THE ROYAL CANADIAN

AIR FORCE JOURNAL

SUMMER 2013 VOL. 2 NO. 3

IN THIS ISSUE

AUTOMATIC TARGET RECOGNITION FOR SYNTHETIC APERTURE RADAR

THE DRAWDOWN IN AFGHANISTAN: LESSONS FROM IRAQ

SHIELD OF DREAMS? ASSESSING CANADA'S NON-PARTICIPATION IN STRATEGIC BALLISTIC MISSILE DEFENCE

AND MUCH MORE!

AEROSPACE WARFARE CENTRE · CENTRE DE GUERRE AÉROSPATIALE · AGILE

PRODUCED BY
THE CANADIAN FORCES
AEROSPACE WARFARE CENTRE

National Defence Défense nationale

Canada

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 aerospace 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 aerospace 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.

EDITORIAL STAFF

Editor-in-Chief: Colonel Martin Cournoyer, CD
Senior Editor: Major William March, CD, MA

EDITORIAL BOARD

Colonel William Lewis (Retired), OMM, CD, M Eng, M Ed, MBA, MDS, PhD
Lieutenant-Colonel Paul Johnston, CD, MA – Canadian Forces College
Major Raymond Stouffer, CD, PhD – Royal Military College
Doctor Allan English, CD, PhD – Queen's University
Doctor James Fergusson, PhD – University of Manitoba
Doctor Stephen Harris, CD, PhD – Directorate of History and Heritage
Doctor Randall Wakelam, CD, PhD – Royal Military College

Published by Canadian Forces Aerospace Warfare Centre
ISSN 1927-7601

ASSISTANT EDITORS

Adri Boodoosingh, Lisa Moulton and Françoise Romard

GRAPHIC DESIGN

Denis Langlois and Luc Leroy

ONLINE EDITION ANIMATION

Hope Smith

http://www.rcaf-arc.forces.gc.ca/en/cf-aerospace-warfare-centre/index.page
http://trenton.mil.ca/lodger/cfawc/eLibrary/Journal/Current_Issue_e.asp

ACTING PRODUCTION MANAGER

Denis Langlois

For copies of this publication or to be placed on a distribution list contact CFAWCProd@forces.gc.ca

NOTE TO READERS

As a bilingual journal, readers should take note that where quotations are translated from their original language, we will use the term [Translation] at the end of the quote to indicate that readers can find the original text in the other language version of the *Journal*. Unless otherwise noted, photographs appearing in the RCAF *Journal* are attributable to the public domain.

THE ROYAL CANADIAN
AIR FORCE JOURNAL

SUBMISSION REQUIREMENTS

THE ROYAL CANADIAN AIR FORCE JOURNAL welcomes the submission of articles, book reviews and shorter pieces (which will be published in the Letters to the Editor, Points of Interest and Pushing the Envelope sections) that 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.

JOURNAL SECTIONS

ITEM	WORD LIMIT*	DETAILS
LETTERS TO THE EDITOR	50-250	Commentary on any portion of a previous *Journal*.
ARTICLES	3000-5000	Written in academic style.
BOOK REVIEWS	500-1000	Written in academic style and must include: • the book's complete title (including sub-title); • the complete names of all authors as presented on the title page; • the book's publisher, including where and when it was published; • the book's ISBN and number of pages; and • a high resolution .jpg file (at least 300 dpi and 5 by 7 inches) of the book's cover.
POINTS OF INTEREST	250-1000	Information on any topic (including operations, exercises, and anniversaries) that is of interest to the broader aerospace audience.
PUSHING THE ENVELOPE	250-2000	Forum for commentary, opinions, and rebuttal on *Journal* articles and/or issues that are of interest to the broader aerospace audience.

* Exclusive of endnotes

AUTHORS ARE ASKED TO NOTE THE FOLLOWING GUIDELINES

- Submissions may be made in either official language.
- Authors must include a brief (one paragraph) biographical sketch which includes current appointment/position, telephone number, and email address. Please include all professional and academic designations as well as military decorations.
- Selected articles that have been peer reviewed have a to the left of the title.
- The Senior Editor will notify contributors on the status of their submission. It may not be possible to publish all submissions.
- All text submissions must be digital, in Microsoft Word or rich text format. Files must not be password protected and must not contain macros. Files may be submitted by mail or email at the addresses provided below.
- All supporting tables, images and figures that accompany the text should be sent in separate files in the original file format (i.e., not imbedded in the text). Original vector files are preferred; high resolution (not less than 300 dpi) .psd or .jpg files may be submitted.
- Authors are now required to provide "alternate text" with detailed description for all figures. The alternate text is to be labelled as such and placed below the caption.
- Copyright permissions are required for all material that is not Department of National Defence or author originated. It is the author's responsibility to obtain and submit the necessary written permissions which must include the author's/artist's name as well as the publisher's name and location. Any material not meeting these requirements may be omitted from the article.
- The Senior Editor may select images or have graphics created to accompany submissions.
- Authors should use *Oxford English* or *Petit Robert* spelling. When required, reference notes should be endnotes rather than footnotes and formatted in Chicago style. For assistance refer to *The Little, Brown Handbook, Le guide du rédacteur,* or CFAWC Production Section at CFAWCProd@forces.gc.ca
- Acronyms and abbreviations should be used sparingly:
  - If they are required in the text, the term is to be written out in full the first time it is used and then followed by the abbreviated form in brackets.
  - If they are required in tables or figures, each table and figure will contain a list of abbreviations.
  - A list of all abbreviations (and their terms) used in the text will be included at the end of each submission.
- The Senior Editor reserves the right to edit submissions for style, grammar, and length, but will not make editorial changes that will affect the integrity of the argument without consulting the author.

CALL FOR SUBMISSIONS

FOR THE **WINTER 2014** ISSUE: **30 OCTOBER 2013**
FOR THE **SPRING 2014** ISSUE: **30 JANUARY 2014**
FOR THE **SUMMER 2014** ISSUE: **30 APRIL 2014**
FOR THE **FALL 2014** ISSUE: **30 JULY 2014**

FOR FURTHER INFORMATION OR TO MAKE A SUBMISSION PLEASE CONTACT THE EDITOR AT:

Canadian Forces Aerospace Warfare Centre
8 Wing Trenton
Box 1000 Stn Forces
Astra, Ontario K0K 3W0
Attn: Major William March
William.March@forces.gc.ca

DISCLAIMER

Opinions expressed in the *Journal* remain those of the author and do not represent Departmental or Canadian Forces policy. Doctrine, training and other material published in the *Journal* does not represent authority for action on that particular topic. All published material remains copyright of the Department of National Defence and may not be used without written permission.

VOL. 2 | NO. 3
SUMMER 2013


CF Photo: Sgt Matthew McGregor


CF Photo: 8 Wing Imaging

ARTICLES

BOOK REVIEWS


CF Photo: Sgt Matthew McGregor

EDITOR'S MESSAGE

I do a lot of writing. However, by far the hardest bit of writing that I do is the four-times-a-year "Editor's Message" for the *Royal Canadian Air Force Journal*. It is my one chance to speak directly to you, the readers, and I do not want to "blow it." Instead, I want to say something that makes the reader go "hmmm" rather than have my narrative turn into a rant about things that bother me. So if I occasionally stray from the "thought-provoking" to the "old curmudgeon grumbling" side of the street, please forgive me—I shall try to keep it to a minimum.

The three things that caught my attention since the last issue have to do with commemoration, organization and publication. With respect to commemoration, if you are reading this then the events to commemorate the 70th anniversary of Operation HUSKY, the Allied liberation of Sicily in World War II, have come and gone. This particular campaign (10 July – 17 August 1943) was the first time that large elements of the Canadian Army fought on European soil (other than Dieppe in August 1942), and 562 soldiers were killed. Although not often thought of as an air campaign, HUSKY saw the employment of a large Allied air armada that included four Royal Canadian Air Force (RCAF) squadrons—417, 420, 424 and 425. From these squadrons, 63 airmen would die in the lead-up to the operation, during the actual campaign and during the immediate aftermath. A further 91, reflecting the manning policies of the day, would lose their lives serving for the most part with Royal Air Force units. We shall remember them.

Reorganization is once more in the air (pun intended). The Commander of the RCAF's staff in Ottawa has been reoriented and, once the official announcement has been made, I can get a keen, young (or not-so-young) staff officer in Ottawa to put finger to keyboard and give us the skinny on the whom, what, where, why and how.

With respect to publication, and for those of you who have not visited the Canadian Forces Aerospace Warfare Centre (CFAWC) website[1] lately, I want to draw your attention to two of its latest publications. Dr. Aaron Jackson's *Doctrine, Strategy and Military Culture: Military-Strategic Doctrine Development in Australia, Canada and*

New Zealand, 1987–2007 provides a good overview and comparison of service and joint doctrine from a Commonwealth perspective, a refreshing change from United States-oriented narratives. As well, you may wish to check out Volume 1, Book 1, of the *Curtis Papers: Canadian Aerospace and Joint Studies*. This is the first in a yearly series that publishes select papers from the Canadian Forces College (CFC) Master of Defence Studies (MDS) programme. The series will examine both aerospace and joint themes. There is some "good stuff" coming out of CFC that should have a wider audience.

Both of these publications are available in hard copy (while quantities last) and electronically via the CFAWC website. Enjoy the read.

Sic Itur Ad Astra

Major William March, CD, MA
Senior Editor

Abbreviations

CD	Canadian Forces' Decoration
CFAWC	Canadian Forces Aerospace Warfare Centre
CFC	Canadian Forces College
RCAF	Royal Canadian Air Force

Note

1. The eLibrary is accessed on the Internet at http://www.rcaf-arc.forces.gc.ca/CFAWC/eLibrary/eLibrary_e.asp and on the Defence Wide Area Network at http://trenton.mil.ca/lodger/CFAWC/eLibrary/Publications_e.asp (both accessed June 10, 2012).

LETTERS TO THE EDITOR

I would like to take this opportunity to comment on the article by Major (Maj) Ken Craig entitled "Canadian Special Security Events: An Improved Framework for Royal Canadian Air Force Command and Control" which appeared in the Spring 2013 edition of the *RCAF Journal*.[1] In the first instance, I would like to thank Maj Craig for his clear interest in the command and control (C2) of air forces. I recall Lieutenant-General Bouchard, now retired, once said in reference to joint operations: "Sort out the C2 and the rest will take care of itself." Over the years I have seen the wisdom in that remark. Clear C2 in the joint environment is both difficult and critical. I share some of Maj Craig's concerns with the C2 employed in Canada for the two Canadian special security events (CSSEs) that he highlights—Operation (Op) PODIUM and Op CADENCE. On the other hand, I disagree with the proposed solution, or framework, that would have the "CANR [Canadian NORAD Region] assets … tasked … to the assigned JTF [joint task force] commander."[2]

In three years as the Deputy Commander of the Continental U.S. NORAD Region (CONR), I have participated in the C2 of many national special security events (an NSSE is the United States [US] version of a CSSE), to include eight in the last 12 months alone. I can respond to Maj Craig's suggestion that "Continental NORAD Region assets could be similarly assigned to a USNORTHCOM [United States Northern Command]-mandated JTF"[3] by stating that this has not and would not happen. In the continental US, over the course of many NSSEs, North American Aerospace Defence Command (NORAD) assets always remained under the direct C2 of the CONR commander. There are several reasons for this, a couple of which I would like to highlight.

NORAD capabilities employed on a continuous basis throughout North America include and extend from the aircraft and crews flying missions to NORAD C2 and communications nodes and networks all the way to the national authorities of the US and Canada. All of the NORAD elements form an essential chain to achieve the missions of aerospace warning and aerospace control. The chain is very frequently operated and exercised in both Canada and the US in order to ensure the very time-sensitive response needed for effective air defence. To parcel out certain "assets" would interfere with that chain, creating vulnerable seams and gaps in the air defence coverage of North America.

In addition, NORAD maintains very close liaison and working relations with security and defence partners in both the US and Canada (e.g., the Federal Aviation Administration, the Department of Homeland Security, Transport Canada, the Royal Canadian Mounted Police, etc.), and solid, effective relations and procedures have developed with these agencies to support air security and air defence operations and requirements. Certainly in the case of the CONR where special security events have been conducted much more regularly than in Canada, assigning responsibility outside NORAD for the air security or air defence of a joint operations area (JOA) would complicate, not simplify, the required coordination in both planning and execution.

Returning to my agreement with Maj Craig, the establishment of a separate air component commander (ACC) for a CSSE, such as occurred for Op PODIUM, seems unnecessary in the Canadian context. It seems to me that except in very extraordinary circumstances the Commander 1 Canadian Air Division will be both the joint forces air component commander (JFACC) for Canadian Joint Operations Command (and will provide support for any domestic JTF) and the combined force air component commander (CFACC) for CANR. His ACC responsibilities cover the entire country, regardless of whether there is a subordinate JOA or not, and he has the C2 capabilities to control air power in all cases. The CFACC/JFACC should provide for the air power needs in the JOA of a CSSE, whether those are NORAD or non-NORAD in nature. The CFACC/JFACC should ensure appropriate coordination and representation at the JTF to effect the mission and tasks and will ensure the synchronization and coordination of the NORAD and non-NORAD air assets. Due to the critical nature of North American air defence and the NORAD construct, there will be a split in the C2 of air assets supporting a CSSE, but that should occur at a level above the JTF.

Maj Craig has done an important service by proposing a solution to the C2 of air forces supporting a CSSE. Notwithstanding the observations and lessons identified during previous CSSEs, to ensure their operational effectiveness, NORAD assets conducting air defence or air security tasks need to remain under NORAD C2. For those continuing this necessary work, the current RCAF Force Employment Concept provides a starting point for an effective framework for C2 of air support to CSSEs.

Major-General C. J. Coates, OMM, M.S.M., CD
Deputy Commander
Continental U.S. NORAD Region

Abbreviations

ACC	air component commander
C2	command and control
CANR	Canadian NORAD Region
CD	Canadian Forces' Decoration
CFACC	combined force air component commander
CONR	Continental U.S. NORAD Region
CSSE	Canadian special security event
JFACC	joint forces air component commander
JOA	joint operations area
JTF	joint task force
M.S.M.	Meritorious Service Medal
NORAD	North American Aerospace Defence Command
NSSE	national special security event
OMM	Officer of the Order of Military Merit
Op	operation
US	United States

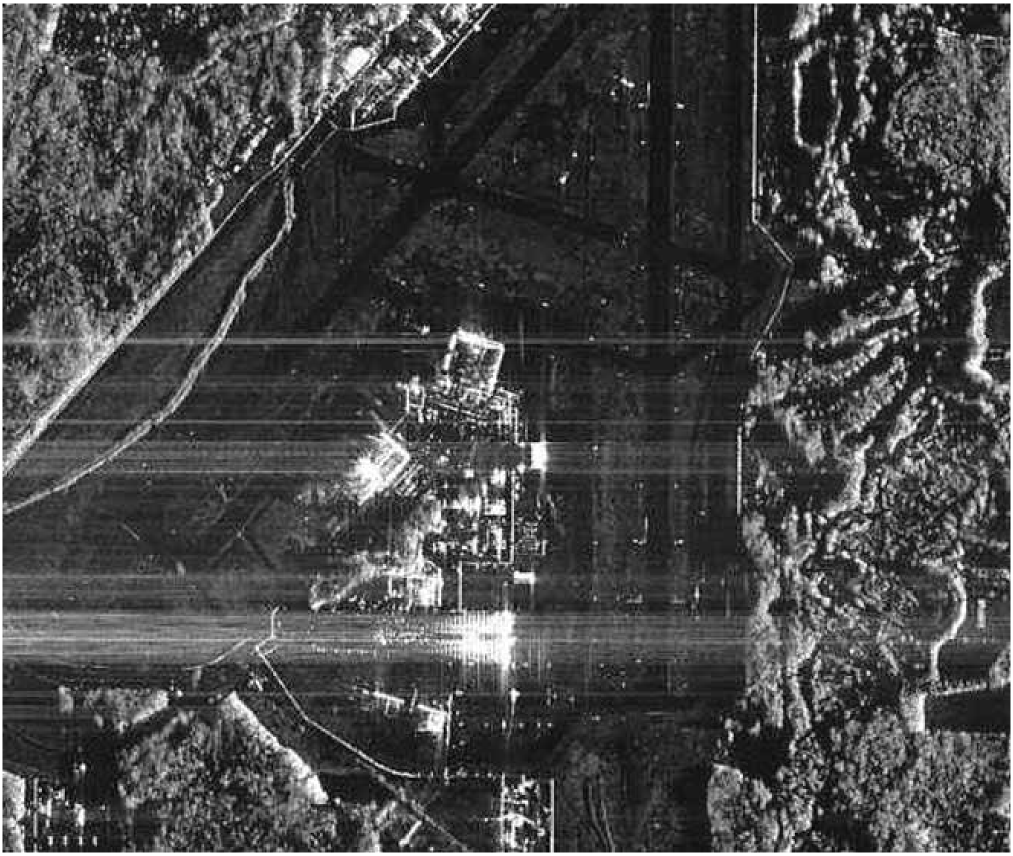
Notes

1. Major Ken Craig, "Canadian Special Security Events: An Improved Framework for Royal Canadian Air Force Command and Control," *Royal Canadian Air Force Journal* 2, no. 2 (Spring 2013): 7–16, http://www.rcaf-arc.forces.gc.ca/CFAWC/eLibrary/Journal/2013-Vol2/Iss2-SPRING/Sections/04-Canadian_Special_Security_Events-An_Improved_Framework_for_Royal_Canadian_Air_Force_Command_and_Control_e.asp (accessed June 10, 2013).

2. Ibid., 13.

3. Ibid.

By Captain Jean-François Gallant



Radar Image from the APS 508 Imaging Radar System

Author's note: This article is an adaption of the technical paper submitted to the Canadian Forces School of Aerospace Studies (CFSAS) for the Aerospace Systems Course. Mike Saville was technical advisor for the paper.

Editor's note: The descriptions for BMP2, BRDM2, BTR60 and BTR70, while incorrect, have been taken from the source document and will be used in this article.

The new era of aerial radar imaging for intelligence, surveillance and reconnaissance (ISR) is upon the Canadian Forces. The CP140 Aurora AIMP (Aurora Incremental Modernization Project) Block III is equipped with the new state-of-the-art APS 508 Imaging Radar System (IRS) that is capable of providing high resolution synthetic aperture radar (SAR) imaging for wide-area surveillance in all weather conditions in land and maritime environments. As opposed to traditional radar systems, SAR imaging is capable of generating a very large volume of details when operated over complex environments such as littoral and overland operations. Currently, the volume of details requires extensive human resources to perform the exploitation and analysis of the information, subsequently increasing the latency of the intelligence gained from SAR and, ultimately, reducing its effectiveness in near real-time operations. Accordingly, the employment of SAR systems in support of near real-time ISR operations depends on an automated capability for target recognition to fully profit from the advanced imaging capabilities.

An automatic target recognition (ATR) system is defined as using a computer to classify a target without user intervention.[1] ATR processes apply various techniques—including image enhancement, feature extraction and template recognition—throughout the detection, discrimination, classification and recognition steps of the ATR processing flow, shown in Figure 1. The initial step of this processing flow is detection; it determines the presence of target signatures in the sensor data and differentiates them from the clutter.[2] Discrimination follows detection and is applied in order to distinguish whether the target is present or not present in the region of interest (ROI). Classification then attempts to reveal whether a target signature can be distinguished from other targets' signatures, including distinguishing targets' signatures from those resulting from clutter and non-targets.[3] Today, detection and discrimination are "solved problems" for ATR, while the classification problem remains to be overcome. This article analyses the current classification problem and investigates the most promising processing techniques—elliptical Fourier descriptors (EFD) and polarimetric whitening filter (PWF)—for the development of complete ATR systems.

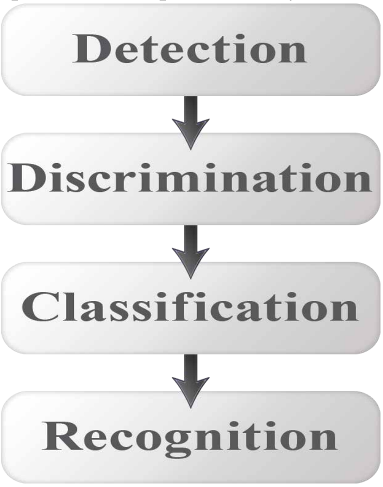


Figure 1. ATR processing flow

Problem definition

The current problem that prevents the development of complete, end-to-end ATR systems for SAR is the lack of automated classification processing of target radar signatures.[4] Although classification uses some of the same imagery processing techniques, the main difference is that detection and discrimination are confined to selection, while classification is employed for recognition of features. One of the issues that contributes to the difficulty of implementing complete ATR systems is the lack of optical resolution of radar imaging in comparison to optical imaging. Optical resolution refers to the ability of a system to resolve details in the object that is being imaged. SAR imaging typically employs frequencies in the microwave range in the X and K bands; in contrast, optical sensors operate in higher bands in the infrared and visual frequency ranges. Thus, achieving comparable optical resolution using lower frequencies is difficult and requires complex procedures for radar imaging. Eventually, the development of faster computer technology increased the internal processing capacity of the new generations of SAR systems. The results are better optical resolution from higher concentration of pixels within the image, subsequently providing sharper target images. Nevertheless, the low optical resolution for SAR, in comparison to optical sensors, still remains a challenge to overcome for the implementation of complete ATR systems.

The other major problem that contributes to the difficulty of implementing complete ATR systems is the complexity of feature extraction using SAR. Unlike images from optical sensors, which provide a suitable depiction of a target, SAR images are described by a set of scattering centres (non-uniformities such as particles and material density that cause radiation to scatter), and they are also highly variable with a pose of the target.[5] The pose is referred to as the two-dimensional azimuth orientation (or heading) aspect of a target.[6] When the pose uncertainty is large, the extraction of robust features of the target's signature becomes difficult, impeding the implementation of effective ATR classification methods.[7] Technologies in the fields of imagery segmentation, high-level feature-based recognition and template-based classification are currently implemented in today's ATR systems. However, segmentation and high-level feature-based recognition technologies are imperfect, as they do not provide sufficient details and allow for the extraction of only a few features. Template-based classification is also rendered ineffective without extracting the pose of the target, as it is not able to provide a pixel-by-pixel comparison with a generated image dataset. Hence, feature extraction for classification remains a complex problem that prevents the implementation of a complete ATR system. EFD and PWF are two processing techniques designed to overcome these challenges.

Elliptical Fourier descriptors processing

Elliptical Fourier descriptors is a processing technique for ATR classification that was developed by Louis Patrick Nicoli from the Florida Institute of Technology. EFD involves two distinct operations that perform image processing and decision making. The image processing operation provides parametric representation of closed contours of the boundary of a target's projected two-dimensional pose based on ellipses. EFD's use of orbits allows for a good estimate of the target's shape, even if only low-order terms of EFD are employed. Through the superposition of phasors associated with their respective coefficient matrix, the closed contours form a boundary defining the signature of the target.[8] Figure 2, which is examining a T-62 main battle tank, demonstrates how EFD reconstructs the closed contours using ellipses that have a few sets of coefficients, which requires less computational complexity than other template-based methods.

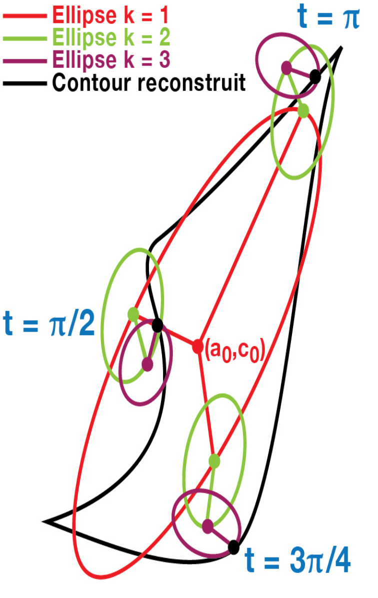


Figure 2. Reconstruction of contours of a T-62 tank target[9]

As defined by the k-1 ellipse (red), the initial harmonic of the first ellipse is particularly important since it provides the geometric properties of the target's region. At the same time, this initial harmonic contains the estimate of the pose derived from the angular position of the semi-major axis. It is a key element of this processing technique, since there is no need to estimate the pose in a separate step, unlike other template-based methods. The semi-major and semi-minor axes of this first ellipse (see Figure 3) provide the estimates of the dimension equalling respectively half the length and half the width of the target region. Once the first ellipse has estimated the pose, shape and dimension of the target, more elliptical descriptors can be applied to further define the target signature. Extracting the pose, shape and size from the initial harmonic of the first ellipse represents a key element that allows software to conduct subsequent operations to generate an "accurate parameterization" of the target.[10] As a result, fewer ellipses are required to complete the boundary of the target's signature, necessitating less computational processing capacity.

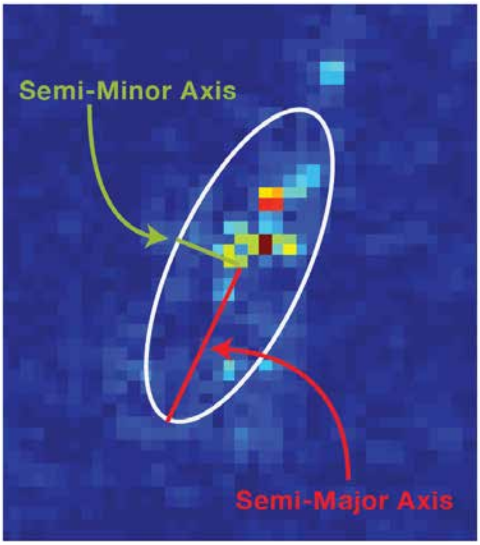
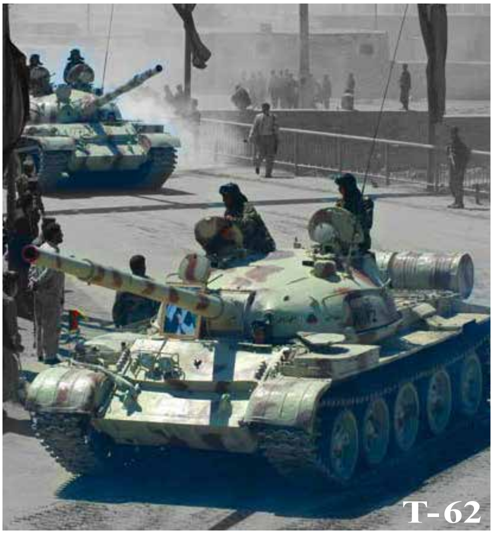


Figure 3. First ellipse on a T-62 tank target region[11]

Once EFD has completed processing the image (see Figure 4), the decision-making operation is then performed using the combination of support vectoring machine (SVM) type classifiers. SVMs are large margin classifiers that use the boundary of the target's signature to generate a match against a dataset. SVM classifiers are designed and trained to perform class separation against specific datasets using binary logic in their decision process. They attempt to maximize the margin in feature space between two classes.[12] They also partition the feature space in ways that different classes are separated in some identifiable manner.[13] Hence, the effectiveness of the imagery processing technique has important impacts on the application of classifiers. It is important that EFD extracts robust features to support SVM classifiers.



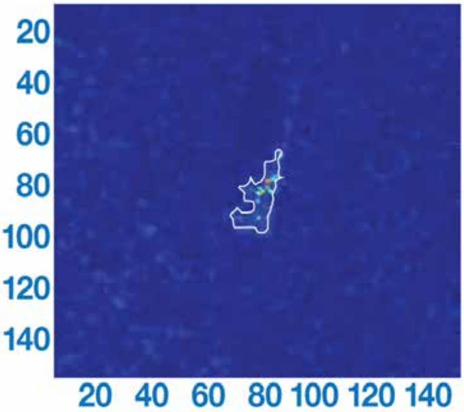


Figure 4. EFD applied on a T-62 tank target region[14]

In addition, the operational environment dictates the number of SVM classifiers required to attain clear separations between the classes, while retaining their general approach to counteract the "overfitting" effects.[16] EFD employs two distinct methods of SVM classifiers: directed acyclic graph SVM (DAGSVM) and Maximum Wins SVM. DAGSVM classifiers provide hierarchically layered separation between target classes to ultimately attain a specific one. A 10 class DAGSVM is shown in Figure 5. Maximum Wins SVM classifiers assign a target class membership based on the estimation of the class that was picked the highest number of times.[17] In the case of the employment of SVMs in a complex environment requiring multi-class classification, it then becomes necessary to employ a large set of SVM classifiers against several imagery datasets to be effective.

To use the pyramid, you start at the top and select 1 or 10. If you select 10, then the arrow leads you to the "2 vs 10" circle to make a selection. If you select 1, then the arrow leads to the "1 vs 9" circle to make a selection. By making such a selection on the top nine rows of the pyramid, on the 10th row you've made a selection between 1 and 10.

Polarimetric whitening filter processing

Polarimetric whitening filter is a processing technique for ATR classification that was developed by researcher Leslie Novak. PWF also involves two distinct operations that perform image processing and decision making. The image processing operation provides enhancement of the image's optical resolution by reducing the speckle content and sharpening the edges of the target signature.[18] PWF uses the combination of three

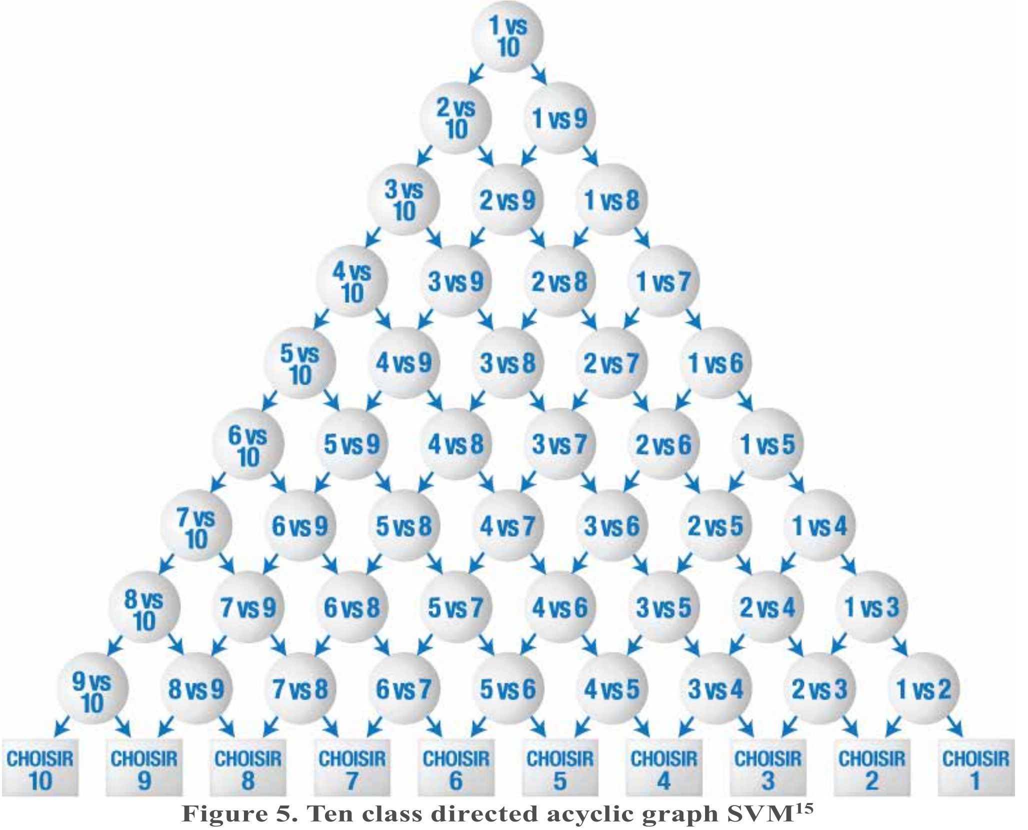


Figure 5. Ten class directed acyclic graph SVM[15]

polarization channels of the target image, which enables the best estimate of a target signature.[19] The polarization process combines the HH (horizontal transmit, horizontal receive), HV (horizontal transmit, vertical receive) and VV (vertical transmit, vertical receive) components of the radar returns.[20] Speckle reduction optimizes the target signature for further application of sophisticated thresholding processing.[21] One key element of this processing technique is its capability of preserving the integrity of the target's signature. In comparison to the single channel (HH) image, the PWF processed image provides a more detailed view of the meadow, trees and dirt roads of a SAR image (see Figure 6) as well as highlighting the details from the significant radar returns such as electrical pylons (see Figure 7).

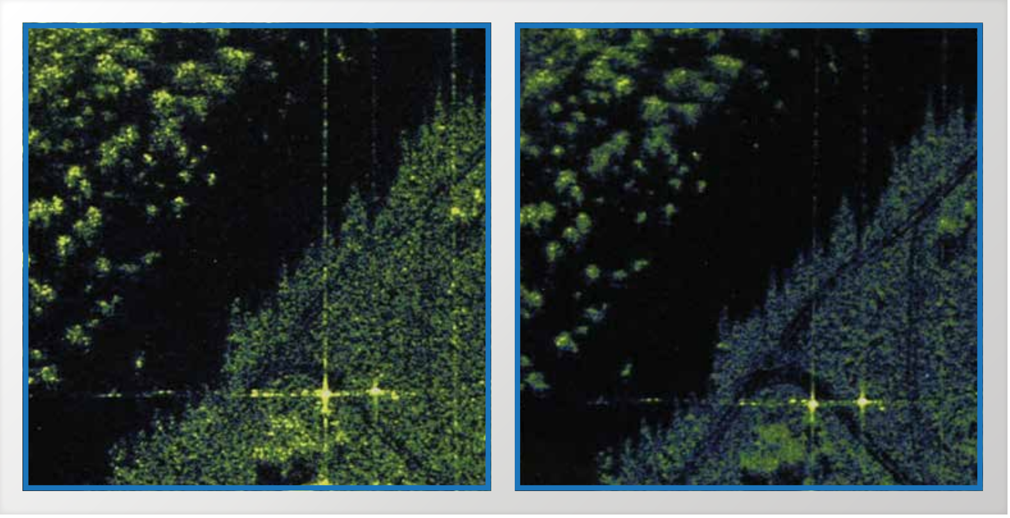


Figure 6. Comparison between single channel HH image (left) and PWF image (right)[22]

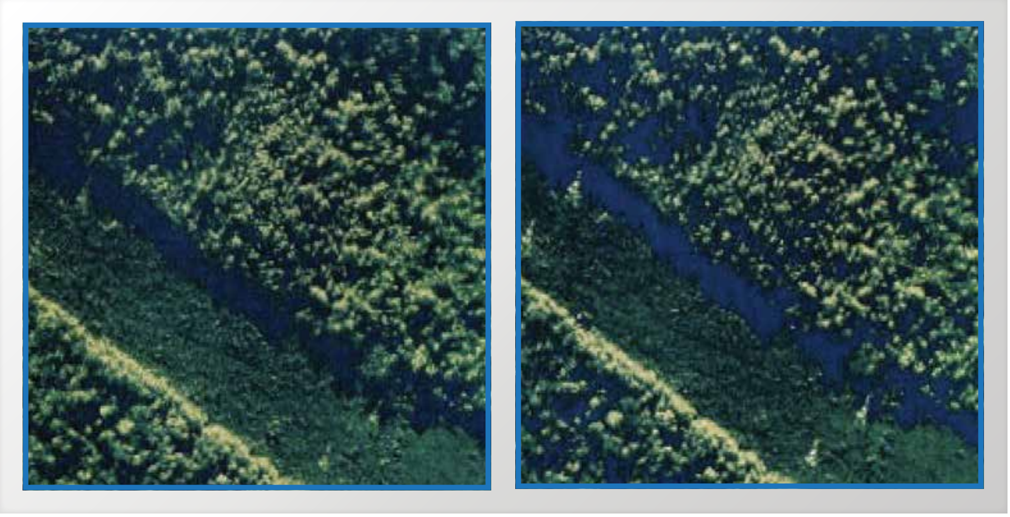


Figure 7. Comparison between single channel HH imagery (left) and PWF imagery (right)[23]

In order to optimize the optical resolution of a SAR image, PWF implements two processing methods referred as the Polarimetric Clutter Model and Minimum-Speckle Image Processing. The Polarimetric Clutter Model provides the first line of processing that characterizes radar returns from spatial homogeneous regions of clutter. It consists of the radar measurement of three complex elements—HH, HV and VV—that are separated in quadrature components.[24] This reduces the negative effects from the radar registration reflectors polarimetrically, which subsequently removes the sources of clutter. The second line of PWF processing is Minimum-Speckle Image Processing. This optimal filtering process uses non-coherent optical averaging to adjust pixel intensity in a way that further minimizes speckle.[25] It applies a whitening filter on the linear-polarized radar measurement and then submits it to an averaging filter that applies the calculated speckle ratio reduction on the uncorrelated polarimetric channels.[26] This averaging procedure optimizes the speckle content and intensifies the concentration of pixels of the linear-polarized radar measurements on the uncorrelated images. Using those two methods for minimizing the image speckle, PWF processing enhances the optical resolution of the SAR image, while preserving the integrity of the target's signature.

Once PWF has completed processing the image, the decision-making operation is then applied using a neural-network classifier developed for PWF. This type of classifier is a self-organizing pixel-by-pixel segmentation algorithm that employs an adaptive-resonance (ART 2[27]) neural network.[28] The neural-network classifier automatically established the correlation between the signatures of a template and a real target. This template matcher is trained to summarize target features at the small increment level on both the template and real signature using a form of feature vector. Figure 8 illustrates an extracted set of 16 single features representing a 16-dimensional feature vector. Those features are extracted from the auto-correlation matrix, which is the summary of several target images. Then, the feature vector is used to establish the correlation between the template and the real target signatures. The feature vector, thus, eliminates the requirement of individually storing each signature image from the template and real target. Consequently, it also becomes important that the PWF processes the target's signature in a way to reduce the clutter and minimize the speckle optimally in order to support this pixel-by-pixel segmentation algorithm.

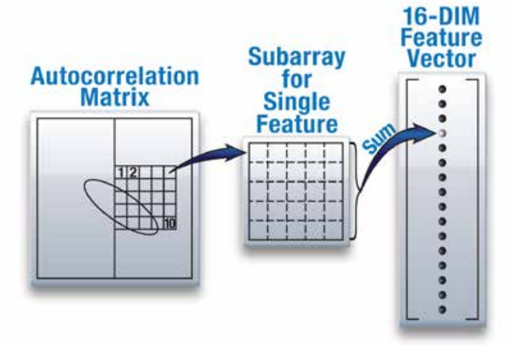


Figure 8. Neural-network classifier process[29]

Analysis

Using the classification problem of low optical resolution and complexity of feature extraction of SAR images, EFD and PWF offer two distinct approaches with respect to their processing techniques and their application of classifiers. EFD provides key strengths in approaching the classification problem of feature extraction. The estimate of the pose of the target derived from the first ellipse is the most important strength of EFD. Knowing the pose of the target enables the dimensions to be extracted from the semi-major and semi-minor axis lengths of the first ellipse. This facilitates the follow-on ellipses to be applied with accuracy for a greater definition of the target's signature. Using fewer ellipses reduces the computational requirements as EFD uses 88.6 times fewer features than other ATR template-based classification methods.[30]

Actual Class	Estimated Class										Class Accuracy (%)
	2S1	BMP2	BRDM2	BTR60	BTR70	D7	T62	T72	ZIL 131	ZSU 23-4	
2S1 (gun)	212	32	4	1	5	0	7	6	6	1	77.4
BMP2 (tank)	1	553	2	0	2	0	2	24	2	1	94.2
BRDM2 (truck)	0	17	197	7	10	0	0	2	2	0	83.8
BTR60 (transport)	2	12	4	150	5	0	2	2	5	4	80.6
BTR70 (transport)	5	24	4	1	153	0	1	1	2	0	80.1
D7 (bulldozer)	0	8	0	0	0	264	0	0	0	2	96.4
T-62 (tank)	9	6	1	6	1	0	197	42	8	3	72.2
T-72 (tank)	2	16	0	3	0	0	7	549	3	1	94.3
ZIL 131 (truck)	7	17	0	13	13	0	1	15	204	4	74.5
ZSU-23-4 (gun)	1	9	1	0	0	1	0	5	6	251	91.6
Estimate Accuracy (%)	88.7	79.7	92.5	82.9	80.5	99.6	90.8	85.0	85.7	94.0	Total 86.67

Table 1. Nicoli's result table for Max Wins SVM with 7 EFDs[31]

Using an ensemble of SVM, EFD is also capable of supporting multi-class classification effectively without requiring extremely large databases. According to Nicoli's research and as shown in Table 1, EFD has an 86.67% classification accuracy. Despite having a classification accuracy of 10% lower than other template-based methods, the capability of providing multi-class classification and the savings in computational requirements represent significant advantages to support near real-time ISR operations.

However, the results of Nicoli's research were obtained using SAR images that have already undergone minimum-speckle processing, and it highlights the lack of image processing as being the most significant weakness of EFD. In fact, the lack of optical resolution of SAR images has significant impacts on the application of EFD. In most situations, the ROI is covered with clutter and speckles from the radar returns. It, then, becomes very difficult to classify a target in an environment filled with erroneous information and hinders the image processor from performing adequately in the extraction of features. Moreover, the "most likely estimate" approach of the Max Wins SVM classifier is another weakness, as it assigns a class to a target regardless of the level of confidence it attains. For example, in eight instances, the classifier identified a BMP2 tank as a D7 bulldozer, despite the significant difference between the vehicles' shapes and sizes (shown in Figure 9).

The most important strength of PWF in approaching the classification problem is the minimum-speckle processing to resolve the low optical resolution of SAR images. The Clutter Reduction Model and Minimum-Speckle Image Processing optimize the polarimetric data to improve the optical resolution of the SAR images. The reduction in speckles and increase in the image pixel intensity allow the classifier to conduct decision-making operations. In a minimum speckle environment, pixel-by-pixel segmentation becomes effective in the implementation of ART 2 neural-network classifier using a vector of 16 features to correlate the signatures from the real and template targets. (Results are shown in Table 2.) A key strength of the neural-network classifier is that it requires less training than other template-matching classifiers. The neural-network classifier provides a much more general approach to classification, as it is less subjected to the effects of overfitting.

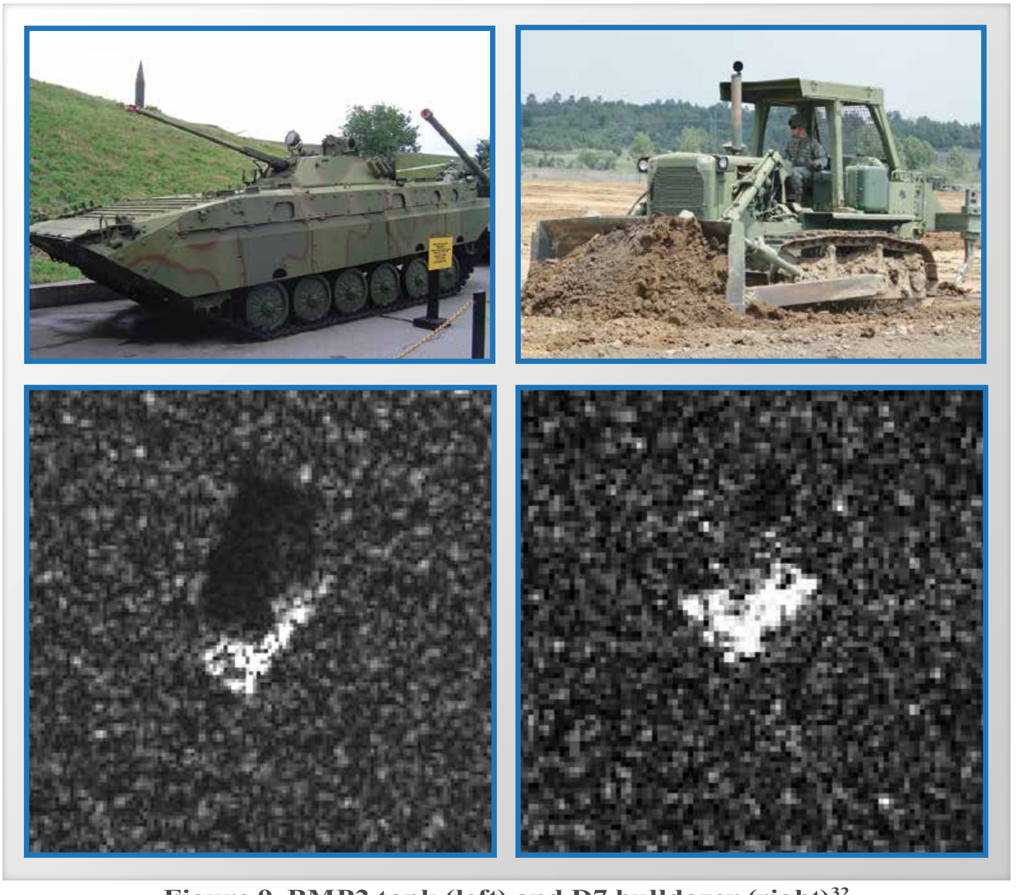


Figure 9. BMP2 tank (left) and D7 bulldozer (right)[32]

Equipment	Estimated As (%)			
	Tank	APC	Howitzer	Clutter
Tank	97	0	0	0
APC	0	100	0	0
Howitzer	4	0	79	17
Clutter	9	0	0	91

Table 2. Novak's result table for ART 2 neural-network classifier[33]

Nevertheless, the results of Novak's research were achieved without extracting the pose of the target, which represents the most important deficiency of PWF. The pose is a key element in extracting the target features, such as size and dimension, to create the feature vector of the target signature. Neural-network classifiers also lack flexibility in effectively attaining a classification decision when confronted with the large variance in the parametric representations. In order to achieve multi-class classification, a large set of features are required to effectively classify targets, increasing the computational complexity of the process. Although the neural-network classifier reduces the processing and storage requirements, they are still very high compared to SVM classifiers because they rely on large numbers of small features.

Based on this analysis, low optical resolution and complexity of feature extraction remain the classification problems to be resolved, preventing the development of complete ATR systems for SAR. EFD and PWF classification methods are still imperfect, and they do not provide the complete solution for end-to-end ATR systems for SAR. Nevertheless, this article suggests a blended classification method for SAR ATR, using the strengths of both EFD and PWF. In theory, this blended method could resolve the issues preventing the implementation of complete ATR systems. In this proposed classification method, PWF would be applied initially to reduce and optimize the speckle content of the ROI. Then, EFD would be applied specifically to the target signature to extract the pose and to form the boundary using contour reconstruction. Furthermore, this blended classification technique would then implement an ensemble of SVM to classify the target. This would cover all the aspects with respect to ATR classification in increasing optical resolution in addition to extracting target features. This blended classification method could minimize the computational complexity requirements and reduce the negative effects of overfitting the classifier. Moreover, this method could meet the requirements of adequately classifying a target without user intervention in the real-time operational environment.

Conclusion

The employment of SAR systems for near real-time ISR operations depends on ATR to fully profit from the advanced capabilities of these radar systems. The exploitation and analysis of advanced radar imaging currently require extensive human resources, increasing the information latency and, ultimately, reducing the effectiveness of the intelligence gained from SAR. Although detection and discrimination are solved problems for ATR, the classification problem remains to be overcome and is attributed to the low optical resolution of SAR and the ensuing complexity of feature extraction. This article investigated elliptical Fourier descriptors and polarimetric whitening filters processing and their contributions to resolving the classification problem. EFD and PWF classification methods were also analysed with respect to their strengths and weaknesses. Although both methods provide key elements for ATR classification, they are still imperfect and do not provide the complete solution for end-to-end ATR systems for SAR. This article proposed using a blended PWF and EFD classification method as a potential solution to resolve the current ATR classification problem. This method could meet the requirements of adequately classifying a target without user intervention in the real-time operational environment.

Captain Jean-François Gallant is currently at 1 Canadian Forces Flying Training School as an air combat systems officer instructor in the Sensors and Communications Section. He graduated from the Aerospace Systems Course 64 in June 2012. Previous assignments include tours at 404 Long Range Patrol and Training (LRP&T) Squadron and 407 (LRP) Squadron as a navigator communicator on the CP140 Aurora.

Abbreviations

APC	armoured personnel carrier
ATR	automatic target recognition
DAGSVM	directed acyclic graph support vectoring machine
EFD	elliptical Fourier descripotors
HH	horizontal transmit, horizontal receive
HV	horizontal transmit, vertical receive
ISR	intelligence, surveillance and reconnaissance
PWF	polarimetric whitening filter
ROI	region of interest
SAR	synthetic aperture radar
SVM	support vectoring machine
VV	vertical transmit, vertical receive

Notes

1. Louis Patrick Nicoli, “Automatic Target Recognition of Synthetic Aperture Radar Images Using Elliptical Fourier Descriptors” (Master of Science thesis, Florida Institute of Technology, 2007), 9,

http://www.amalthea-reu.org/pubs/Nicoli_fit_ms_thesis_2007.pdf (accessed June 24, 2013).

2. Jim Schroeder, "Automatic Target Detection and Recognition Using Synthetic Aperture Radar Imagery" (Workshop on the Applications of Radio Science held 20–22 February 2002 in Leura, Australia), 2.

3. Ibid., 3.

4. Leslie M. Novak, Gregory J. Orwirka, and Christine M. Netishen, "Performance of a High-Resolution Polarimetric SAR Automatic Target Recognition System," *The Lincoln Laboratory Journal* 6, no. 1 (1993): 22, http://www.ll.mit.edu/publications/journal/pdf/vol06_no1/6.1.2.polarimetricsar.pdf (accessed June 24, 2013).

5. P. Han and others, "An Efficient SAR ATR Approach," in *2003 IEEE International Conference on Acoustics, Speech, and Signal Processing*, vol. 2, *Speech Processing II, Industry Technology Tracks, Design & Implementation of Signal Processing Systems, Neural Networks for Signal Processing* (Hong Kong: The Institute of Electrical and Electronics Engineers, Signal Processing Society, 2003), 429.

6. Nicoli, 3.

7. Han and others, 429.

8. Nicoli, 47–48.

9. Ibid., 49.

10. Ibid., 50–51.

11. Ibid., 52.

12. Ibid., 28.

13. Ibid., 20.

14. Ibid., 50.

15. Nicoli explains that overfitting effects occur "when a classifier becomes too specific to the training data. An overfit classifier does a good job of identifying class membership of the training set, yet lacks enough generality to have similar classification accuracy on test data." Ibid., 28.

16. Ibid., 56.

17. Ibid., 55.

18. Novak, Orwirka, and Netishen, 12.

19. M. C. Burl and L. M. Novak, "Polarimetric Segmentation of Synthetic Aperture Radar Imagery," 1, http://les-novak.com/les_novak2.html (accessed June 24, 2013).

20. Ibid., 12.

21. L. M. Novak and others, "Optimal Processing of Polarimetric Synthetic Aperture Radar Imagery," *The Lincoln Laboratory Journal* 3, no. 2, (1990): 274, http://www.ll.mit.edu/publications/journal/pdf/vol03_no2/3.2.5.opticalprocessingSAR.pdf (accessed June 24, 2013).

22. Ibid., 276.

23. Novak, Orwirka, and Netishen, 17.

24. Ibid., 2.

25. Novak and others, "Optimal Processing of Polarimetric," 277.

26. Ibid., 278.

27. ART 2 is the adaptive resonance theory model that extends network capabilities to support continuous inputs.

28. L. Novak and others, "High Resolution Radar Target Identification," in *Conference Record Twenty-Sixth Asilomar Conference on Signals, Systems & Computers* (n.p.: The Institute of Electrical and Electronics Engineers, 1992), 1048, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=269138 (accessed June 24, 2013).

29. Ibid., 1057.

30. Nicoli, 60.

31. Ibid.

32. Ibid., 5.

33. Novak and others, "High Resolution Radar Target," 1052.

The Drawdown in Afghanistan: Lessons from Iraq

Introduction

Many of the unseen challenges of war involve the planning and execution of logistics. Most combat troops just expect logistics to happen, and they do not realize the amount of planning that goes into it. Others underestimate the critical role that logistics plays in winning a conflict, as well as preserving defense dollars.

By Chief Warrant Officer Two Willieray G. Woodberry

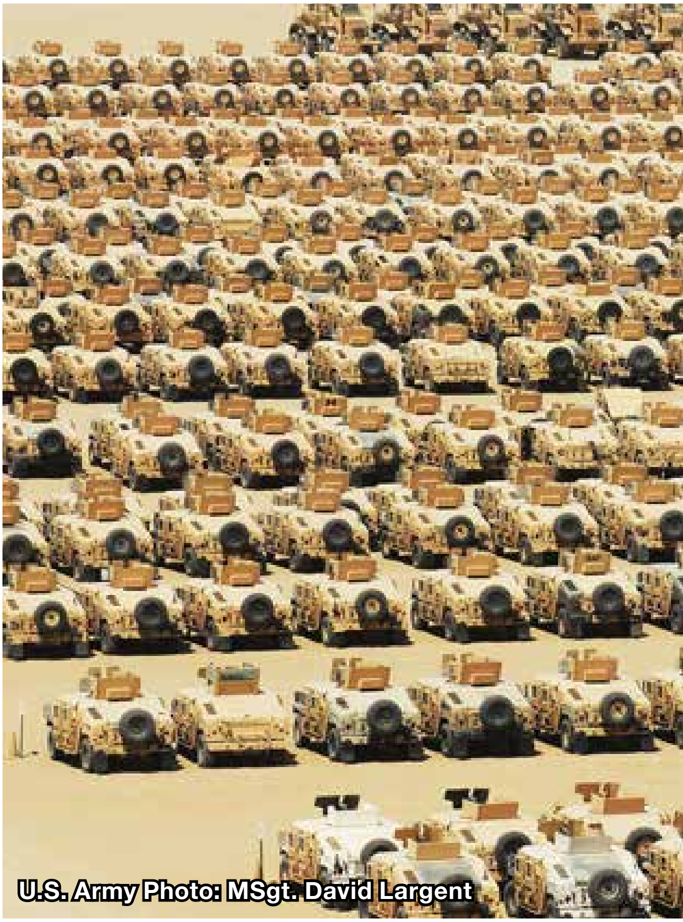
Editor's note: In editing this article, the author's American spelling and idiomatic conventions have been maintained.

One of the most critical tasks of logistics is deploying and redeploying equipment and personnel. The United States (US) Civil War is regarded as the turning point for America's post-war drawdown and demobilization policy. It marked the first significant logistical drawdown of troops and equipment for America. Some of the significant logistical drawdown missions that followed include: the Spanish–American War as well as World Wars I and II. At the end of World War II in Europe, the US conducted a mission known as "Operation Magic Carpet." This was a monumental redeployment of forces and equipment. Even with Iraq, that operation is probably the most complex logistical mission in history. The mission consisted of redeploying over a million troops and hundreds of thousands of military vehicles from Europe back to the US. With the advent of the global war on terror, America now faces modern logistical drawdown challenges in both Iraq and Afghanistan.

When President Barack Obama entered office, there were about 142,000 American troops on the ground in Iraq. Based on a 2008 agreement between Baghdad and Washington, all troops and equipment were supposed to be out of Iraq by December 31, 2011. The White House was aware of the challenges involved with the drawdown of an area our military had spent the last eight years building up. The drawdown of Iraq, and build up of Afghanistan, has been referred to as the largest logistical operation since World War II. On December 15, 2011, the US officially ended nine years of operations in Iraq, which also ended the drawdown of troops and equipment in this country. It is important for the Obama administration to quickly assess the lessons learned from the drawing down of troops and equipment in Iraq and, if possible, apply them when executing the drawdown in Afghanistan, which is scheduled to be completed by the end of 2014. Despite the fact that the US completed the Iraq drawdown with minimal damage, the Afghanistan drawdown will present even greater logistical challenges. To prevent waste with respect to troop effort and defense budget, the administration must refine its decision-making process for the Afghanistan drawdown.

My experience in Iraq

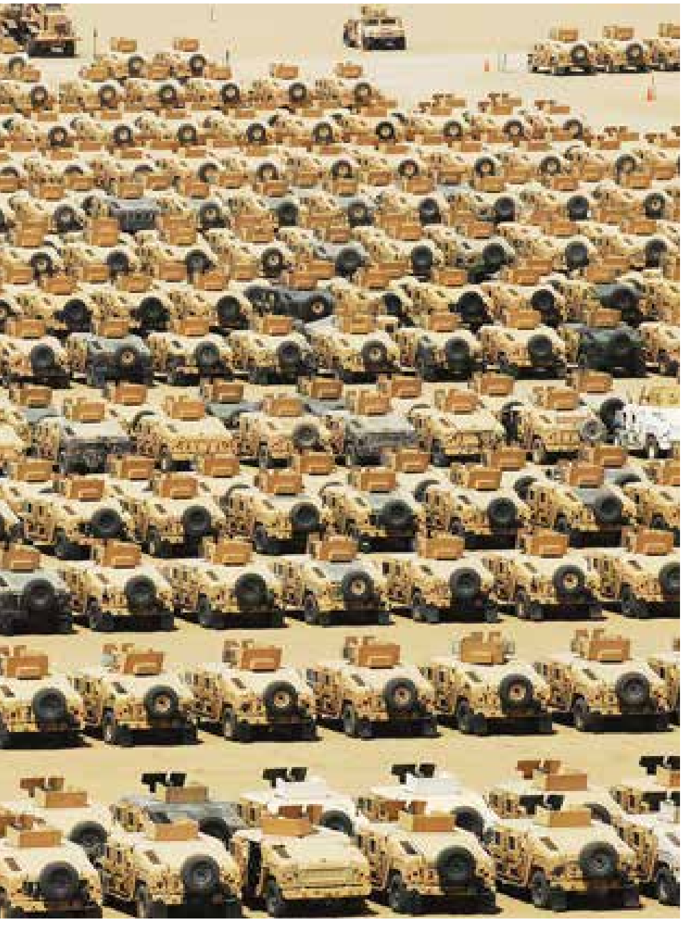
When I arrived in Iraq on July 4, 2011, I found myself in the middle of America's largest logistical operation since World War II. Having received tasking orders assigning me to the Combined Joint Special Operations Task Force – Arabian Peninsula, I had no idea the challenges I was up against. However, being



U.S. Army Photo: MSgt. David Largent

a Property Book Officer,[1] I figured my work was cut out for me. Upon arrival, I realized I was assuming the role as the senior Property Book Officer in Iraq for the special operations forces. This involved being responsible for drawing down and redeploying over US$5.6 billion worth of equipment throughout various locations in Iraq. I initially questioned why they brought me in, having no experience with the special operations community or their specific equipment. There were many other Property Book Officers who had this kind of experience, and it seemed to be more logical to bring one of them in for a mission of this magnitude. But I just accepted it as challenge, and a challenge it certainly was.

Another concern was the lack of progress that had taken place prior to my arrival.



This was a drawdown that had begun back in 2008, and I expected that as I was going in towards the end of the drawdown I would be just tying up loose ends. That was certainly not the case. Considering that I arrived in July of 2011, I was shocked at the amount of equipment that still remained. The property book still contained over 400,000 pieces of equipment. Part of the reason for this was our intent to engage the enemy until the end, and the other part was our administration awaiting a decision from the Government of Iraq.

The decision was whether they wanted a small element of troops to stay past the December 31 withdrawal date. There had been discussion of leaving anywhere from 8,000 to 15,000 troops behind to continue training the Iraqi military. This residual force would have also sent a clear message to Iraq and its neighboring countries that America would still maintain an interest in this region. Of course, this hindered our drawdown mission. Our commanders were stuck deciding whether to: a) be proactive in order to meet the drawdown timeline or b) maintain an equipment level that would allow them to meet the potential requirement to stay in Iraq. Around mid-August, we started to reduce our equipment at a more rapid pace, but at this stage, it still was not rapid enough. Most of the equipment was used to supplement shortages in Afghanistan.[2] In my opinion, this was effective reutilization of defense dollars. It did, however, involve a lot of planning and coordination.

Another aspect of the planning included sustaining troops for a potential enduring presence. We could not ignore the fact that the decision to remain in Iraq still loomed. But as we moved closer to the withdrawal date, the potential to stay seemed less and less likely. Then the number of troops that would stay, if they asked us to, continued to get smaller. Still we had every indication that the drawdown would not "go to zero."[3]

After a couple of months of a gradual drawdown, the decision finally came down on October 15. The US government had given our troops the order to "go to zero." This decision was a long time in the making, and many felt we had given the Iraqis too much time to decide. Ultimately, it was more of a non-decision. In either case, we had a lot left to do and only two months to do it.


U.S. Army photo

It quickly became a mad scramble to get equipment out of Iraq and move it just about anywhere else. With so many units trying to exit, property was lost and shipments were misplaced. Due to time and cost constraints, air and ground shipments were redirected. Some of our units had to leave equipment in place or sign it over to the Government of Iraq. Furthermore, the situation created difficulties with our initial plan to retrograde[4] most of our equipment to Afghanistan.[5] We were now sending a majority of it to Kuwait because it was easier to transport trucks and troops down there as opposed to flying them to Afghanistan. It had not been difficult to anticipate this outcome. Our administration gave the Government of Iraq so long to decide that our troops now had to carry the burden of getting everything out by December 31.

Fortunately, we had the advantage of using Kuwait as a backup retrograde plan which prevented what could have been a massive logistical nightmare. With a drawdown of this magnitude, success can be measured by how little we lost in government equipment. In my unit's case, we turned in, transferred and redeployed over US$5.6 billion of equipment. Less than 0.01 per cent of that dollar value was determined to be a loss to the government. Many other units throughout Iraq had similar success stories. All things considered, the consensus was that we had averted a disaster.

Different challenges for Afghanistan

Although we assess lessons learned from Iraq, no two drawdowns will be identical. All historical examples have faced different logistical issues. It is important to understand that some of our mistakes from Iraq could prove to be critical in Afghanistan. Some of the differences between what we faced in Iraq and what will be potentially faced in Afghanistan include:

- more equipment accumulated over a longer period;
- limited access to supply routes for ground transportation; and
- determining location to retrograde equipment leaving Afghanistan.

The first distinctive challenge will be the amount of equipment Afghanistan will have compared to Iraq. As we conducted the equipment drawdown in Iraq, there was a simultaneous build up taking place in Afghanistan. More than half of the equipment that came out of Iraq was slated to fill


US Photo: Sgt Manual J. Martinez

shortages in Afghanistan. Though some of the equipment was diverted to Kuwait as a contingency for an immediate retrograde, it will still be reset and sent to Afghanistan in the near future. This fact highlights a key difference between the two drawdowns. In a sense, it could be considered kicking the can down the road. However, Afghanistan does have a legitimate need for this equipment.

It has been argued that more resources were devoted to Iraq than Afghanistan.[6] These resources are now being redirected to Afghanistan as we employ a similar strategy used in Iraq—building up before the withdrawal. It is also important to remember that Afghanistan is officially the longest war in America's history. We are facing over ten years' worth of build-up rather than just eight. It would be a fair assumption to expect twice the amount of equipment which came out of Iraq to be retrograded out of Afghanistan.

Another challenge that will differentiate Afghanistan from Iraq is the limited access to supply routes for ground transportation. This factor will also force the US to rely on the more costly air transportation method. Even before the drawdown, getting equipment in and out of Afghanistan had already been costly and logistically challenging. Derek Mitchell, an Assistant Secretary of Defense for Asian and Pacific security affairs, summed up the issues by stating: "Look at the geography of getting things into Afghanistan" and "Look at the countries that surround [Afghanistan], the nature of their relationships [to] and the distance from the United States."[7]

An example of what Secretary Mitchell is referring to is the chaos evolving with the supply routes going through Pakistan. In November, Pakistan closed access to key supply routes for US and North Atlantic Treaty Organization (NATO) forces following air strikes.[8] Pakistan said an attack by the American-led NATO force based in Afghanistan that killed 24 Pakistani soldiers had triggered "rage" in the nuclear-armed nation and reversed progress in repairing ties with the US.[9] The US could not afford to lose access to these routes during a critical drawdown period.

This dilemma forced the US to establish what is referred to as the Northern Distribution Network. This route basically links Baltic and Caspian ports with Afghanistan via Russia. This will limit the requirement for the US to have to transport cargo through Pakistan. In 2011, an average of 63 per cent of all US military surface cargo moved through the Northern Distribution Network.[10] The US also has to rely on air transportation, which is a much more costly method. What we learned in Iraq is that waiting until the last minute limits our movement options even further.

The last significant difference between the Iraq and Afghanistan drawdowns is the ability to retrograde to "in-theatre" locations. As I mentioned previously, in Iraq, we had the luxury of retrograding most of our equipment to Afghanistan or Kuwait. Upon receiving the "go to zero" order, time was of the essence. At that point, the bottom essentially fell out of Iraq, and Kuwait became the primary receiving ground for the majority of the equipment exiting Iraq. Major General Thomas Richardson (US Army), J4 (Joint Logistics)

Northern Distribution Network

Director, US Forces–Iraq, described our drawdown efforts as building a "mountain of steel" in Kuwait. Because of this mountain of steel, Afghanistan may not have the same opportunity to use Kuwait as a location to retrograde equipment. Storage space is currently limited and will probably remain limited throughout the Afghanistan drawdown. With that in mind, the US now has to explore its options of where to send the equipment as we exit Afghanistan.

Conclusion: Applying lessons from Iraq to Afghanistan

We escaped the Iraq drawdown with minimal loss of equipment and defense dollars because Iraq had a better logistical infrastructure than what exists in Afghanistan.

Afghanistan will have more equipment, less access to supply routes and very limited options to retrograde the equipment. The post-World War I and post-World War II Army relied on stockpiles of material and equipment from the previous war. The post-Afghanistan Army may have to as well. Budget cuts have negatively impacted the ability to buy new and modern equipment. Equipment coming from Iraq and Afghanistan can be used to sustain the military's readiness for future combat missions.

The biggest setback of the Iraq equipment drawdown was the amount of equipment that was left for the government of Iraq. If our troops had been given adequate time, I have no doubt we could have preserved even more equipment and tax dollars than we did. Our timeline to pull out of Afghanistan needs to be dictated by the White House. We do not need to have US and allied forces sit and wait for another country's government to decide whether they want our help. Afghanistan's government needs to play some role but not as crucial a role as we allowed the Government of Iraq to have. We need to speed up the timeline in order to reduce the burden on the troops on the ground. In my opinion, Iraq was only practice for the big game. If we wait too long to decide our fate in Afghanistan, we will have a logistical nightmare that will result in a massive loss of equipment and defense dollars.


US Marine Corps Photo: Cpl Ned Johnson

Willieray G. Woodberry was born in Oklahoma City, OK in 1980. Willie enlisted in the US Army in 1998. Since then, he has lived in Alaska, Georgia, Washington, D.C. and Texas. Mr. Woodberry has achieved the rank of Chief Warrant Officer Two in the field of Property Accounting Technician, which manages the accountability of all Army equipment. His most prominent assignments include: Senior Supply Sergeant for the White House Communications Agency and Property Book Officer for Joint Forces Special Operations Component Command –Iraq. He is currently serving as the 11th Transportation Battalion Property Book Officer in Virginia Beach, VA. Mr. Woodberry received his Bachelor of Science in Business Administration at University of Maryland University College and is working towards a Master of International Relations at the University of Oklahoma.

Abbreviations

NATO	North Atlantic Treaty Organization
US	United States

Notes

1. As the Accountable Property Officer, the Property Book Officer, plans and directs the facility property management program

for a particular area of responsibility. The Property Book Officer uses the Property Book Unit Supply System Enhanced (PBUSE) to accurately account for all non-expendable property; requests, receives and issues nonexpendable property items to Primary Hand Receipt Holders; and provides general guidance and policies to the Government Property Administrator regarding property management procedures for Government Furnished Property. Source: United States Office of Personnel Management, "USA Jobs, Property Book Officer," United States Office of Personnel Management, https://www.usajobs.gov/GetJob/ViewDetails/323345700 (accessed April 11, 2013).

2. We had an asset visibility monitor located in Qatar that would basically look across the Central theater to determine if our excess equipment was needed in another location. If so, we would be given an order to transfer the equipment to a particular location. In the end, we redistributed a majority of our equipment to Afghanistan.

3. "Go to zero" means to remove all US forces and equipment from the area.

4. "Retrograde" means to move backwards (i.e., move "backwards" out of Iraq).

5. Throughout the Iraqi conflict, many units deployed with equipment and left it in country for other units to use. The US contractors also brought in equipment. When we departed for good in 2011, we had to determine what to do with all the equipment. In 2009, Colonel Michael A. Armstead described seven possible destinations for retrograded equipment as follows: "remain in Iraq to be used by Government of Iraq, disposed of in country, redistributed to Afghanistan, sent back to the CONUS [Continental United States], placed in APS [Army Preposition Stocks], donated to ACSA [Acquisition Cross Service Agreement] member countries, or placed in one of the Forward Deployed Equipment Sites." Based on my experience, that was spot on. Colonel Michael A. Armstead, "The Retrograde of United States Military Equipment out of Iraq" (Strategy Research Project, US Army War College, 2009), 18, http://www.dtic.mil/cgi-bin/GetTRDoc?/AD=ADA498068 (accessed February 22, 2013, site discontinued).

6. See A. Rashid, *Descent into Chaos: The U.S. and the Disaster in Pakistan, Afghanistan, and Central Asia* (New York: Penguin Books, 2008) and S. G. Jones, *In the Graveyard of Empires: America's War in Afghanistan* (New York: W.W. Norton, 2010).

7. Quoted in an article by Tom Gjelten, "U.S. Now Relies on Alternate Afghan Supply Routes," National Public Radio, September 16, 2011, http://www.npr.org/2011/09/16/140510790/u-s-now-relies-on-alternate-afghan-supply-routes (accessed April 11, 2013).

8. N. Hodge, "U.S. Faces New Afghan Test," *Wall Street Journal*, November 28, 2011, http://online.wsj.com/article/SB10001424052970204753404577064361792550488.html (accessed January 31, 2013, subscription required).

9. H. Anwar and S. Anwar, "NATO Attack Has Triggered 'Rage': Pakistan," Bloomberg, November 27, 2011, http://www.bloomberg.com/news/2011-11-26/nato-forces-kill-24-pakistani-soldiers-in-raid-on-border-post.html (accessed April 11, 2013).

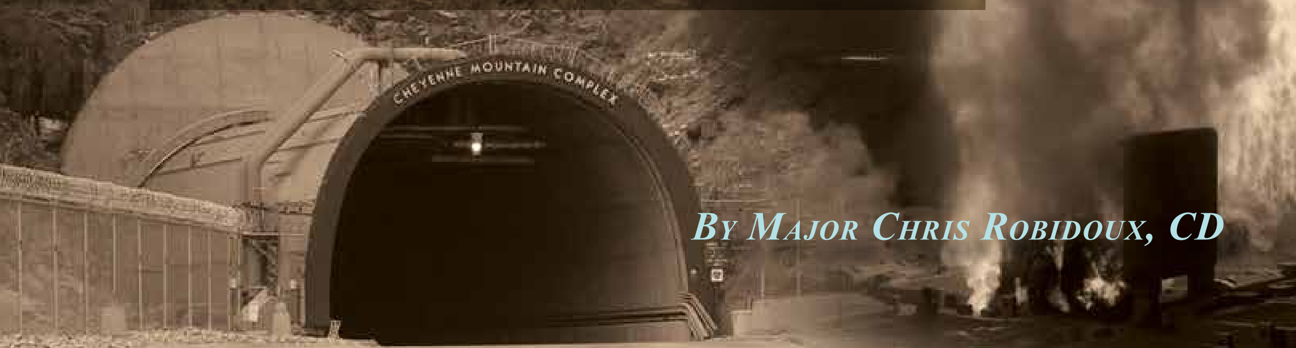
10. Hodge.

Shield of Dreams?

Assessing Canada's Non-participation in Strategic Ballistic Missile Defence

[W]e respect the right of the United States to defend itself and its people. Indeed, we will continue to work in partnership with our southern neighbours on the common defence of North America and on continental security. However, ballistic missile defence is not where we will concentrate our efforts.[1]

– Pierre Pettigrew,
Minister of Foreign Affairs,
24 February 2005



By Major Chris Robidoux, CD

INTRODUCTION

Ballistic missile defence (BMD), in its various iterations, was certainly a major issue at the time of Pettigrew's announcement in February 2005. Indeed, it had dominated the political landscape in Canada for months prior to the decision to politely decline participation in the latest American plan to defend North America from a limited ballistic missile attack. Due to geographical considerations and shared collective defence interests, Canada had been invited to participate in the North American "missile shield" for decades. The Liberal Government of the day—bombarded with tough questions from the Americans, Canadian press and various lobby groups—wanted to avoid a scenario where they would be tied to the "American missile shield" as a major election issue. All was not well for Paul Martin's minority government, as their support was extremely weak in Quebec due to the advertising scandal; furthermore, the New Democratic Party and Bloc Quebecois were aggressively pressing for a Liberal decision of non-participation.[2] Additionally, high profile celebrities, retired generals and countless academics publically advocated for non-participation.[3] The nail in the BMD coffin, however, was an EKOS poll in mid-February 2005; it indicated that public opposition to Canadian participation in ballistic missile defence was 54 per cent and increasing. Only 34 per cent of the nation would support a decision to participate, a 3 per cent decrease over the previous five months.[4] The political pressure became too great, especially with an election on the horizon. As a result, Pettigrew made the above non-participation announcement on 24 February 2005.

In late 2004, President George W. Bush stated during a press conference in Halifax that he and the Prime Minister had "talked about the future of NORAD [North American Aerospace Defence Command] and how the organization can best meet emerging threats and safeguard our continent against attack from ballistic missiles."[5] There can be little argument that the United States (US) government would have strongly preferred Canadian participation and a public display of support and cooperation, but the Americans were prepared to press ahead with BMD, unilaterally if required, and were not truly concerned with the outcome of the Canadian decision.[6] This idea is supported by Dr. James Fergusson, Canada's leading authority on ballistic missile defence, who stated that there was no real need to make a decision on BMD participation. After all, there were no ongoing formal negotiations with the US on the terms of Canadian participation and there was no significant pressure from the US, especially given the premature state of the technological aspects of the BMD programme.[7]

Pettigrew's announcement was surely frustrating for President Bush and his staff, as he did not return the Prime Minister's personal phone call informing him of the decision of non-participation.[8] The US Ambassador to Canada, Paul Cellucci, was equally frustrated, stating "We really don't get it. I personally don't think it's in Canada's sovereign interest to be outside the room when a decision is being made about a missile that might be coming towards Canada. We will deploy. We will defend North America."[9] Although a negative response from the Americans was undoubtedly expected, one had to wonder about the repercussions for Canada in the coming months and years. Although successive governments had never committed to join the initiative, talks had been ongoing for years. Nobel Prize winner and Pugwash group founder John Polanyi once warned that "the Canadian government, having held back from President George W. Bush's rush to war in Iraq, appears likely to join his rush to missile defence" and that Canada has "angered the Americans over Iraq, and we must now placate them over missile defence," another indication that a decision to participate was imminent.[10]

During the 2004 negotiations, the US government was told that participation in the BMD programme would be predicated on no additional cost to Canadian taxpayers, no missiles based in Canada, the provision of a clearly defined level of influence in the decision-making process in the event of a launch against North America, insight into the development and effectiveness of the system, and a guarantee that the weaponization of space would not occur.[11] Obviously, any sovereign government would require a significant amount of detail regarding the operation, effectiveness and protocols of a defensive system prior to joining the initiative. Unfortunately, the US government required a public decision before any of these details would be released and refused to clarify their outlook on how Canadian cities would be defended in the event that both Canadian and American cities were attacked simultaneously.[12] These issues, along with the significant public debate in Canada concerning "fortress North America" and a dearth of public support from voters, led to the non-participation announcement.

There were those in Canada who feared that non-participation in the BMD programme would result in a decline in relations with the United States. Fergusson, for one, stated that Martin's decision "represents a blow to the manner in which bilateral defence, if not broader foreign policy relations, are [sic] conducted with the Americans and other nations."[13] Although Canada has enjoyed its place as the United States' most important trading partner and had a privileged position as a NORAD equal, it is entirely possible that Canada's decision may have soured these relations.

It has been over seven years since Pettigrew's announcement of Canada's non-participation in North American ballistic missile defence. The time has come for a retrospective on the fallout of the Canadian decision to decline the American invitation to cooperate in the ballistic missile defence of the continent. There are countless aspects of domestic politics, foreign policy, collective defence and trade that, together, contributed to the decision not to participate in BMD. It is argued that the decision was taken because detailed technical characteristics of the BMD system would not be provided, casting doubts on its utility; the rogue state threat was still quite immature; the future of NORAD had been secured prior to the decision; and Canada's long history of trade and foreign relations with the US would surely trump one difference of opinion. Still, this particular choice could have led to a significant sovereignty issue for Canada, given that no Canadian inputs would be injected into the decision-making process should North America be attacked by ballistic missiles.

V-2 rocket

Creative Commons attribution Chmee2, 2009, http://creativecommons.org/licenses/by/3.0

THE EVOLUTION OF BALLISTIC MISSILE DEFENCE

In order to fully understand the reasons behind the decision, a detailed understanding of the threat, as well as the defence against it, is absolutely required. The concept of ballistic missile defence can be traced back to the

Second World War. During the last months of the conflict, German scientists began perfecting their long-range V-2 rocket system, which was essentially the precursor to today's cruise missile technology.[14] Although the V-2's guidance and propulsion systems were comparatively immature, the Germans were able to strike at targets deep into Britain. Almost immediately, military strategists and scientists started to discuss effective ways to counter the threat. In the years immediately after the war, the capabilities, accuracy and ranges of these weapons began to increase significantly, as did tensions between the United States and the Soviet Union.

By 1957, the Soviets not only had developed nuclear weapons but also were able to successfully launch Sputnik, the world's first artificial satellite. Although the Americans were under the assumption that they were the world-leading technological power, the Soviet Union's ability to launch an object into orbit exposed the United States' vulnerabilities to attack from what would become known as the intercontinental ballistic missile (ICBM).[15] The Americans were determined to ensure they could field an adequate defence against this type of threat, and efforts to nullify this new capability were redoubled, culminating with the development of the Nike series of ballistic missile interceptors. The Nike series of ICBM interceptors, most notably the Nike-Zeus and Nike-X, evolved throughout the late 1950s and early 1960s. Unfortunately, antiballistic missile technology was still at a premature stage, and these missiles were plagued by rudimentary propulsion, guidance and computational issues.[16]

During this time frame, the government of Prime Minister Lester B. Pearson was quietly monitoring the American antiballistic missile (ABM) initiative. While it was Pearson's preference to remain outside of the ABM initiative, he worried that Canada's participation in NORAD would mean an "automatic" inclusion in ABM, due to NORAD's missile warning mandate. To assuage Pearson's apprehension, US Secretary of Defense Robert McNamara assured him in 1967 that participation was optional and that the NORAD agreement would continue regardless of the Canadian decision. Although Canada participated indirectly through its NORAD missile warning responsibilities, no Canadian would participate in the command and control of any ABM intercept.[17] Dr. Joel Sokolsky, a noted professor specializing in Canadian foreign and defence policies, suggests that Canada's participation in NORAD provides the government with "not so much a seat at the table as a seat at the console,"[18] which allows the Canadian government to participate in NORAD deliberations in the event of a missile attack on North America. The fact that Pearson did not have a seat at the "ABM table" seemed to be an acceptable price to pay for not having to deal with the politically volatile ABM issue in Parliament.

Unfortunately for the developers of the Nike systems, the programme was cancelled in 1967 by President Lyndon B. Johnson in favour of the Sentinel ballistic missile defence system. The Sentinel system utilized the long-range Spartan and short-range Sprint missiles in the first attempt to defend American cities using a layered approach. Both missiles were nuclear tipped to enhance their effectiveness, compensating for their lack of accuracy and guidance.[19] Although Sentinel was far from perfect and there were doubts that it would be able to actually succeed in the interception of an ICBM, Johnson ordered the system's deployment in 1967 to address the issue of an "ABM gap," which would likely become an issue during the presidential election in 1968.[20]

The American obsession with ballistic missile defence resulted in a series of arms control summits in the late 1960s and early 1970s. While some have argued that the Soviets were particularly worried that the existence of American ballistic missile defence interceptors would tip the strategic balance in their favour and eliminate the Soviet nuclear deterrent, the opposite may have actually been true. According to Ernest Yanarella, Soviet strategic doctrine in this time frame was favourably disposed to the development of ABM systems. In June 1967, Premier Kosygin stated that the Soviets did not regard ABM systems as inherently destabilizing, given that they were not offensive in nature and could only provide a thin defence against an ICBM capability.[21] Arms control summits between the Americans and Soviets continued, culminating with the Anti-Ballistic Missile Treaty of 1972.

Conceptualization of a Soviet ABM site

The ABM Treaty was considered by many as the "crowning achievement of the US–Soviet arms control process."[22] After nearly three years of Strategic Arms Limitation Talks (SALT I), which limited ICBM and submarine-launched ballistic missiles (SLBM) numbers on both sides, the Americans and Soviets further agreed to terms on the ABM Treaty. This agreement limited each side to two ABM sites, separated by no less than 1,300 kilometres (km), to ensure the provision of limited coverage. Additionally, the treaty specifically banned the deployment of a nationwide ABM system.[23] The treaty was amended in 1974 to further limit both sides to one ABM site each. The Soviets chose to deploy the Galosh ABM system to defend Moscow, with the Americans already having deployed the Safeguard system to defend their ICBM silos in Grand Forks.[24]

Since the ABM Treaty was ratified, BMD has evolved from the Safeguard concept, through Ronald Reagan's science-fiction-like Strategic Defense Initiative (SDI) to the current ground-based, mid-course defence (GMD) system. GMD was designed to defend against an ICBM launch by using ground-based interceptor missiles from Fort Greely, Alaska, and Vandenberg Air Force Base, California. These missiles would, theoretically, intercept incoming ICBMs during the mid-course phase of flight. In other words, the interceptor would kinetically "kill" the incoming warheads while still in the space-based phase of flight. Despite the significant effort and cost that went into the development of the GMD system, some wondered if the idea of a ballistic missile defence system was worth it. Others—such as US Army Lieutenant General Robert Gard, who was a former president of National Defense University and the Director of the John Tompkins University Center in Bologna—were sceptical that any type of high-speed intercept in the mid-course phase would be successful. In a less than stellar endorsement of BMD, Gard once stated that any missile shield "amounts to putting a useless scarecrow in the sky, that is unlikely to ever work as envisioned."[25]

Just as it seemed that ballistic missile defence was losing steam in the United States, Saddam Hussein ordered the Iraqi invasion of Kuwait in August 1990, which resulted in international outrage, condemnation and sanctions against Iraq. Following six months of failed diplomacy and an allied force build up, US and coalition forces began operations in an attempt to expel Iraqi troops from Kuwait on 23 February 1991. Almost immediately, Hussein ordered the launching of Scud tactical ballistic missiles against targets in Saudi Arabia and Israel.[26] Although the Iraqis did not possess a ballistic missile with the range required to attack North America, it became clear that some "rogue state" would eventually develop these capabilities. As such, the Americans redoubled their efforts to establish an effective missile shield.

ICBM threat analysis: Fact or fiction?

To complete a detailed analysis of the utility of BMD, it is essential to understand where future ICBM threats may come from. The severity of these threats informed Prime Minister Martin's opinion on the utility of BMD as well as Canada's participation in the programme. Given the American experience with 9/11, the US government has elevated its tracking of nuclear and launch capabilities of all of the major players worldwide. With the elimination of Iraq as a potential nuclear threat following the Iraq War of 2003, the US government identified the Democratic People's Republic of Korea (DPRK) and Iran as the two primary states of concern due to their continued efforts to acquire and develop ICBM and nuclear technology.[27] To better contextualize the potential usefulness of ballistic missile defence, the nuclear and launch capabilities, as well as the foreign policies, of both the DPRK and Iran will be considered in greater detail.

Democratic People's Republic of Korea

Since the armistice ending the Korean War in 1953 and the subsequent placement of American forces in the Republic of Korea (ROK), the DPRK has demonstrated a continuous concern for its national security. Given the proximity of the nuclear-capable American forces in the ROK, North Korea's "founding father," Kim Il-sung, laid the foundation of a nuclear capability by requesting Soviet nuclear training for North Korean students and scientists in the 1950s. As part of this "Atoms for Peace" initiative, the Soviets assisted in the building of a nuclear research reactor in Yongbyon to provide training for North Korean scientists, resulting in a self-sufficient nuclear capability in the DPRK by the 1970s.[28] Throughout the 1970s and 1980s, the DPRK expanded their nuclear programme to include the development of graphite-moderated reactors and an experimental five megawatt-electric (MWe) reactor, which enabled the extraction of plutonium from spent fuel. Given that the DPRK was not a member of the Nuclear Non-Proliferation Treaty (NPT) during this time frame, Pyongyang was not required to declare these nuclear capabilities to the International Atomic Energy Agency (IAEA).

North Korean test launch of ICBM

Additionally, the DPRK continued with the development of its ballistic missile programme and went so far as to conduct a long-range rocket launch over the Japanese archipelago. While the North Koreans claimed that the launch was conducted for the purposes of putting its first satellite into orbit, the Americans feared that the launch was a test for North Korea's Taepodong-1 ICBM, a multiple-stage rocket system that could conceivably strike Alaska or Hawaii.[29] Congress shared these doubts and refused to allocate the funding required to construct two promised reactors as part of the Agreed Framework, further eroding the already tenuous relationship between the two states. Finally, accusations of pursuing alternate nuclear capabilities and uranium enrichment techniques by the Bush administration effectively ended the Agreed Framework and provided the DPRK a convenient excuse to withdraw from the NPT in 2003.[30]

During the last decade, the North Koreans have attempted to refine their ICBM and uranium enrichment techniques in an attempt to develop a home-grown nuclear deterrent to the United States, even though they had agreed to a moratorium on missile testing in the early 2000s. Underground nuclear test detonations occurred in 2006 and 2009, clearly demonstrating to the international community that the DPRK had no intention of willingly giving up its nuclear capabilities.[31]

North Korean rocket on launch pad

Islamic Republic of Iran

The Islamic Republic of Iran has also been active in its efforts to develop or obtain nuclear and multiple-stage rocket capabilities for decades. As a former ally of the United States and one of the first countries to sign the NPT, Iran began a programme devoted to the research of peaceful uses of nuclear energy in the 1950s. The US government sold the Iranians a small research reactor and assisted them in establishing the Nuclear Research Center at Tehran University in 1957. Peaceful Iranian nuclear research was conducted quietly for years, resulting in the decision in the 1970s to develop nuclear power plants to save Iranian oil and gas reserves. Iran continued with its nuclear ambitions throughout the next two decades, eventually developing a nuclear enrichment facility at Natanz and a heavy-water reactor at Arak. Although the construction of these facilities was not a violation of the NPT, the Iranian decision not to inform the IAEA of their existence resulted in significant concern throughout the international community, as it was widely believed that Iran was pursuing nuclear weapons.[32] Iran continued to pursue its nuclear interests throughout the 2000s, claiming a desire to produce low-enriched uranium (LEU). Citing the NPT provision of its "inalienable right" to develop a peaceful nuclear energy capability, Iran pursued a home-grown enrichment capability similar to those of Japan, Brazil and South Korea. This led to further apprehension internationally, as Iran's enrichment plant could easily be converted to produce weapons-grade uranium with little or no warning.

Bushehr nuclear power plant reactor

FARS Photo :Hamed Malekpour FARS NEWS AGENCY

During the latter half of the 2000s, Iran continued to alternate between negotiation and aggravation in its dealings with the US and the IAEA on its nuclear activities. Due to its aggressive pursuit of highly enriched uranium (HEU) and its ongoing attempts to weaponize it, the United Nations (UN) Security Council passed several resolutions in recent years demanding cooperation with the IAEA, additional inspections and the imposition of trade sanctions and arms embargos on Iran.[33] A recent resolution from the IAEA on Iran's nuclear activities states that the IAEA "expresses deep and increasing concern about the unresolved issues regarding the Iranian nuclear program, including those which need to be clarified to exclude the existence of possible military dimensions."[34] It was clear that Iran had no intention of giving up its nuclear aspirations, even in the face of intense international pressure and in spite of the sanctions imposed against them.

Iran has also been active in its pursuit of a long-range ballistic missile capability in parallel with its efforts to achieve a weaponized nuclear capability. It has one of the largest inventories of ballistic missiles in the Middle East and has expended significant effort in improving the range and capabilities of these weapons. Although the Iranians were initially bound to the procurement of existing ballistic missile systems for decades (such as the Scud variants from the Russians, the No Dong missiles from the DPRK and the CSS-8 systems from China), they have recently begun significant research and development in an effort to design and build more effective short- and medium-range systems.[35] The Iranian government increased funding to its ballistic missile development program in the mid-2000s, achieving moderate upgrades on its systems. Its Shahab series of missiles, based on Scud and No Dong missiles, were tested extensively and are estimated to have a range of approximately 1,300 km.[36] Over the last decade, the Iranians have conducted extensive testing and experimented with solid propellants in an attempt to improve missile ranges and reliability. In 2007, Iran reported that it had developed two new ballistic missiles, the Ashura and the Ghadr-1, which were capable of striking targets in excess of 2,000 km. Although outside analysts stated that the capabilities of these missiles were likely considerably exaggerated, the Iranian use of solid propellants suggested an improved understanding of ballistic missile technology, further heightening international concerns about Iran's improving weapons capabilities.[37]

Sejil-2 missile

Since 2007, Iran has continued in its efforts to improve its ballistic missile arsenal. The Sejil family of solid-propellant missiles was designed as a replacement for the liquid-fuelled Shahab missiles. In 2008, Iran announced the testing of the Sejil-1, a two-stage missile with a reported range of 2,000 km and followed with the testing of the Sejil-2 in 2009. According to US Secretary of Defense Robert Gates, the upgraded Sejil-2 has a range of between 2,000 and 2,400 km, and if launched from northwestern Iran, the Sejil-2 could reach from Vienna in the west to the interior of India in the east.[38] Again, the Iranian pursuit of such weapons has resulted in significant apprehension in Europe. As such, many European countries have pushed for a European system of ballistic missile defence.

Rogue states: Is the threat real?

It is without question that Iran and the DPRK are still significantly short of a nuclear ICBM capability. Due to the opacity of both regimes, the intentional misdirection of their capabilities and the difficulty in acquiring usable intelligence concerning Iranian and

North Korean research and development, it is difficult to forecast when this capability will be developed. Given their progress thus far, however, and due to the proliferation of technology and training between like-minded "states of concern," it is possible that both of these countries will develop a marriage between their nuclear and ICBM capabilities in the next decades.

In 1998, the Rumsfeld Commission suggested that Iran and North Korea could develop an ICBM capability, complete with a nuclear warhead, in a little as five to ten years.[39] Obviously, this commission was overly pessimistic in its assessment. More recently, however, the United States Air Force's National Air and Space Intelligence Center stated that "with sufficient foreign assistance, Iran could develop and test an ICBM capable of reaching the United States by 2015."[40] Over time and with enough assistance from existing nuclear states, either North Korea or Iran could finally develop a home-grown nuclear warhead small enough to be delivered on an ICBM. Defence planners must assume that, given their respective anti-American rhetoric and foreign policies, these states of concern could assist each other in the development of this type of weapon, lending credence to the American stance on the critical requirement for BMD.

Effects on NORAD

For over 50 years, NORAD has set the world standard for how a binational, collective defence arrangement can function, deter and evolve in the face of significant exterior threats and a revolving door of security challenges. Although originally designed to deter and warn of a Soviet bomber attack on North America, NORAD seamlessly refocused once the Soviet Union developed its ICBM capability. The command quickly developed an early warning and missile tracking capability that could operate in parallel with its bomber detection responsibilities. Once technology and engineering permitted, NORAD was one of the first agencies to take advantage of outer space, effectively using remote sensing, communications and missile tracking to optimal effect.[41] If anything, NORAD was exceptionally resilient, demonstrating an uncanny ability to expand its roles and improve its practices in the name of effective collective defence.

Even after decades of successes and resilience in the collective defence of North America in an exceptionally dynamic environment, some believed that Canada's decision not to participate in the American BMD plan in 2005 would result in significant changes for, if not the end of, the NORAD arrangement. This scenario could have been devastating, as participation in NORAD resulted in significant access to American defence plans, space-based initiatives and strategic developments. In this respect, NORAD may be more important for Canada than it is for the United States, and the loss of NORAD could mean a considerable loss of access.[42]

The NORAD agreement was renegotiated in 2004 to allow for NORAD's provision of integrated tactical warning and attack assessment (ITW/AA) to the missile defence system, regardless of the Canadian decision whether to participate. The alternative would have been to take the ITW/AA function from NORAD due to the bilateral nature of the organization, essentially eliminating much of NORAD's function and utility.[43] The BMD aspects of the negotiation would occur later, where Canada and the US would discuss the specific nature of the Canadian involvement, command and control issues, prioritization of targets to protect, and the costs involved. Before Canada would participate in the programme, very detailed answers to these questions had to be provided by the Americans. In addition, Canadian officials requested technical details of the ground-based, midcourse systems and sensors, for consideration by Canadian scientists. Given the opposition among Canadians, the effectiveness of the system had to be evaluated. Finally, many Canadians sought assurances that future iterations of the BMD system would not involve space-based interceptors, as this was considered "weaponizing" space according to the Outer Space Treaty. Unfortunately, the Americans required a firm and public "yes" before any classified information would be provided and certainly would not guarantee that they would never actually design and launch satellites with defensive capabilities. At this point, negotiations became increasingly difficult. These negotiating points, along with the soft support on BMD with voters, influenced the decision not to participate. It is interesting to note, however, that Canada only declined to participate in BMD *after* the new NORAD renegotiation was formalized just months earlier.[44]

By late 2005, the lessons from 9/11 had been learned, resulting in a more robust aerospace tracking posture, and Canada and the United States had agreed on NORAD's provision of ITW/AA data for GMD, but with no implicit Canadian participation in its command, control or defence prioritization. While the US was not going to need ITW/AA data from NORAD forever, as it had other means of obtaining this information, it made political sense to continue to use NORAD for this function, as it provided an existing and well understood mechanism for communicating an attack warning to Canada.[45] Finally, having Canadians continue their contribution to NORAD and having NORAD provide the crucial ITW/AA data for the GMD system, left a small crack in the door should Canada ever decide to reconsider their decision to contribute to the GMD initiative.

It was clear that both Canada and the US were determined to get over the BMD issue. Starting in 2006, significant changes began to occur at NORAD. Firstly, NORAD moved out of Cheyenne Mountain and into its new operations centre at Peterson Air Force Base at Colorado Springs. Next, NORAD added a maritime surveillance responsibility to its aerospace and space surveillance duties, tracking targets of interest on the maritime approaches to North America. Canada and the US also made the surprising decision to make the NORAD partnership a permanent one on 8 May 2006, removing the requirement for renegotiation every five years, a mere 15 months after Pettigrew's announcement.[46]

NORAD was also affected in a positive manner when the Tri-Command Framework was signed by the commanders of United States Northern Command (USNORTHCOM), NORAD and Canada Command in September 2009. Following nearly two years of study and negotiation, the Tri-Command Framework was created to clearly define the command relationships, responsibilities as well as liaison and support structures between the three commands charged with the collective defence of North America. One significant benefit of the Tri-Command Framework is that it acknowledges that there are unique missions in which sovereignty issues are paramount and allows for unilateral action as required, even though NORAD, a bilateral command, is supporting. This clause allows for significant NORAD support to either Canada or the United States for an event such as the 2010 Olympics in Vancouver.[47]

Conclusion: Canada, BMD and the Future

It has been several years since the Martin decision, and very little has changed for the Stephen Harper government on the issue. While Fergusson and others have assessed that Harper's Conservatives would be willing to entertain future discussions on participation in the American GMD plan, there has been no public indication that the Obama administration is inclined to reopen discussions. Since Canada agreed that NORAD would provide the required ITW/AA data to the GMD system and given that there is no current plan to request the use of Canadian territory for ground-based interceptors, radars or other infrastructure, there would be very little reason to revive the issue from an American perspective. It is clear, however, that the US intends to continue with its efforts to provide a layered defence of North America and its forward deployed troops, regardless of Canada's opinion on the matter.

As stated earlier, the nuclear ICBM capabilities of the DPRK and Iran are likely years, and possibly decades, away from maturity. Given the research, development and testing difficulties of some of the American BMD systems, it is plausible that both sets of capabilities may mature in parallel. While these capabilities develop, Canada could be an active participant on the world stage to ensure a more secure future for its allies.

MDA Photo

Firstly, Canada could continue to be an advocate of, and set an example for, responsible military operations. Canada's continued support of the UN Security Council Resolutions concerning sanctions on Iran and the DPRK are critical to promoting nuclear responsibility. As long as these rogue nations continue to develop their clandestine nuclear programmes, Canada and its allies are less secure. Always active on the non-proliferation front, Canada should continue to set the example, such as in its participation in the NPT, the Comprehensive Nuclear Test Ban Treaty and the Fissile Material Cut-off Treaty. Additionally, Canada will surely continue to encourage disarmament and mutual arms reductions of the world's nuclear powers. It is crucial for Canada to encourage its allies, as well as "states of concern," to adhere to the restrictions set out in the Outer Space Treaty. While space will be utilized for military applications such as satellite communications, navigation and remote sensing, the weaponization of space could result in a new "arms race" that would heighten tensions and utilize scarce resources that could be used for more beneficial endeavours. It is also important for Canada to continue to lead the way on non-nuclear issues. Excellent examples are Canada's continued efforts on the banning of anti-personnel landmines and its support of human rights issues internationally. By continuing to be a respected and trusted advocate on these critical matters, Canada may be able to subtly influence the foreign and defence policies of various states in a positive way.

Secondly, the government could continue to refocus and build on the capabilities of NORAD. Canada and the US share a unique opportunity to cooperate closely and in an interoperable fashion to ensure the collective defence of an entire continent. Threats to North America will continue in the coming years, and NORAD must be ready to meet these security challenges. Although it is not likely that Russian aircraft will be flying over the North Pole with nuclear payloads, NORAD must be vigilant in its monitoring of the maritime approaches to the continent as well as incorporate a more robust land-monitoring capability. As former NORAD

Commander General Victor Renuart Jr. once stated: "NORAD today remains the most formidable aerospace defense capability in the world" and "has served as a credible deterrent to any aggression that might threaten North America."[48] Canada should do everything in its power to ensure NORAD's continued effectiveness.

Canada's decision not to participate in the BMD programme was based on three issues: a) Martin's belief that the US BMD capabilities and the rogue threat were both still quite immature; b) NORAD's future had already been secured; and c) that significant trade and foreign relations difficulties would be temporary due to Canada's long, rich history as an ally of the United States. Scholars such as Fergusson have suggested that Canada's non-participation in the ballistic missile programme could be detrimental to Canada in the long term, but this view appears to be short-sighted given the significant partnership that Canada has developed with its closest ally, as this decision did not have the suggested negative consequences. Recent governments were able to encourage a new and improved NORAD renewal, and a permanent one at that. While foreign relations with the US may have been temporarily soured, they improved significantly, resulting in several successful bilateral initiatives. Finally, any trade penalties suggested by these scholars simply never occurred, as both Canada and the United States enjoyed increases in imports and exports over most sectors.

At this point, however, the United States seems satisfied with the status quo. Their GMD system, based at Fort Greely and Vandenberg Air Force Base, is deployed and is being modified and improved continuously. While the concept of "hitting a bullet with a bullet" is a nearly impossible feat to achieve from a technological and engineering standpoint, great strides have been made in recent years to improve the likelihood of an ICBM intercept. In addition, the United States likely has at least a decade before a rogue state develops the capability to strike the homeland, which buys them some time to perfect their own technology.

Fort Greely missile silo

The US also seems satisfied with the NORAD ITW/AA arrangement. Although Canada is not directly participating in BMD, the use of the NORAD ITW/AA data resulted in less expensive and fewer technical BMD-specific layers for the GMD system. No doubt future developments with respect to BMD will be dictated by the requirements of the day; however, the onus will be placed on the Canadian government to reflect the will of the people with respect to any level of participation.

Major Chris Robidoux is an air combat systems officer (ACSO) currently employed in the Vice Chief of the Defence Staff Group. He joined the Canadian Forces (CF) in 1993 and has been privileged to serve in various capacities as a tactical CC130 ACSO at 8 Wing Trenton. Major Robidoux has been deployed on three 6-month deployments in support of operations in Afghanistan and, most recently, has completed a tour at 436 (T) Squadron. He is currently the officer responsible for the analysis and expansion of the CF force development scenario set at the Chief of Force Development.

Abbreviations

ABM	antiballistic missile
ACSO	air combat systems officer
BMD	ballistic missile defence
CF	Canadian Forces
DPRK	Democratic People's Republic of Korea
GMD	ground-based, mid-course defence
IAEA	International Atomic Energy Agency
ICBM	intercontinental ballistic missile
ITW/AA	integrated tactical warning and attack assessment
km	kilometre
NORAD	North American Aerospace Defence Command
NPT	Nuclear Non-Proliferation Treaty
ROK	Republic of Korea
UN	United Nations
US	United States

Notes

1. Steven Staples, *Missile Defence: Round One* (Toronto: James Lorimer & Company Ltd, 2006), 207.

2. James Fergusson, *Canada and Ballistic Missile Defence, 1954–2009: Déjà Vu All Over Again* (Vancouver: UBC Press, 2010), 251.

3. Fraser A. F. MacKenzie, "Should Canada Re-Examine Its Position on Missile Defence?" *Canadian Military Journal* 9, no. 2 (2012): 102.

4. Staples, 207.

5. Fergusson, *Canada and Ballistic Missile Defence,* 249.

6. David Dyment, *Doing the Continental: A New Canadian–American Relationship* (Toronto: Dundurn Press, 2010), 42.

7. Fergusson, *Canada and Ballistic Missile Defence*, 250.

8. Staples, 221.

9. Ibid, 222.

10. Mel Hurtig, *Rushing to Armageddon: The Shocking Truth about Canada, Missile Defence, and Star Wars* (Toronto: McClelland & Stewart Ltd, 2004), 182.

11. Staples, 201.

12. Fergusson, *Canada and Ballistic Missile Defence*, 241.

13. James Fergusson, "Shall We Dance? The Missile Defence Decision, NORAD Renewal, and the Future of Canada–US Defence Relations," *Canadian Military Journal* 6, no. 2 (Summer 2005): 14.

14. Ernest J. Yanarella, *The Missile Defense Controversy: Technology in Search of a Mission* (Lexington: The University Press of Kentucky, 2002), 6.

15. Columba Peoples, *Justifying Ballistic Missile Defense: Technology, Security, and Culture* (Cambridge: Cambridge University Press, 2010), 100.

16. Yanarella, 90.

17. Fergusson, "Shall We Dance?" 16.

18. Joel J. Sokolsky, "A Seat at the Table: Canada and Its Alliances," *Armed Forces and Society* 16, no. 1 (Fall 1980): 21.

19. Peoples, 80.

20. Yanarella, 170.

21. Ibid., 183.

22. Ashton B. Carter and David N. Schwartz, *Ballistic Missile Defense* (Washington: The Brookings Institute, 1984), 221.

23. Richard Dean Burns and Lester H. Brune, *The Quest for Missile Defenses: 1944–2003* (Claremont: Regina Books, 2003), 72.

24. Carter and Schwartz, 219.

25. Staples, 141.

26. Yanarella, 202.

27. Fergusson, *Canada and Ballistic Missile Defence,* 259.

28. Ibid.

29. Yanarella, 209.

30. Siegfried S. Hecker, "Lessons Learned from the North Korean Nuclear Crisis," in *The Survival of North Korea: Essays on Strategy, Economics, and International Relations*, ed. Suk Hi Kim, Terence Roehrig, and Bernhard Seliger (Jefferson: McFarland & Company Publishers, 2011), 217.

31. Victor D. Cha, "Challenges for North Korea's Nuclear Endgame," in *New Challenges in North Korean Foreign Policy*, ed. Kyung-Ae Park (New York: Palgrave MacMillan, 2010), 187.

32. Ash U. Bali, "At the Nuclear Precipice: Iran," in *At the Nuclear Precipice: Catastrophe or Transformation*, ed. Richard Falk and David Krieger (New York: Palgrave MacMillan, 2008), 98.

33. Ibid., 108–9.

34. International Atomic Energy Agency, "IAEA Board Adopts Resolution on Iran," International Atomic Energy Agency, http://www.iaea.org/newscenter/news/2011/iran-resolution.html (accessed February 27, 2013).

35. Steven Hildreth, *Current Debate on Missile Defense* (Hauppaugge: Nova Science Publishers, Inc, 2004), 12.

36. Central Intelligence Agency, "Unclassified Report to Congress on the Acquisition of Technology and Advanced Conventional Munitions, 1 July through 31 December 2003."

37. Victoria Samson, *American Missile Defense: A Guide to the Issues* (Santa Barbara: Praeger, 2010), 15.

38. George Mader, "Assessing the Iranian Missile Threat," *Military Technology* (November 2009): 36–37.

39. Nik Hynek, "Missile Defence Discourses and Practices in Relevant Modalities of 21st-Century Deterrence," *Security Dialogue* 41, no. 4 (August 2010): 438.

40. Samson, 16.

41. Ibid, 156.

42. Fergusson, *Canada and Ballistic Missile Defence*, 221.

43. Ibid.

44. Brian W. Tomlin, Norman Hillmer, and Fen Osler Hampson, *Canada's International Policies: Agendas, Alternatives, and Politics* (Don Mills: Oxford University Press, 2008), 112.

45. Fergusson, "Shall We Dance?" 18.

46. Kim Richard Nossal, Stephane Roussel, and Stephane Paquin, *International Policy and Politics in Canada* (Toronto: Pearson Canada Inc., 2011), 343.

47. Ibid.

48. General Victor Renuart Jr. was the NORAD Commander from 2007 to 2010. Victor E. Renuart Jr., "The Enduring Value of NORAD," *Joint Forces Quarterly*, no. 54 (3rd Quarter 2009): 94, http://www.ndu.edu/press/lib/images/jfq-54/23.pdf (accessed February 27, 2013).

Advanced Integrated Multi-sensing Surveillance:

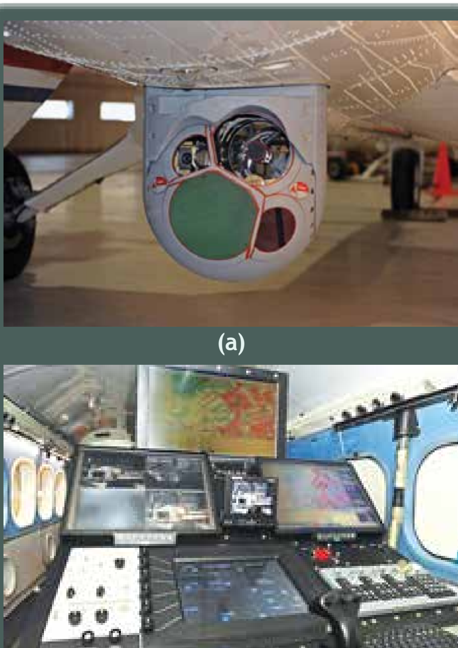
Capabilities for Future SAR and ISR Missions

By N. Léchevin
V. Larochelle
S. Roy
Captain K. E. Likuski
T. Rea

Context

Recent progress in active imaging adds a new sensing capability to standard electro-optical systems exploited in airborne applications. Active imaging systems provide their own illumination, enabling target interrogation in absence of ambient light. This capability is complementary to both thermal imagers and passive image intensifier systems. To deliver useful imagery, thermal imagers require thermal contrast. Passive image intensifiers sometimes cannot provide sufficient contrast in conditions of very low light (overcast nights) or in degraded visibility conditions (rain, fog or snow). In the absence of thermal contrast and in very low-light level conditions, active imaging systems stand out.

The Advanced Integrated Multi-sensing Surveillance (AIMS) system (Figure 1) is, to the best knowledge of the authors, the first airborne, range-gated, active-imaging-based technology integrated in an electro-optical multi-sensing gimbal demonstrator.[1] This demonstrator, led by Defence Research and Development Canada – Valcartier (DRDC Valcartier), was developed to significantly improve the all-weather, day and night intelligence, surveillance and reconnaissance (ISR) as well as search and rescue (SAR) sensing capabilities of the Canadian Forces (CF). The multi-channel, geo-referenced motion imagery capability benefits the CF via demonstrations, trials, experiments and exercises and, ultimately, helps the CF shape future procurement efforts.



(a)

(b)

Figure 1. AIMS system[2] (a) and operator station (b)

This article provides a preliminary performance assessment of AIMS in detecting and identifying targets, whether in an ISR or SAR context. The system received airworthiness certification in 2010, and two trials were conducted in 2011 using a National Research Council Flight Research Laboratory (NRC-FRL) Twin Otter (DHC-6) aircraft. A winter trial at Canadian Forces Base Valcartier, Québec, and a fall trial in Summerside, Prince Edward Island, allowed the team to test performance in various natural environments as well as lighting and weather conditions.

Technology

Figure 2. AIMS design concept

AIMS sensors consist of an active imager (AI),[3] a thermal imager, wide and narrow field of view (FOV) colour cameras, a laser rangefinder, a global positioning system (GPS) and an operator station.[4] The displays allow the operator to understand, process, integrate and control the information flow in a timely and effective manner (Figure 2). With high-resolution sensors and accurate pointing, the system can accurately geo-localize targets.[5] Sensor data (audio, video and still imagery), metadata and mission logs are recorded on a network video and recorder playback device and are presented to the operator using a stand-alone mapping, sensor control and user interface.

Central to the technology demonstrator's sensor suite is the active imager, which consists of a visible/near-infrared (IR), narrow, field-of-view, range-gated, intensified camera and a laser diode array illuminator. Advantages of active illumination include: surveillance in complete darkness, detection of objects based on their reflectivity contrast, detection of optical sights (binoculars, riflescopes and cameras) and penetration through glass. Further (as shown in Figure 3), the active imager range gating controls the camera intensifier to significantly reduce backscattered light caused by aerosols such as fog, smoke, rain and snow. Background effects, blooming effect caused by the presence of bright light sources and the potential of being dazzled are also reduced.

(a)

(b)

Figure 3. Ground observation of a car at night through snow before (a) and after (b) the activation of range gating

Performance assessment

Throughout the two trials, flight conditions (altitude, flying speed, slant distance as well as flights during day, night and twilight) and operating conditions (field-of-view angle and sensor slant angle) of the AIMS sensors suite were varied to assess its performance[6] by flying two types of missions: orbital flights centred on various targets and SAR mission flights. The SAR missions involved flying along parallel track patterns that covered a 5-kilometre (km) by 5-km area where the targets were deployed. The targets consisted of objects such as parachutes, letter panels, a 4-metre (m) by 5-m aircraft wreck mock-up, debris, seats, boxes (cooler), a 3.15-m by 5.65-m optical resolution target, strobe lights and a vehicle with armed soldiers wearing camouflage battledress.

Target detection, classification and identification

Although the sample size of the dataset resulting from the trials is too small to compute empirical conclusions with a satisfactory confidence level, the following three definitions qualify how we assessed performance.

Detection rate. Detection of an object ranges from 0 to 100 per cent as the object fills more and more pixels with sufficient contrast on the specific imager under consideration. The number of pixels required for 100 per cent detection is not sufficient to provide any shape information. An object such as a box can be discriminated from its environment, but there is not enough information to classify it as a box, a ball or a tree.

Classification rate. Classification of an object ranges from 0 to 100 per cent as the shape of the object becomes more and more defined for the specific imager under consideration. Thus, classification would be solely based on shape, which requires that a sufficient number of pixels are available to provide a good definition the object's outline. Moreover, the main variations in time and space of the

Target	Detection range (m)		Identification range (m)	
	Active imager	Infrared imager	Active imager	Infrared imager
Life jacket retro-reflectors	≥ 8,350	≥ 2,500		
Aircraft parts	5,433		1,726	5,277
Letter panel	4,500		1,646	2,456
Soldier	5,433	5,277	2,234	2,369
Seats	5,433	4,211	3,431	3,472

Table 1. Discrimination limits for various targets characterized at night

shape of an object should be detectable, thus enabling the classification of objects such as dynamic/static or animate/inanimate. For instance, the three sizes of white letter sequences on the black panel can be differentiated. Human beings can be considered as a class, but there is not enough information to identify a human as a military person with a battledress and gun or as a civilian.

Identification rate. Identification of an object will range from 0 to 100 per cent as more details about the object are revealed for the specific imager under consideration. The details could include identifying features such as its colour scheme, the presence of specific structures or the ability to read a name of other identifying text. Identification of the soldier is achieved when features such as the battledress, snowshoes, rifle, helmet and walkie-talkie can be recognized.

Quantitative analysis

Quantitative analysis establishing correlations between measure of performances (MoPs)—like sensor resolution or geo-positioning accuracy—and operating variables—such as slant distances and FOV angle—has been carried out with the optical resolution target, complying with theoretical estimates and with the ground sample distance. This distance corresponds to the diffraction limit angle and represents the lower bound of the active imager's resolution.

Winter trial night-time flights, performed under clear sky, provided the characterization lower bounds (slant range) for the targets presented in Table 1. Empty cells correspond to missing data.

Reading letters, such as aircraft registration signs, may be central to identifying targets (in night-time tactical as well as search and rescue missions) or ships. Signs of 15-centimetre (cm) and 30-cm height were stuck on the wing, fuselage and elevator of the aircraft wreck mock-up. Black panels with white letters of various sizes (10.2 cm, 17.8 cm and 35.6 cm) were also deployed. As shown in Figure 4, 30-cm registration signs located on the rudder can be read with AI at an altitude of 4,090 feet (ft) (1,246 m) and a slant distance of 1,627 m. It should be noted that only C, J and part of A letters remained fixed on the elevator. The other letters were removed.

Figure 4. Aircraft registration signs revealed at night by the active imager[7]

(a)

(b)

Figure 5. Letter panel displayed by (a) the active imager[8] and (b) the narrow FOV visible camera (passive mode)[9]

Figure 5(a) shows that 17.8-cm and 35.6-cm white letters can be read on a black panel at an altitude of 7,084 ft (2,159 m) and a slant distance of 2,456 m (night-time). The 10.2-cm letters cannot be clearly read; although, it is still possible to classify these white objects as being letters. For comparison purpose, Figure 5(b) shows the same panel displayed by the narrow FOV visible camera used in passive mode before twilight (slant distance is 1,994 m). Results are similar in both cases (active mode at night and passive mode at twilight).

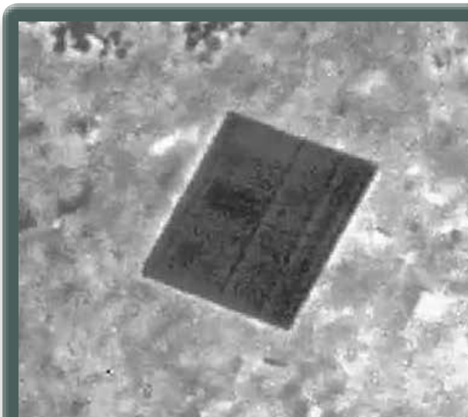
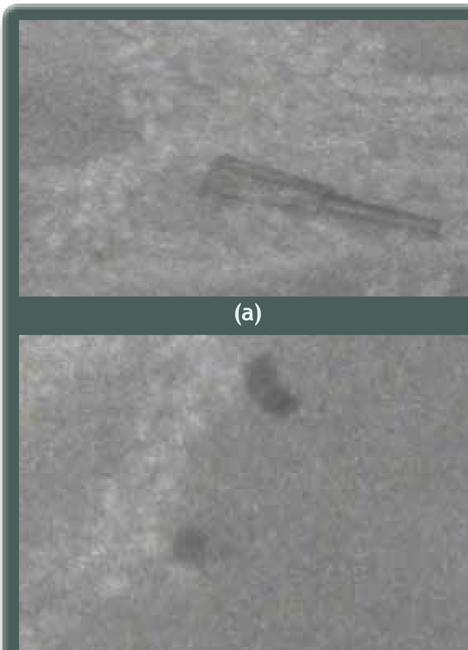


Figure 6. Letter panel displayed by the infrared image

As shown in Figure 6, the letters cannot be read using the IR imager under the same flight conditions as Figure 5. Attempts to read the letters at 19h40 (twilight time) lead to the same result, despite a possible greater thermal contrast.



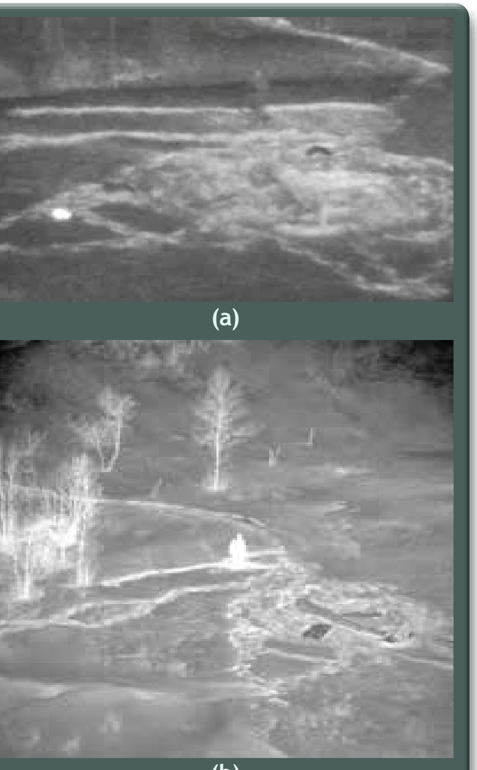
(a)

(b)

Figure 7. Black pipes (a) and two seats (b) displayed by the active imager at night[10]

A set of black pipes, a 1-square metre piece of metal, two seats, strobe lights and a red can were deployed to represent a mock-up of a burned aircraft. As shown in Figure 7, it was found that every object can be identified at a distance greater than or equal to 3 km. The strobe lights can be detected at a slant distance greater than 6 km whether AIMS active imager is in passive or active mode (Figure 8).

Figure 8: Strobe light and other elements of the burned aircraft mock-up displayed by the active imager at night



(a)

(b)

Figure 9. Aircraft wreck mock-up displayed at night by the active imager (a) and by the thermal imager (b)[11]

Qualitative analysis

Effective operator training is central to achieving fast detection of objects. This training includes understanding the object signature in various contexts and accounting for factors such as the type of terrain and cover, temperature and lighting conditions. Indeed, complementary information obtained from the combined exploitation of the infrared and active imagers should be fully leveraged.

Figure 9 suggests how to benefit from the use of both imagers by noticing that the life jacket retro-reflector can be clearly detected using the active imager at night, at a distance of 2,741 m, while thermal contrast such as those entailed by footprints in snow, the soldier and the aircraft mock-up wings are clearly displayed by the infrared imager at night. In Figure 9(a), the retro-reflector tape appears as a very bright object.

One of the targets included two soldiers with winter camouflage (white) and personal small arms. The active imager is sensitive to reflectivity contrast at its illumination wavelength (860 ± 5 nanometre [nm]) such as that resulting from the white battledress and the black weapons, and we clearly identify the two rifles in Figure 10(a). The contrast is lower in the thermal image; although, the FOV angle is larger than that of the active imager. Warm parts such as the head and gloves of each soldier can be identified. As shown in Figure 10 (b), due to a very low ambient temperature, -23°C, the thermal contrast between the rifle and the background make it extremely difficult to identify the rifle at a slant distance of 1,840 m and an altitude of 1,556 m.

(a)

(b)

Figure 10. Two soldiers at night with winter camouflage and small arms displayed by the active imager (a) and the thermal imager (b)[12]

Three points are worth mentioning: First, reflectivity contrast may result from the type of textile and not necessarily from its colour. Indeed, it has been shown that, given a type of textile, a high reflectance is obtained at 860 nm regardless of the colour of the textile.[13] Second, the position and orientation of the sensors with respect to a target may affect the appearance since thermal and reflectivity contrasts of the environment change with the viewing slant angle. Finally, object identification is facilitated when using video (kinetic images) as opposed to using a still image, as shown in the figures of this article. Over multiple video frames, the human brain tends to average out random noise in the raw data. Many real-time noise reduction techniques are available, but they are beyond the scope of this article.

Interestingly, targets of opportunity, detected while flying near or over the trial area, helped assess AIMS detection and identification capabilities. For instance, a bird formation flying at low altitude was detected at night, using the IR imager, at a slant distance of 3.1 km. Owing to the range gating, which is tuned to assess ground opportunity targets, the bird formation remained undetected with the active imager. However, a single bird flying over a water area was detected by the active and infrared imagers at a slant distance of 2.1 km. A group of three slow moving animals was detected in a field using the infrared imager at a slant distance of 3 km. The active imager clearly displayed a reflective object attached to each animal (most likely cows). The reflective objects were likely small identification tags attached to the ear of each cow. We also observed a family of beavers at ranges beyond 1.5 km; we were able to identify them by the shape of their tails (IR) and when they were looking towards us from the retro-reflections in their eyes (active mode), while clearly resolving the two eyeballs.

How AIMS may impact target search

SAR-type missions with AIMS

A parallel track pattern was adopted to search at night-time for a set of four targets (aircraft wreck mock-up, parachutes, burned aircraft and a vehicle with two armed soldiers) deployed over the trial areas. This pattern was selected for its simplicity. Several track spacing values were selected depending on experimental parameters such as the flight altitude as well as AIMS sensor FOVs and looking angles.

It would be highly desirable to assess the lateral range function[14] of AIMS, particularly that of the thermal imager. This assessment would be done in a closed loop with an operator working in a SAR mission target detection context. The best sweep width could then be determined, thus defining the track spacing characterizing a standard SAR pattern. The lateral range function is the cumulative probability that an object will be detected in the sensor field of view at a specific range.

The lateral range function of AIMS is central to allocating available searching effort, determining the search pattern parameters and computing the probability of detection over a given area and then the probability of success of the search mission. As the determination of the AIMS-operator lateral range function remains to be done, the sweep width was set to the maximum detection range. This range corresponds to the FOV width of the sensor given a prescribed FOV angle and flight altitude. The coverage factor, which is the ratio of the sweep width to the track spacing, was set to 1.4 to ensure sufficient margin between two consecutive passes in case of drift.

The track spacing used to define SAR patterns is typically twice as much as the visibility horizon, resulting in spacing equal to 10 nautical miles (18.5 km) for night searches.[15] However, active imaging in search missions is limited by its small field of view angles. For instance, assuming a slant angle of 30 degrees (°), a FOV angle of 0.47° and a flight altitude of 10,000 ft (10 kft or 3,048 m) give a sweep width of 50 m. Consequently, the active imager cannot realistically be used for target detection unless the likelihood that the search object is contained within the known boundaries of a very small area is very high.

Thus, the thermal imager was used for night search with a FOV angle of 22°. The wide FOV color camera was also used for daytime target search. Target assessment was carried out with the colour narrow FOV imager and the IR imager smaller FOV angles for daytime missions and with the thermal imager and the active imager smaller FOV angles for night-time missions.

Lessons learned

Detecting an object of potential interest, whether at night or at day, is a strenuous task.

First, the area displayed on the monitor, which depends on the sensor slant angle and the aircraft altitude, was deemed too large to achieve an efficient target search with a reasonable workload for the operator. For instance, a sensor slant angle and a flight altitude set to 30° and 3 kft [914.4 m], respectively, result in a search area of 645 m by 1,422 m displayed on AIMS monitors (FOV angle of 20°). Higher altitudes (5 kft [1,524 m], 7 kft [2,133.6 m] and 9 kft [2,743.2 m]) were flown, giving rise to larger areas to be scanned on monitors.

Second, the speed at which an object remains on the monitor is also a factor that may impede the detection process. For instance, the Twin Otter aircraft, flying at a speed of 120 knots (61.7 metres/second), took 23 seconds to fly over a longitudinal FOV length of 1,422 m (altitude of 3 kft [914.4 m], sensor looking angle of 30° and FOV angle of 20°). The ground moved too quickly on the monitor to be properly evaluated.

Interestingly, the active and infrared imagers significantly enhance target and terrain assessment at night by adjusting, in real time, the FOV angles of both imagers. In so doing, the aircraft altitude remains unchanged throughout the mission, therefore resulting in pattern flights that are more time efficient and less hazardous than those followed when using para flares. Indeed, target and terrain assessment is frequently carried out by means of para flares, if conditions permit. Para flares are dropped from 4,500 ft [1,371.6 m] above ground level (AGL) and burn for 5 minutes. The time needed for the aircraft to descend for target assessment (1,000 ft [304.8 m] AGL) or for terrain assessment (2,000 ft [609.6 m] AGL) is such that only 1 to 2 minutes remain available for actual target identification.[16]

Conclusion

The exploitation of active and IR imaging provides complementary information that tends to improve target assessment, thus contributing to enhanced situational awareness. The active imager is best used for target identification and confirmation rather than for target search, owing to the narrow laser field of illumination and intensified camera limited FOV.

Active imaging is efficient in recognizing and identifying, at night, objects and signs of various sizes at ranges up to 10 km. The active imager excels at detecting reflective objects as well as objects with high contrast at the illumination wavelength. For example, this capability allows the registration number on the wing of a wreck or a ship to be read at night. Indeed, the use of even small retro-reflective tapes on life jackets, for instance, is highly recommended, should an active imager be integrated as a search tool into the future fixed-wing SAR aircraft. However, except when detecting optical sights or retro-reflectors in daylight, the active imager is limited; it is suited to improving the night-time detection and identification capabilities of thermal imagers.

While we performed preliminary search concept of operations (CONOPS), image types need to be compared to FOV settings—a method for sweeping the search area with sensors (forward mode and auto mode). Furthermore, (near-) optimum flight conditions (such as the aircraft altitude and speed as well as the type of search pattern) remain to be defined.

Way Ahead

To assess the effectiveness of the AIMS-operator system with a view towards proposing near-optimal CONOPS and flight patterns, we recommend that statistically significant experiments be undertaken. Measures of effectiveness should include the lateral range function; false alarm and misclassification rate; time for target detection, classification and identification; and evaluation of the operator's workload during a target search mission.

Interestingly, the National Research Council Flight Research Laboratory is leading, in collaboration with DRDC Valcartier, a three-year project[17] that plans to conduct an extended statistical analysis of the in-flight operation of an electro-optical multi-sensing system like AIMS which is used to detect a class of targets that are typical of SAR missions.

Regarding degraded night weather conditions, preliminary results have shown that range-gated active imaging is quite efficient through snow and rain. Furthermore, recent tests conducted with the presence of various types of dust and smoke in the aerosol chamber at DRDC Valcartier have shown that one can obtain detection and identification range improvement compared to low-light-level cameras, and even better than IR sensors in low thermal contrast conditions.

Further experiments should be conducted to assess long-range performance (between 10 km and 20 km) and low-visibility performances by testing AIMS sensors in actual dust conditions. To this end, trials involving tactical scenarios with AIMS installed onboard a CC130 Hercules aircraft by means of the Rapid Mount Airborne Sensor System (RMASS),[18] shown in Figure 11, are planned in 2013–2014.

Figure 11. Preliminary phase of RMASS and AIMS systems integration on the DND CC130 training Hercules at 8 Wing Trenton

Although conceived in 2004 and testing started in 2010, AIMS performances could be improved in the near future. Imaging technologies evolve at a very fast pace. For instance, in 2012, Obzerv Technologies, the manufacturer of the tested active imaging system active imager, advertised an active imager of similar size with four times the power as that embedded in the AIMS turret, while drawing substantially less power and generating less heat. Similarly, fleets of stabilized turrets are now standardized around digital products, thus offering superior high definition resolution and very low noise.

Acknowledgement

The authors would like to acknowledge Ramesh Srinivasan, Marc Alexander and their crew members at the National Research Council Flight Research Laboratory in Ottawa for contributing in every aspect of the planning and execution of the flight trials mentioned in this article.

Mr. Nicolas Léchevin works as a defence scientist at Defence Research and Development Canada – Valcartier in Quebec. He is currently involved in command, control and intelligence projects.

Mr. Vincent Larochelle graduated from Sherbrooke University, Quebec, with a BSc and an MSc (physics) in 1976 and 1978, respectively. He works as a defence scientist at Defence Research and Development Canada – Valcartier in Quebec. He is the scientific authority of the Advanced Integrated Multi-sensing Surveillance Technology Demonstration Project (TDP). He is currently involved in ISR projects.

Dr. Simon Roy received his PhD (electrical engineering) from Laval University, Quebec, in 2008. He works as a defence scientist at Defence Research and Development Canada – Valcartier in Quebec. His research interests include active sensing and imaging systems for tactical applications. He is currently involved in ISR projects.

Captain Katherine Likuski graduated from the Royal Military College of Canada with a BSc and an MSc in Physics in 2008 and 2010, respectively. She is currently employed at the Director General Aerospace Equipment Program Management, Radar and Communication Systems in Ottawa. She is the Project Manager of the AIMS TDP.

Mr. Terry Rea is a graduate of the Royal Military College of Canada and the Canadian Land Forces Command and Staff College. He holds a BSc (Applied) and MEng (electrical). A former Army officer with a broad experience in weapons and sensors and a resident consultant at DRDC Valcartier, he is the AIMS TDP Deputy Project Manager.

Abbreviations

°	degree
AGL	above ground level
AI	active imager
AIMS	Advanced Integrated Multi-sensing Surveillance
CF	Canadian Forces
cm	centimetre
CONOPS	concept of operations
DND	Department of National Defence
DRDC Valcartier	Defence Research and Development Canada – Valcartier
FOV	field of view
ft	feet
GPS	global positioning system
kft	10,000 feet
IR	infrared
ISR	intelligence, surveillance and reconnaissance
km	kilometre
m	metre
nm	nanometre

RMASS	Rapid Mount Airborne Sensor System
SAR	search and rescue
TDP	technology demonstration project

Notes

1. See for instance, V. Larochelle, S. Roy, L. Forand and N. Léchevin, "AIMS/Northern Watch TDPs," (presentation at NATO SET156 RTG86 meeting, Québec, Canada, November 6–8 2012); and G. R. Fournier, "Sources et Systèmes Laser au RDDC Valcartier," http://www.photoniquequebec.ca/documents/RDDC_Georges_Fournier.pdf (accessed April 29, 2013).

2. Delivered to the Department of National Defence (DND) by Wescam (MX-20 turret).

3. Delivered to DND by Obzerv Technologies.

4. Delivered to DND by Thales Systems Canada.

5. AIMS-ISR software delivered to DND by CarteNav Solutions.

6. Ms. G. Toussaint, Major S. Doyle, Dr. E. Vincent, and Mr. V. Larochelle, "Measures of Effectiveness for Search and Rescue: Airborne Integrated Multi-sensor System," *The Canadian Air Force Journal* 1, no. 1 (Spring 2008), http://www.rcaf-arc.forces.gc.ca/CFAWC/eLibrary/Journal/Vol1-2008/Iss1-Spring/Sections/06-Measures_of_Effectiveness_For_Search_and_Rescue-Airborne_Integrated_Multi-sensor_System_e.pdf (accessed April 29, 2013).

7. Altitude of 1,232 m and slant distance of 1,627 m (Time 20h39; 2011/09/28).

8. Altitude of 2,160 m and slant distance of 2,456 m (Time 22h41; 2011/09/29).

9. Altitude of 1,550 m and slant distance of 1,991 m (Time 18h11; 2012/09/28).

10. Altitude of 2,113 m and slant distance of 6,024 m (Time 19h48; 2011/02/15).

11. Altitude of 914 m and slant distance of 2,741 m (Time 01h25; 2011/02/15).

12. Altitude of 1,757 m and slant distance of 1,840 m (Time 18h44; 2011/02/15).

13. J. A. Herweg, J. P. Kerekes, E. J. Ientilucci, and M. T. Eismann, "Spectral Variations in HSI Signatures of Thin Fabrics for Detecting and Tracking of Pedestrians," in *Active and Passive Signatures II*, Vol. 8040, ed. G. C. Gilbreath and C. T. Hawley, (Proceedings of SPIE, 2011).

14. J. Frost, "The Theory of Search: A Simplified Explanation," (Soza & Company Ltd and Office of Search and Rescue US Coast Guard, 1996), http://www.navcen.uscg.gov/pdf/Theory_of_Search.pdf (accessed April 29, 2013).

15. Canada, Department of National Defence, SMM 60-130-2605, *Standard Manoeuvre Manual: Search and Rescue (SAR) Operations, CC130 Hercules Aircraft* (Department of National Defence: Ottawa, 2009).

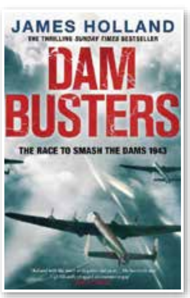
16. Ibid.

17. The determination of AIMS lateral range function and other measures of effectiveness will be carried out under the "Evaluation and Statistical Analysis of EO/IR Sensor Performance for CONOPS Development," National Search and Rescue Secretariat New Initiatives Fund research project conducted by Dr. Jocelyn Keillor (National Research Council – Institute of Aerospace Research) from 2012 to 2015.

18. RMASS, which is a DND-sponsored project, is a sensor deployment and observation platform designed for the CC130 aircraft.

BOOK REVIEWS

DAM BUSTERS: THE RACE TO SMASH THE DAMS, 1943



By James Holland

London, United Kingdom: Bantam Press, 2012
437 pages
ISBN 978-0-593-06676-8

Review by **Lieutenant-Colonel Doug Moulton, CD, MBA**

As the Canadian Forces Liaison Officer to the United Kingdom Air Warfare Centre at Royal Air Force (RAF) Waddington, I have been privileged and honoured to view the RAF from a unique perspective. Not far from RAF Waddington, one can find The Petwood Hotel, just outside of Woodhall Spa, the mess of 617 Squadron during World War II. The hotel, filled with mementos from that era, can quickly take you back to the days and stories of this special squadron. Mr. James Holland, a historian and member of the Guild of Battlefield Guides, has recently written a new book detailing the exploits of this squadron in their efforts to cripple the German war machine. His book, *Dam Busters: The Race to Smash the Dams, 1943* is an outstanding read, which I recommend to anyone with an interest in this squadron's exploits.

Interestingly, despite the notoriety of the movie *The Dam Busters*, there have only been two other significant works detailing this operation. Given its 1951 writing and the vagaries of Hollywood, accuracy was not *The Dam Busters* prime concern.[1] With most World War II files declassified, Holland has had an opportunity to get to the real meat of the operation, and he has not disappointed.

The book, written chronologically, interweaves the life experiences of a number of British personalities to tell the story of Operation CHASTISE. Delivered in four parts, the book initially examines the development of the weapon and the man behind it. It then explains the heroic effort required to establish this specialized squadron and the personalities that drove it. The actual raid is chronicled in exquisite detail, and Holland brings all the pain and triumph of Operation CHASTISE to life. Finally, the book examines the legacy of 617 Squadron and its impact on the RAF.

An extensively researched book, Holland has taken the opportunity to provide a unique insight into the story behind the legend of 617 Squadron. Focusing on the main characters, Holland presents both their personal and professional lives. From Mr. Barnes Wallis—Assistant Chief Designer, Vickers-Armstrong Aviation Department, who created the idea of UPKEEP—to Air Marshal Sir Arthur Harris, Commander-in-Chief, Bomber Command to Wing Commander Guy Gibson, Commanding Officer of 617 Squadron, Holland discusses those who made Operation CHASTISE the success it was and describes the personal toll on those involved.

The appropriate maps, figures and photographs complete Holland's effort in the retelling of Operation CHASTISE, as they allow the reader to contextualize the events. Holland also takes the time to provide a cast of characters at the beginning of the book that identifies the major players from defence and industry as well as the crews of 617 Squadron that were involved in the operation. Additionally, the inclusion of technical drawings of the weapons and the dams allows the reader to really understand the challenge Operation CHASTISE presented.

Dam Busters: The Race to Smash the Dams, 1943 is a well-researched and well-written book that will prove an enjoyable and easy read for the air power enthusiast.

Lieutenant-Colonel Doug Moulton, a Sea King pilot, is currently the Deputy Chair Department of Exercise and Simulation, Canadian Forces College, Toronto.

Abbreviation

RAF Royal Air Force

Note

1. James Holland, *Dam Busters: The Race to Smash the Dams, 1943* (London, United Kingdom: Bantam Press, 2012), Author's Note.

TARGET LONDON: UNDER ATTACK FROM THE V-WEAPONS DURING WORLD WAR II

By Christy Campbell

Little Brown Book Group Publishers, 2012
544 pages
ISBN 1408702932

Review by **Sean M. Maloney, PhD**

This fascinating book is an object lesson in the personalized politicization of intelligence as well as a study in strategic targeting and air power. Some readers may be familiar with the broad aspects of Nazi Germany's advanced weapons programmes during the Second World War. In addition to rocket and jet-propelled aircraft, the Fieseler F-103 cruise missile, better known as the V-1, and the A-4 ballistic missile, better known as the V-2, became notorious as Hitler's Germany sought a means to retaliate for the Allied combined bomber offensive. What we are not overly familiar with is the internal British intelligence debate over these new threats, the planned use of weapons of mass destruction as one possible Allied response, and how the two issues were connected. *Target London* is really the first work to use primary sources to seriously explore this linkage.

The issue of how to reconcile the early Second World War histories with the 1970s' revelations on Anglo–American signals intelligence, collectively known as "Ultra," is handled extremely well in *Target London*. Indeed, Christy Campbell's mother worked at Bletchley Park, and the author's keen interest in events at that special facility are woven into the narrative. In addition to the technical aspects of Nazi Germany's advanced weapons programmes, Campbell's depiction of the internal British debate over their capabilities should be used as a case study in the role of personalities and their foibles in suppressing intelligence. The ostensible (and historic) heroes of the story are brought down to earth, as it were, as we see the unelected bureaucrats block the elected political protagonists from vital information the political leadership needed to make timely decisions to respond to the emergent threat. Indeed, when intelligence data disproves the dismissive attitude towards the new weapons that one faction indulges in, that information was downplayed, if not suppressed. Reading Campbell's depiction of the internal bureaucratic competition between several separate agencies over V-weapons intelligence is nothing short of disturbing, especially when the tone and attitude virtually replicate the tenor of the intelligence failures that prevented the 9/11 attack plots from being uncovered before they occurred and the Iraqi weapons of mass destruction intelligence fiasco. It was only with the intervention of a strong leader, in this case Winston Churchill, that anything got done. Lacking perceptive and strong leadership at the top in situations like these is a sure path to disaster.

In effect, Churchill and those around him were so disturbed by the initial V-1 cruise missile attacks in the summer of 1944, and the subsequent V-2 attacks that fall, that they contemplated chemical and biological weapons use against German cities and their populations. It appears as though the V-weapons were, in fact, having a greater impact on British morale and will than was previously understood in the historical literature—and the damage was much greater. Indeed, the fact that there was no possibility of point or terminal defence against the V-2 played right into this state of affairs. *Target London* explains that chemical weapons factories tooled up and anodyne bombs, termed "light case bombs," were churned out and stockpiled near the six forward filling depots, facilities that would have placed the chemical agent in the bomb, in late 1944 in anticipated preparation for their use. Parenthetically, the possibility of dropping Anthrax (which, incidentally, would have been produced by Canadian facilities, the most advanced in the free world at this time) was seriously explored.

A contributing factor that Campbell delves into was the problem of targeting. There were only so many strategic bombers and only so many tactical fighter-bombers. What proportion should be diverted from other activities to deal with the launch sites? Especially when those other activities included the strategic bombing offensive and operational-level interdiction on the Normandy front? When resources wiped out the detectable V-1 sites, the Germans shifted to mobile launcher units which were next to impossible to target. This is an interesting precursor of the 1991 Scud-hunt problem during Operation DESERT STORM. Shifting again to attacking production facilities at source was more problematic: the sinister *Schutzstaffel* (SS) General Hans Kammler's ability to work 17,000 slave workers to death digging what amounted to an underground city to build the V-1s and V-2s was seriously underestimated. Using missile construction gantries to hang recalcitrant workers en masse sums up the psychopathology of the Nazi enterprise through its mixture of the medieval and the ultra-modern in the pursuit of the insane.

The Canadian angle is buried in the work, and this comes as no surprise. The Canadian contribution to Bomber Command presumably would have been part of the response (there were three forward filling depots assigned to Bomber Command), and this raises interesting questions. To what extent did Mackenzie King and his government know about these preparations? To what extent did the Royal Canadian Air Force (RCAF) and its leadership know? How did all of this relate to existing Canadian policy on chemical weapons use? And why is none of this discussed in any significant detail in the Directorate of History and Heritage's relatively recent RCAF histories?

There are many threads that Campbell tantalizingly leaves undone. One of them is a possible motivation for the ultimately disastrous Operation MARKET GARDEN in September 1944 and its relationship to the need to cut off the launch sites in the Netherlands from their resupply chain back into Germany. Another is the constant effort by the British leadership and intelligence community to keep their fellow American allies in the dark. We are today used to our military people being subjected to American NOFORN (no foreign) policies so it is interesting to see the same compartmentalization process applied to them by the British in 1944.

Campbell has done us a good turn by the questions he raises in *Target London*. This well-sourced and well-written work should make for serious discussion and elaboration.

Dr. Sean Maloney serves as the Historical Advisor to the Chief of the Land Staff and is an Associate Professor of History at Royal Military College of Canada. He is the author of *Learning to Love the Bomb: Canada's Nuclear Weapons and the Cold War.*

Abbreviation

RCAF Royal Canadian Air Force