame the best practices from these two close allies and help pave the path for the RCAF in its approach to the C4ISR challenge.

The US military's edge is based in part on its technological advantage on the battlefield, and as such, it has encountered the challenges of the information age ahead of most militaries. To adapt to these new realities, the United States Air Force (USAF) approached its C4ISR problem with a fresh new perspective, following many of Kotter's steps to organizational change. The first initiative was to tackle the problem doctrinally; Air Force Doctrine Document 2-9, *Intelligence, Surveillance, and Reconnaissance Operations* was reviewed and revised extensively in 2007 to impart a *sense of urgency* to change how C4ISR was viewed. Building on this doctrinal foundation, USAF *created a powerful vision*: "a transformational vision of networked and linked sensors that is shrinking the sensor-to-shooter cycle and is giving commanders greater situational awareness and better predictive intelligence necessary to achieve decision superiority and battlefield dominance."[18] Enabled by this vision, USAF *empowered* its technological leaders to develop the distributed common ground system (DCGS) to connect its multiple intelligence sensors and platforms into a network-centric weapon system.[19] The DCGS was pivotal in enabling the C4ISR vision. To continue *communicating* the change initiative and reinforcing the strategic vision, a document entitled "Air Force ISR 2023: Delivering Decision Advantage" was released in 2013. It continued to provide "vision, mission, core tenets, and priorities—that will guide the AF ISR enterprise."[20] To *institutionalize* this refocus, a complete restructure of its C4ISR enterprise was carried out. This recently realigned the entire USAF C4ISR capabilities under the 25th Air Force, moving intelligence assets from the Deputy Chief of Staff ISR to the Air Combat Command, making official the concept that C4ISR is not a supporting enterprise but, rather, is a core operational focus of USAF.[21] Finally, in its latest future-operating-concept document, the vision of a connected C4ISR enterprise is pushed even further into the core missions of multidomain command and control (MDC2) and global integrated intelligence, surveillance, and reconnaissance (GIISR). GIISR supports the idea that, at least the ISR portion of, C4ISR "is the foundation upon which every joint, interagency, and coalition operation achieves success."[22] In the last decade, USAF—following many organizational-change principles—has carried out this C4ISR transformation convincingly. They have developed a more coherent C4ISR enterprise, with better sensors integrated into a robust interconnected system of systems, within a revitalized organizational structure, optimized for its operational role.

The Royal Australian Air Force (RAAF) is also espousing a path of transformational change in its C4ISR enterprise. However, the RAAF shift has followed a different dynamic than USAF did. The catalyst of the change initiative in this case is an unprecedented level of equipment renewal. In the recent past and short-term future, the RAAF has and will acquire an array of high-technology platforms such as the F-35A Lightning II, the EA-18G Growler, the P-8A Poseidon, the E-7A Wedgetail and the MQ-4C Triton.[23] This provided the perfect culmination of events to *create a sense of urgency* from within the RAAF and initiate a vision for organizational change. This vision was articulated in a transformative programme, Plan Jericho, that seeks to inspire the entire organization towards an RAAF optimized for the information age. Plan Jericho's *vision* is "to develop a future force that is agile and adaptive, fully immersed in the information age, and truly joint."[24] Although Plan Jericho is not a uniquely C4ISR initiative, most of the programme of work is geared towards networking "a modern, fully integrated combat force that can deliver air and space power effects in the information age."[25] One of the most compelling and recurring themes for this transformation is the statement that Plan Jericho will make "the difference between being an Air Force with fifth generation aircraft, and being a fifth generation Air Force."[26] The RAAF is careful to ensure its workforce contributes to change with the second theme of Plan Jericho: "develop an innovative and empowered workforce."[27] This approach of bottom-up innovation seeks to encourage initiative at all levels of the organization, as suggested by Kotter in his step five: empowering others to act on the vision.[28] The RAAF is shifting from new beginnings into the neutral stage, and following Kotter's step of creating short-term wins, it is deliberately communicating its immediate success within Plan Jericho, as reported recently:

> Operators of the AP-3C Orion aircraft within Air Force's Surveillance and Response Group adapted an existing military surveillance video technology for use outside the classified networks, such as by state and federal emergency services. The Orion is an older aircraft, not one typically looked to for creating new capability. At the recent Air Power Conference, Group Captain Phil Champion demonstrated the results of the improvements by streaming full motion video from one of his aircraft, live, during his presentation.[29]

Sgt Brian Nelson, an Airborne Electronic Sensor Operator on 407 Sqn at 19 Wing Comox, carries out a check of the MX 20 Wescam Turret Electro-Optic Infrared (EO/IR) Camera System onboard the Aurora CP140 aircraft. Photo: DND

Canadian Forces Griffon and Chinook helicopters fly in formation from Kandahar Airfield to Camp Bastion to begin OP MOSHTARAK. Photo: DND

The first Heron UAV, built for operations in Afghanistan. Photo: DND

CAF C4ISR CHALLENGE

In the Canadian context, the struggle with the complex C4ISR problem is more recent. Up to a few years ago, CAF did not have a unified C4ISR strategy, leaving individual environments to manage their needs in isolation. This left an empty space that created significant environment rivalries and, as Buchanan and Badham suggest, room for political manoeuvring to secure funds to procure similar capabilities. A lack of C4ISR governance structure to harmonize requirements and doctrine across CAF was detrimental to the enterprise, as noted by the VCDS:

> Platforms and assets are controlled across several levels of command and by many services, components, departments, and agencies without joint or integrated doctrine or standards guiding integration and force employment. Sensors for the most part, have been platform specific, operated by single organizations and not well integrated into operational networks.[30]

With the experience of the Afghanistan conflict highlighting the need for "timely and reliable access to intelligently fused information," the Chief of the Defence Staff (CDS) issued a directive in June 2012 to align "C2, CIS, and ISR into an integrated C4ISR architecture."[31] This CDS directive established the Chief of Force Development (CFD) as the CAF lead for joint C4ISR requirements in an effort to help the C4ISR enterprise converge across CAF. To achieve this, within the CFD organization, the Directorate of Integrated Command and Control became the Directorate of C4ISR (D/C4ISR) and was designated as the "C4ISR Lead Architect for the Department."[32] Arguably, the chain of command for D/C4ISR within the CFD organization—falling under the Director General Space (DG Space) and later moved under the Director General Cyberspace (DG Cyber)—was not conducive to raising the profile of C4ISR to the level it should have been. The C4ISR organization, at a minimum, should be at the director general (DG) level, alongside DG Space and DG Cyber. This would have better served the C4ISR enterprise when the change effort was introduced and could have created a stronger sense of urgency of the required change intent. With many level one advisors (L1s)—such as the environmental chiefs of staff (ECSs), the Commander of the Canadian Joint Operation Command (CJOC), the Commander of the Canadian Forces Intelligence Command (CFINTCOM) and the Assistant Deputy Minister (Information Management) [ADM(IM)]—as stakeholders in the complex C4ISR problem, the limited authority and legitimacy of a directorate-level organization (D/C4ISR) reduced the immediate impact of the CDS directive. This can be related to Kotter's step two of not creating a powerful-enough guiding coalition. In an effort to increase the legitimacy of the C4ISR enterprise, a year later in another CDS directive, the Strategic Joint Staff, an L1 organization, was tasked to "identify a CAF OPI [office of primary interest] that will institutionalize ISR operations in the CAF."[33]

Nonetheless, the initial CDS directive was well understood by the newly created D/C4ISR, and it created a vision that gives direction to the CAF-wide C4ISR enterprise. Under the authority of the VCDS, D/C4ISR crafted and recently released two documents that have the potential to shape the CAF C4ISR enterprise. The first document, *The CAF C4ISR Strategic Vision, Goals and Objectives*, provides CAF with an all-encompassing C4ISR vision statement: "To provide the right knowledge to the right people at the right time in a secure, reliable, and integrated manner in support of Canadian Armed Forces operations."[34] This is the capstone document for the strategic approach that CAF is directed to take to conceive, design and build its C4ISR capabilities.[35] The second document, "Joint Intelligence Surveillance and Reconnaissance Operating Concept," is subordinate to the first document, and it seeks to emphasize more specifically the establishment of a "framework for the efficient, flexible, adaptable development of JISR capabilities."[36] This document is more focused in its approach by concentrating specifically on the ISR portion of the

C4ISR enterprise and by placing emphasis on collection operations driven by intelligence requirements. There is a danger in isolating JISR within the CAF C4ISR enterprise, as it might reinforce the division of responsibilities and capabilities that is the source of one of the major obstacles of implementing an all-encompassing CAF C4ISR enterprise.

However, the direction provided in these two documents should help bring legitimacy to the C4ISR enterprise by following Kotter's steps of creating and communicating the vision as well as creating a powerful-enough coalition. Unfortunately, Kotter's initial step of establishing a sense of urgency seems to be lacking in both rather lengthy documents.

RCAF C4ISR

In the last 10 years, the RCAF also faced a colossal C4ISR challenge with the introduction of new sensors in various platforms such as the CF188 SNIPER pod, the CP140 MX-20 camera and Block 3 modernized mission suite, the CH146 Griffon MX-15 camera and the Heron unmanned air vehicle (UAV) in Afghanistan as well as the upcoming CH148 Cyclone and Joint Unmanned Surveillance and Target Acquisition System (JUSTAS). Many of these new or upgraded systems were introduced in isolation without consideration of how the huge volume of information they gather would be shared across the RCAF and CAF.

The RCAF is aware of the challenge of integrating its existing platforms into a C4ISR capability of a system of systems. In the last few years, it has captured this concept within a series of documents, both at the strategic and operational levels, but has not done so within a specific C4ISR framework. The RCAF has articulated its overall strategic guidance framework in *Air Force Vectors* (*AFV*), the capstone RCAF publication that "contains the broad guidance necessary to illuminate and target what the future Air Force will look like."[37] *AFV* also establishes the RCAF vision of having "An agile and integrated air force with the reach and power essential for CAF operations."[38] *AFV*'s second vector, "integrated," states that the RCAF "will maintain and advance interoperability and pursue full-networked capability" which are clearly goals that are necessary for the success of the C4ISR enterprise.[39] However, it fails to specifically link these efforts to the C4ISR concept and does not use the acronym even once in the whole "integrated" vector section. Although *AFV* espouses jointness and establishes surveillance and reconnaissance as one of its core capabilities, it fails to integrate C4ISR as an RCAF operating concept within the CAF C4ISR enterprise. At the doctrine level, B-GA-402-000/FP-001, *Canadian Forces Aerospace Sense Doctrine* supports those same principles but fails to address the complex C4ISR problem as a whole.

In *The Royal Canadian Air Force Future Concepts Directive* (*FCD*), the RCAF seeks to foster a force development (FD) framework to help shape the future RCAF. The second core theme in the *FCD*, "Networked Sensors with a Shared Picture," addresses the RCAF C4ISR challenge directly, even though it does not use the term C4ISR.[40] Yet, again, it fails to explicitly make the link to higher CAF C4ISR concepts and keeps each domain separate in later sections. This decreases the impact of tackling the complex C4ISR problem and reduces the opportunity to funnel resources to develop integrated solutions in a future C4ISR-enabled RCAF.

Finally, the *Royal Canadian Air Force Campaign Plan* is the execution document for the Commander RCAF to prioritize efforts at the strategic level. In this document, C4ISR is not addressed directly. The only mention of systems related to C4ISR is in the "support" section where intelligence and PED support are touched on briefly.

At the operational level, the Commander of 1 Canadian Air Division (1 Cdn Air Div) recently released the 1 Cdn Air Div ISR directive.[41] Although it is ISR specific, this document clarifies the functions and responsibilities of ISR operations in 1 Cdn Air Div. It is both prescriptive in how ISR will be accomplished and educative for those who are less familiar with ISR principles. The ISR directive is a step in the right direction, as it demystifies the ISR and PED processes, but it is overly focused on existing capabilities and the overland full-motion video (FMV) mission at the expense of the greater C4ISR enterprise. It deliberately ignores ISR operations in the maritime surface and subsurface domain as well as the processing of other ISR data, such as synthetic aperture radar (SAR) imaging, ground moving target indicator (GMTI) data and signals intelligence (SIGINT) data. It does, however, explain and significantly develop the PED capability that is nascent at the Combined Aerospace Operations Centre (CAOC), but it leaves many questions as to how C4ISR will come together lower in the organization at the wing and squadron levels.

A significant strategic-level challenge for the RCAF is the current organizational structure, with responsibility for C4ISR being spread out among many players without a clear C4ISR champion at a high enough level to provide the convergence necessary to guide the required progress. Because those responsibilities are shared, close coordination between the Director General Air Force Development (DG Air FD), the Director General Air Readiness (DG Air Rdns) and the Next Generation Fighter Capability (NGFC) office is required. Even within DG-level organizations, the C4ISR portfolio is spread thin across many stakeholders. Within DG Air FD, the Directorate of Air Requirements (DAR) has responsibilities split between DAR 3 (maritime systems for the CP140 and CH148) and DAR 8 (unmanned aircraft systems, including the JUSTAS programme). The Directorate of Air Domain Development (DADD) has three separate subdirectorates, DADD 2 – Air Force Information Management / Information Technology, DADD 3 – C4ISR – Communication Computer Command and Control Intelligence Surveillance Reconnaissance, and DADD 4 – Communications, Navigation, Air Surveillance. Within the force-generation mandate, DG Air Rdns also has a piece of the C4ISR puzzle with D Air Rdns 2 – Strategic Readiness. As each of these subdirectorates holds part of the strategic RCAF C4ISR enterprise, it is difficult to harness the RCAF energy towards a common goal without the possibility of leaving valuable C4ISR initiatives uncoordinated and unfulfilled. As Buchanan and Badham state, this is also a possible source of power struggles between the various power brokers which could lead to destructive political behaviour if conflicting agendas are not identified.

ANALYSIS AND RECOMMENDATIONS FOR THE RCAF

Similar to the RAAF, the RCAF is in a situation where its modernized aircraft and future acquisitions—such as the CF188, CP140, CH146, JUSTAS and Cyclone—will require a significant shift in how C4ISR operations are conducted. Kotter's first step of creating urgency for the change effort was well executed by the RAAF with its Plan Jericho. The RCAF should leverage this opportunity in a similar manner by raising awareness about the magnitude of the change necessary to keep its forces relevant in the rapidly changing information age. It needs to emphasize how the entire C4ISR effort is connected throughout the RCAF and CAF and how this is a decisive moment because of the crucial impact that an integrated and connected C4ISR system will have in defining future operations.

Through various documents and initiatives, the RCAF has stated its intent to pursue the goal of supporting joint operations and becoming more integrated with our allies as well as other CAF environments and organizations. However, it has not crafted a specific overarching RCAF C4ISR strategy that could guide the efforts of the various stakeholders within the organization nor conveyed a strong sense of urgency. This is a significant obstacle in moving the RCAF C4ISR enterprise in line with the direction given in the CDS directive and the recent *CAF C4ISR Strategic Vision, Goals and Objectives*. Following USAF's example of using Kotter's steps three and four of "creating and communicating the vision" the Commander should publish an RCAF-C4ISR-strategic-vision document in addition to the already existing doctrine and capstone publications. This vision document should be concise, establish clear goals and objectives, assign responsibilities and accountabilities to its stakeholders, and create urgency for the change effort. The strategic vision must be tirelessly communicated through all means at the disposal of the RCAF, such as the *Royal Canadian Air Force Journal*, *Crew Brief* and RCAF web-based communications. This message should be sustained so that there is no doubt that the RCAF leadership is committed to the C4ISR enterprise.

Because the RCAF is so deeply involved in C4ISR, it must be at the forefront of CAF's C4ISR enterprise. To avoid the trap of political behaviour and to be one of the major power brokers from the onset, it should play an active role in developing solid relationships among the leading C4ISR stakeholders across CAF. This implies that, at the strategic level, the Air Staff needs an organizational restructure to create a single C4ISR champion, at the DG level at a minimum, so that it can have a unified voice outside of the RCAF at an influential rank level. Within this restructure, the Air Staff should be regrouped in more functional areas that could remove the boundaries of the requirements and the air-domain development. Both these initiatives will ensure that the RCAF has a powerful guiding coalition to lead the C4ISR change effort and that opportunity for power struggles and political manoeuvring will be minimized.

At the operational level, the 1 Cdn Air Div ISR directive should be renamed the 1 Cdn Air Div C4ISR directive in its next iteration. This will ensure that the 1 Cdn Air Div message is in line with the VCDS C4ISR vision and the proposed RCAF C4ISR strategic vision, thus creating a coherent set of documents that will convey a clear message as to the importance of the change effort. Following the example of USAF with its 25th Air Force and to create a strong guiding coalition at the operational level, the RCAF should regroup its C4ISR people, assets and capabilities in a single organization and, to the maximum extent, in a single location. The RCAF should create a C4ISR wing at 14 Wing Greenwood, already home to the only dedicated C4ISR platform in the RCAF, the CP140 Aurora. This C4ISR centre of excellence should also be home to the upcoming JUSTAS capability and be the main PED node for the RCAF. The PED should be based on the US DCGS, be the main entry point to process data provided by manned and unmanned platforms throughout the RCAF and CAF, and also be connected with our US allies. Collocating flying and non-flying aircrews with intelligence specialists would create a synergy within the C4ISR enterprise and help develop shared goals, thus creating a true sense that C4ISR are operations. Within this construct, a C4ISR presence should be kept on the West coast at 19 Wing Comox, but it should be functionally controlled by the C4ISR centre located at 14 Wing. In particular, members of the C4ISR wing should be empowered to develop new ways to optimize C4ISR operations, and these successes should be celebrated loudly across the C4ISR enterprise and CAF writ large, to sustain the change effort and allow the transition from the neutral phase into new beginnings.

CONCLUSION

With the recent clear directive given by the VCDS, the RCAF must react to adapt its C4ISR enterprise to that of CAF's vision. By looking at recent change initiatives in USAF and the RAAF, the RCAF is in a good position to draw on the best lessons of both allies.

USAF was equally skilful at creating and communicating a powerful vision for its C4ISR organizational-change effort. It empowered its workforce to develop and implement the DCGS, which is now their key PED asset. Perhaps the best lesson that can be drawn by analysing the USAF C4ISR plan is how it used a structural reorganization to cement its change effort. By regrouping all its C4ISR assets under the 25th Air Force and putting it under the Air Combat Command, USAF has built a nearly unstoppable guiding coalition that feeds from its own successes. The focus of the USAF C4ISR enterprise is undeniable, and the level of authority conferred to the Commander of the 25th Air Force ensures that the C4ISR voice is heard at the highest levels of the organization.

In its adaptation to the information age, the RAAF was especially good at leveraging its unprecedented acquisition of high-technology platforms to create a sense of urgency with its Plan Jericho. It made sure that there was room for bottom-up innovation, therefore empowering its members to be creative in moving C4ISR forward. The RAAF is communicating its change vision tirelessly and is adept at sharing its short-term wins to build the momentum necessary to shift the organization to the new-beginnings phase.

The RCAF can follow the best practices of these two organizations in shaping its C4ISR enterprise and incorporating organizational-change principles in its effort. It must embrace this opportunity to adapt to the information age by crafting an RCAF C4ISR strategic vision that is both compelling in creating a sense of urgency and concise enough that it can be embraced by every member of the organization. By creating a better structural strategic organization that incorporates a C4ISR champion at a high-rank level, the RCAF will ensure that its voice is heard at the CAF C4ISR table. By doing so, it will also minimize opportunities for power struggles from within and be ready to engage external stakeholders from the onset to reduce possible political behaviours at the CAF level. Finally, it should follow USAF's lead by regrouping all its C4ISR people, assets and capabilities into a single organization at the operational level. This will create a synergy that will drive the C4ISR organization to new heights faster and more efficiently and make everyone understand that C4ISR activities are operations.

By doing so, the RCAF will become a better integrated component of CAF, ready to lead the C4ISR change effort and ensure that it remains relevant within this technological paradigm shift that is the information age.

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ABBREVIATIONS

1 Cdn Air Div	1 Canadian Air Division
AFV	*Air Force Vectors*
C2	command and control
C4ISR	command, control, communications, computers, intelligence, surveillance and reconnaissance

CAF	Canadian Armed Forces
CDS	Chief of the Defence Staff
CFD	Chief of Force Development
CIS	communication and information systems
DADD	Directorate of Air Domain Development
DAR	Directorate of Air Requirements
D/C4ISR	Directorate of C4ISR
DCGS	distributed common ground system
DG	director general
DG Air FD	Director General Air Force Development
DG Air Rdns	Director General Air Readiness
DG Cyber	Director General Cyberspace
DG Space	Director General Space
DND	Department of National Defence
FCD	*The Royal Canadian Air Force Future Concepts Directive*
ISR	intelligence, surveillance and reconnaissance
ISTAR	intelligence, surveillance, target acquisition and reconnaissance
JISR	joint intelligence, surveillance and reconnaissance
JUSTAS	Joint Unmanned Surveillance and Target Acquisition System
L1	level one advisor
Op	operation
PED	processing, exploitation and dissemination
RAAF	Royal Australian Air Force
RCAF	Royal Canadian Air Force
RCN	Royal Canadian Navy
TDL	tactical data link
US	United States
USAF	United States Air Force
VCDS	Vice Chief of the Defence Staff

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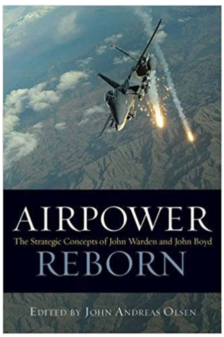


AIRPOWER REBORN: THE STRATEGIC CONCEPTS OF JOHN WARDEN AND JOHN BOYD

COMD RCAF'S READING LIST

Edited by John Andreas Olsen

Annapolis, MD: Naval Institute Press, 2015
239 pages
ISBN 978-1-61251-804-6

Review by **Major Adam Emond, MSc**

Colonel John Andreas Olsen, Norwegian Ministry of Defence, has assembled leading civilian researchers, military operational commanders and airpower thinkers to provide a foundational introductory text on the role of air power in achieving national political objectives. These contributions provide recent historical context and chart a path forward in developing a more robust theoretical structure on which to base the application of air power and the cultivation of airmindedness. There are stand-alone chapters from Colonel Peter R. Faber (Retired), United States Air Force; Air Commodore Frans P. B. Osinga, Royal Netherlands Air Force; Colonel John A. Warden III (Retired), United States Air Force; Dr. Alan Stephens, University of New South Wales, Australia; and Dr. Colin Gray, University of Reading, England.

By weaving together these stand-alone chapters, Olsen commences with an overarching holistic approach to airpower. His chapter provides not only a clear and concise overview of the critical contentions found within each contributor's specific chapter but also a "campaign" plan for reading the text. Without an overall concluding chapter at the end of the book, Olsen's highly readable and succinct treatise provides both the roadmap and the concluding themes of the book without dwelling on any specific historical or theoretical perspectives in overly great detail. As a stand-alone article, Olsen's own contribution is an excellent summary and guide to the sometimes dense and disjointed academic arguments that followed.

In the first major chapter, Colonel Faber risks losing the reader by immediately delving into the language of war, but an attentive reading is quickly rewarded, as the differing usage of language among armies, navies and air forces lays bare the struggle for the theoretical underpinnings of air power. He follows by providing an excellently structured tool for assessing airpower theories and finally summarizes the 13 theories of airpower that have been developed over the course of aviation history until the 1970s. While the text is difficult to read, Faber provides excellent summary tables that contain a listing of various theorists and contrasts their theories' desired political outcomes, target set(s) and mechanisms to achieve the stated outcomes. Key takeaways from this chapter are a condensed introduction to airpower history and a conceptual framework for assessing airpower theories.

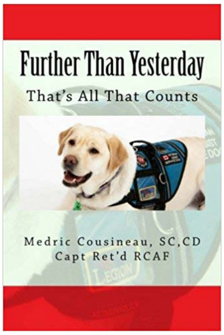
This introduction to airpower history is followed by chapters on the two modern theories of airpower: John Boyd's Observe-Orient-Decide-Act (OODA) loop and John Warden's Five Rings Model. While both chapters provide dense in-depth examination of the theories, Air Commodore Osinga presents a more balanced examination of Boyd's OODA loop through a point-counterpoint dissection of the theory and criticisms that have been generated, along with the major misunderstandings that have formed around Boyd's work. Colonel Warden's treatment of his own theory relies too much on his own perceptions and fails to take a more critical exploration of the Five Rings Model. It suffers from being a first-hand account rather than a balanced assessment. Both contributors attempt to provide analysis of modern post-1990s operations in the context of the presented theories, but these analyses are cursory and isolated at best.

The following chapter draws together the previous sections by introducing the concept of a fifth-generation strategy. With extensive usage of historical examples, Dr. Stephens convincingly argues the merits of air power and the conceptual underpinnings that are required to be understood by all air force officers in order to effectively advise the civilian governments to whom they are accountable. This chapter easily describes the Clausewitzian strategic model and aptly identifies modern strategic failures (Iraq 1991, Iraq 2003 and Afghanistan). As well, it places both Boyd's and Warden's theories in context of what could be described as successful application of air power within a national power projection context (Bosnia, Kosovo and Libya), as long as appropriate language and concept of military as an instrument of national power are used. Similarly to Olsen's initial chapter, Stephens' is very readable, although he relies heavily on knowledge of historical airpower theories, the roots of the modern theories and Western military history.

The final chapter, written by Dr. Gray, is an attempt to provide a unified airpower theory. A dense, academic exposé, it consists of 27 declaratory statements, not only covering what would be familiar to Royal Canadian Air Force doctrine but also delving into air force organizational and mission constructs as well as briefly mentioning space and cyber power. Unfortunately, this chapter provides a very disjointed conclusion to the book. While the practical utility of the statements would require further analysis, the chapter supports the overall thrust of the book in developing the conceptual foundations of air power. Gray's statements require careful consideration to chart a course forward with respect to air power development.

In summary, although many chapters are somewhat dense or abstract, and at times the book verges on being disjointed, the critical sections are highly readable. Additionally, the concrete modern operational examples are treated superficially, which increases the complexity in going from theory to application. Nevertheless, Olsen succeeds in providing a foundational introductory text on the role of air power in attaining national political objectives. *Airpower Reborn: The Strategic Concepts of John Warden and John Boyd* provides a solid account and analysis of historical airpower theories, while convincingly arguing the merits of air power and the conceptual underpinnings that are required to be understood by all air force officers in order to effectively advise the civilian governments to whom they are accountable.

Major Adam Emond is currently employed as a flight test engineer at the Aerospace Engineering Test Establishment. He has had field tours as a maintenance officer on the CC130, CH146, CF188 and CT114, which included deployments for Operations BOXTOP and ATHENA as well as a staff tour at 1 Canadian Air Division Headquarters. He holds a Bachelor of Mathematics in Applied Mathematics from the University of Waterloo and a Master of Science in Flight Test and Evaluation from the National Flight Test Institute.



FURTHER THAN YESTERDAY: THAT'S ALL THAT COUNTS

By Captain Medric Cousineau (Retired), SC, CD

Halifax, NS: Invictus Maneo Publishing, 2015
287 pages
ISBN 978-151466196-3

Review by **Lisa Moulton**

The first of a planned trilogy, *Further than Yesterday* is an autobiography by Captain Medric Cousineau (Retired), who enrolled in the Canadian Forces in 1979, graduated from the Royal Military College in 1983 and served as a Sea King navigator until his release in 1991.

The night of 6 October 1986 changed his life. From that point on, Cousineau battled depression, anxiety, panic, suicidal ideation and addictions; suffered from dissociative episodes; was cut off from family, friends and society; and had a full psychotic breakdown.[1]

So what happened that night? The most succinct account is the citation on Cousineau's Star of Courage:

> On the night of October 6, 1986, Lt. Medric Cousineau, a member of the crew of a Canadian Armed Forces Search and Rescue helicopter, risked his life to rescue two seriously-injured crewmen from an American fishing boat. At the time of the rescue it was dark and weather conditions were terrible, with rain, strong winds and heavy seas; and the deck of the boat, which was pitching and rolling continuously, was obscured by antennae, fishing apparatus and machinery. Fully aware of the hazardous conditions, Lt. Cousineau volunteered to be lowered to the deck of the vessel in order to move the injured men from the boat to the helicopter. On the first attempt he was thrown overboard when the boat pitched violently, but on a second attempt, although he fell into the sea, he managed to scramble aboard. He was able, despite the flying spray and the tremendous noise of the large helicopter hovering close overhead, to quickly organize the preparation and evacuation of the two injured crewmen. Had Lt. Cousineau not willingly put his own life in jeopardy, both of the injured men would certainly have died.[2]

The book has a prologue and is divided into five parts. The prologue opens with a short description of Cousineau's thoughts and feelings as they attempt the rescue and then fast-forwards 25 years, to May 2012, when he hears that he is being paired with Thai, a psychiatric service dog. "Part One: The Before Time" covers the author's experiences at Royal Military College, including playing football, that formed him as a military officer. Included are lessons learned and topics that set the stage for the remainder of the book. At times, this part was disjointed and difficult to place on a timeline. "Part Two: The Rescue" covers the night of 6 October 1986 and follow-up events, including the awarding of the Star of Courage (the second highest award for bravery which recognizes acts of conspicuous courage in circumstance of great peril),[3] his panic attacks and early therapy sessions.

"Part Three: New Beginnings" describes being matched with a service dog in 2012, gaining more control of his life, coming up with the idea for his Long Walk for Sanity and its initial planning. "Part Four: The Long Walk" to Sanity was Cousineau's advocacy and fundraising effort to pair 50 veterans with their own service dogs. Over 50 days, he walked a half marathon a day and covered 1,065 kilometres in four provinces. Interspersed with the walking were presentations to groups and media events. "Part Five: The Aftermath" details the results of the walk and includes addressing cadets at the Royal Military College of Canada to prepare them as individuals and future leaders to cope with post-traumatic stress disorder, providing testimony to a Veterans Affairs committee and meeting with the Minister of Veterans Affairs, Julian Fantino, and the Chief of Military Personnel, Major-General Dave Millar, to advocate for changes within the two departments.

Why has Cousineau become an advocate for psychiatric service dogs? He points out that of the 168 hours in a week, an individual is lucky to have one to two hours with a mental health professional, and they are on their own for the other 166–167 hours; their service dog is with them 24/7. Second, the service dog senses the changes in an individual's biochemistry. When an individual has a stress response, a series of neurobiological events occur and result in the release of pheromone in the skin, which is sensed by the service dog. The dog then gets the individual's attention. As the individual pets the service dog, oxytocin is released into their system, thus calming them.[4] For Cousineau, Thai intervenes in his night terrors, watches his back in public and recalls him from panic/anxiety attacks and dissociative recall. Finally, Cousineau is adamant that service dogs are an adjunct therapy and that an individual who has a service dog will require other support.[5]

A consummate story teller, Cousineau's writing is at times graphic and then poetic. When describing certain events and emotions were running high, "the vocabulary is not the finest of the Queen's English."[6] Cousineau describes hanging out the back door of the Sea King while trying to get the helicopter in place as "another straw pressing on my back, threatening to break it, and send me into the abyss. Coppery bile pushed up into the back of my throat as the Sea King was tossed by the gale."[7]

Included in the book are copies of official documents (including Cousineau's commissioning scroll and the Star of Courage citation) and other supporting material (a 443 Squadron newspaper article about the 6 October events, speeches given by Cousineau [including testimony at a Veterans Affairs committee], the Governor General's address at the presentation of awards and government announcements related to research and policy on service dogs). The book includes a section with photographs and a glossary of abbreviations. One critique and a distraction, for me, was the lack of or improper editing, as sentences at times were unclear due to typos or missing words.

Further than Yesterday is an important resource for those, military and civilian, who wish to understand how debilitating post-traumatic stress disorder is for not only our current and former members but also their families.

Lisa Moulton, a member of the Class of 85 and a former Electrical and Mechanical Engineering officer, is an editor at the Canadian Forces Aerospace Warfare Centre.

Notes

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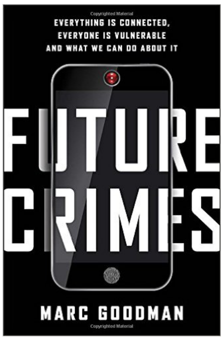

FUTURE CRIMES: EVERYTHING IS CONNECTED, EVERYONE IS VULNERABLE, AND WHAT WE CAN DO ABOUT IT

By Marc Goodman

New York, Doubleday, a Division of Random House, 2015
392 pages
ISBN 978-0-385-53900-5 (Hardcover)
ISBN 978-1-137-27955-2 (Hardback)

Review by **Lieutenant-Colonel Paul Fleury, CD**

Marc Goodman has extensive experience in both law enforcement and technology. He worked as a futurist in residence with the Federal Bureau of Investigations, a senior advisor to Interpol, and served as a police officer. He was the founder of the Future Crimes Institute and sat as the chair for Policy, Law, and Ethics at Silicon Valley's Singularity University. He is highly qualified to provide a thesis for the future of technology and the associated future of cybercrime.

This book is well written and an unnerving exposé of society's general lack of awareness regarding the risk of baring every aspect of our lives through our highly technological, interconnected world. The book comes with a warning that your life will change forever, and that certainly holds true if you are at all "connected." The risks we take today with insecure devices, poorly written code, and the exponential growth in the technologies of today (e.g., robotics, Internet of Things,[1] synthetic biology, three-dimensional printing, artificial intelligence, nanotechnology, etc.) are and will continue to provide a treasure trove for criminals now and in the future. With worldwide militaries' ever increasing reliance on technology, hactivists, terrorists, and criminals at every level will have even more opportunities and capabilities to hijack military activities during peace and war.

Goodman paints a grim picture of how easy it is for bad actors to hack our computers, cell phones, tablets, baby monitors, and anything else connected to the Internet. As more technologies get hooked to the Internet of Things, we will see hackers using it to commit crimes. The book reads like a page-turning thriller and keeps you at the edge of your seat with real-life examples of individuals, militaries, and companies that have been hacked—a stark realization that we are all vulnerable.

Goodman also provides a view of the dark recesses of the Internet, referred to as the Deep Web, the Dark Net, the Secret Web, the Digital Underground, and the Invisible Internet, just to name a few. He explains how cyber criminals use this area of the Internet to pass information, such as the gene sequence for smallpox or the 1918 Influenza virus, and how you can buy everything on it, from drugs and counterfeit currency to weapons, ammunition, and explosives. Just over the horizon is technological advancement unparalleled to date, and we need to be ready for it. Chemical and biological weapons are becoming easier and cheaper to obtain, giving terrorists an arsenal that will be hard to control or stop.

Future Crimes is a must read for anyone with an online profile, those who are interested in technology and where it will take us in the not-so-distant future, and—in particular—military practitioners. Goodman provides excellent examples of how terrorists have exploited technology in order to gain an edge over adversaries. According to the book, in 2011, it was estimated that 1 in 50 troops in Afghanistan was a robot, and by 2023, there may be 10 robots for every human soldier. Facebook posts have been used by terrorists to geolocate troops and helicopters for a precise mortar attack. With the plethora of drones and even more autonomous weapons systems coming to fruition, we will need to ensure our systems are even more secure. What does the future hold? You can read it here.

Lieutenant-Colonel Paul Fleury is an aerospace controller with an extensive background in air traffic control. He has significant experience with the North American Aerospace Defence Command and United States Northern Command and has deployed to Afghanistan as the Chief of Air Space Management. A graduate of the Royal Military College of Canada, he is currently employed as the Canadian Armed Forces Royal Canadian Air Force Liaison Officer to the Royal Australian Air Force Air Power Development Centre in Canberra, Australia.

Note

1. Jacob Morgan, "A Simple Explanation of 'The Internet of Things,'" *Forbes*, May 13, 2014, accessed November 28, 2016, http://www.forbes.com/sites/jacobmorgan/2014/05/13/simple-explanation-internet-things-that-anyone-can-understand/#556b98166828.