Synthetic Aperture Radar (SAR) and Search and Rescue

Tom I. Lukowski

Canada Centre for Remote Sensing
588 Booth St. Ottawa, Canada K1A 0Y7
Phone: (613) 995-0386 Fax: (613) 947-1383
email: tom.lukowski@ccrs.nrcan.gc.ca

François J. Charbonneau

ISOSCELES Information Solutions Inc.
201-1128 Church St., Manotick, Canada K4M 1A3
Phone: ((613) 995-9034 Fax: (613) 947-1383
email: francois.charbonneau@ccrs.nrcan.gc.ca
(Under contract to CCRS)

Abstract

Researchers at the Canada Centre for Remote Sensing have explored the uses of remotely sensed imagery to assist Search and Rescue in Canada. Studies concentrated on the uses of SAR imagery for the detection and classification of crashed aircraft. This work has supported the feasibility of using such imagery for these purposes, although current spaceborne systems are proving limited in their capabilities. With further development in technologies, improved coverage of the Canadian land-mass of future systems, and improvements in techniques, it will be possible to assist in Search and Rescue for land targets. This is expected to bear fruit for RADARSAT-2 and other future satellite SAR systems.

Introduction

Most of the Canadian landmass is sparsely populated, and there are significant northern areas that are in total darkness for prolonged periods each year. Airplane traffic over these areas continues to increase. The need to reach crash sites (often of airplanes carrying less than half a dozen passengers) and to assist the victims is served by Search and Rescue (SAR) in Canada, which is the responsibility of the Department of National Defence [1].

A major improvement in capabilities to save lives of crash victims was the development of the COSPAS-SARSAT program [2] which makes it possible to detect Emergency Locator Transmitters (ELTs). The current Canadian Search and Rescue procedure, well detailed in the National Search and Rescue Manual [3], involves listening for ELTs and visual searches from spotter aircraft. Unfortunately, although systems have been improving, the functioning of ELTs has been problematic. Statistics (obtained for the United States, and expected to be similar in Canada) indicate that ELTs function only about 25 percent of the time [4]: In most cases, the ELT does not operate and other methods of finding the crash site are required.

The possibility of using imagery from spaceborne systems to assist in search and rescue has been considered previously; indeed such possibilities were initially considered many years ago. (e.g. [5])). The need to find such crash sites in inclement weather and darkness provides the opportunity for scientists to assist in the development of techniques that make use of microwave remote sensing systems. These can provide imagery during periods when both visual searches and optical imaging systems are not able to help. Furthermore, because of their sensitivity to metallic structures, radars exploit another type of target signature to assist in finding the crashed aircraft.

It is fortunate that in recent years, there have been active initiatives in this area, in particular at the Search and Rescue Mission at NASA Goddard Space Flight Center, which launched a project in 1988 to investigate the feasibility of using space and airborne remote sensing technology to aid in beaconless searches [6]. The SAR^2 Project, has carried out experiments beginning in 1989 with several systems for a variety of test targets and locales in the United States [7]. A Canadian initiative at the Royal Military College examined the use of SAR and optical imaging (from spaceborne and other systems) in Search and Rescue [8]. Furthermore, Search and Rescue has been identified as an opportunity for RADARSAT-2 [9].

Synthetic Aperture Radar is particularly useful for the location of crashed airplanes because of the microwave scattering by the dihedrals formed by parts of the airplane structure. It has been found that these often survive the crash: If the orientation between the SAR system and the target makes it possible to image these dihedral structures, it can be easier to find the crashed aircraft (e.g. [10]).

In these studies at CCRS, various techniques, including interferometric coherence and polarimetric signatures, have been examined for detection and, where possible, classification of targets as crashed aircraft. Examples using two of these techniques are described in this paper.

Interferometric Coherence

Interferometric coherence can be used to locate non-changing, man-made targets within regions of natural targets. The location of crashed aircraft has been examined in coherence analyses performed with three RADARSAT-1 Fine Beam 5 images acquired in 1998 (July 4, July 28, and October 8). The target was a Fairchild-27 that crashed in Northern Canada in 1968 (Figure 1).

Figure 1a and b. *Crashed Fairchild-27, Cornwallis Island, Canada. (Courtesy of P. Budkewitsch, CCRS).*

Figure 2 was originally a colour composite of two coherence pairs (July 28, 1998 – October 8, 1998 and July 4, 1998 – October 8, 1998) with the July 28 1998 intensity image as background. Close scrutiny of the colour version of Figure 2 indicates that only one target was highlighted in white (i.e. the Fairchild-27). This is a consequence of the crashed aircraft having high backscatter and there being high coherence in

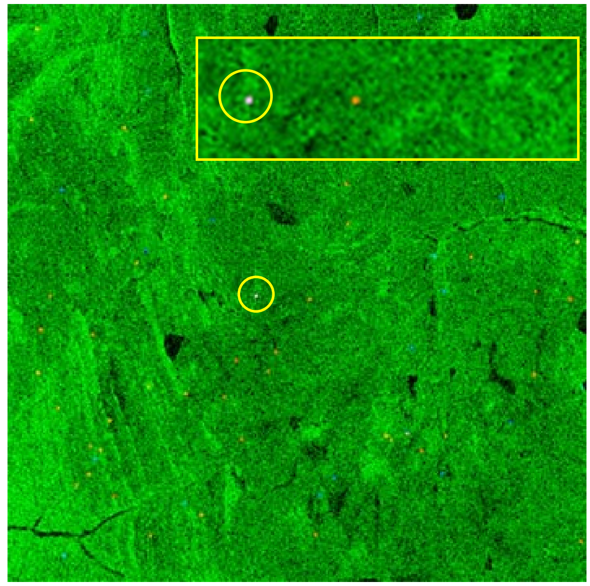

Figure 2 *Originally, a colour composite of RADARSAT-1 F5 images over the Fairchild-27 on Cornwallis Island. Red Channel: July 28,1998 – October 8, 1998 Coherence; Blue Channel: July 4, 1998 – October 8, 1998 Coherence; Green Channel July 28, 1998 Intensity. Circle indicates the airplane location. Inset shows enlargement in area of aircraft.*

both image pairs (resulting in a white composite sample). The number of false alarms detected would be less than .03 per square km.

Polarimetry

The distinctive polarimetric signatures of man-made targets provide an aircraft detection and classification opportunity. We began by employing a methodology based on work at NASA GSFC SAR^2 [10]. Our development and testing used data acquired by the C-SAR on board the Environment Canada Convair-580 operating in polarimetric mode [11][12].

A number of aircraft parked for the winter at the Carp, Ontario airport (Figure 3) were imaged on March 18, 1999. Signal data were processed at CCRS to calibrated imagery in each of the four polarimetric Scattering Matrix components (S_{HH}, S_{HV}, S_{VH}, and S_{VV}) at resolutions of 6 m (slant range) by 1 m. (azimuth) [13].

Imagery annotated with ground truth information is presented in Figure 4.

Figure 3. Parked aircraft at Carp Airport, March 19, 1999

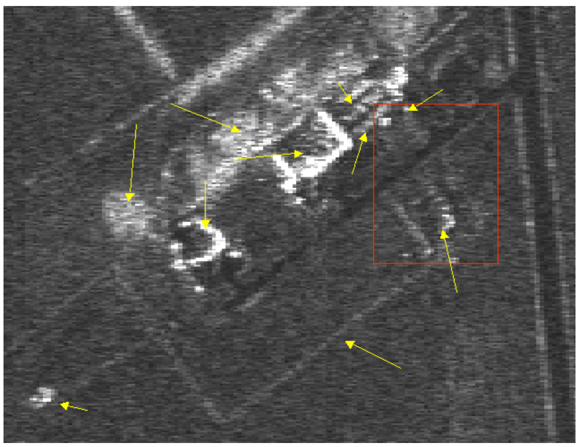

Figure 4. *Annotated SAR image of Carp Airport.*

Results presented in Figure 5 corresponding to the image of Figure 4 show that man-made targets including the aircraft were detected: The small aircraft have been identified (as expected) and classified as aircraft based on their polarimetric signatures (dihedrals or narrow dihedrals). This study was complicated by the proximity of a number of other man-made targets (buildings) which are not expected to cause such difficulty in an actual search.

Conclusions

These examples show potential use of Synthetic Aperture Radar for detection of man-made targets, in particular, crashed aircraft. However, considerable development is required to move from these preliminary results to an operational capability. There will soon be an increase in available spaceborne SARs with more complex operating modes. The possibility of saving lives and mitigating the effects of aircraft crashes will thus improve.

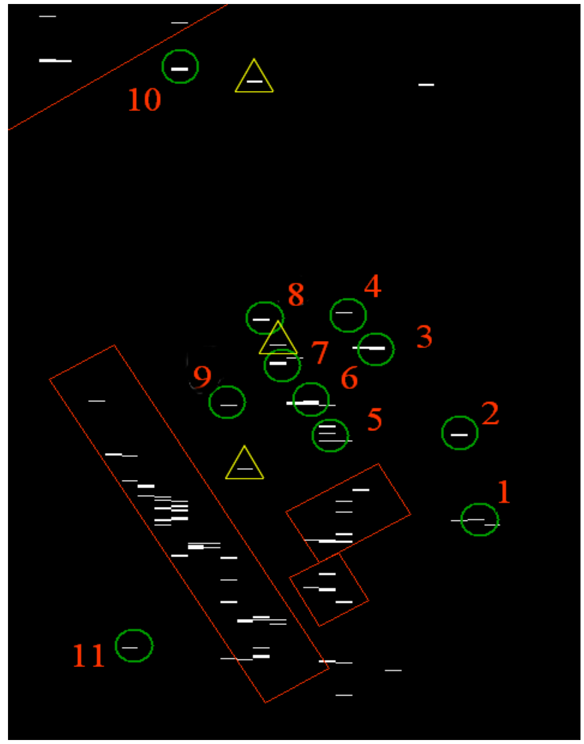

Figure 5. *Classification of area of Carp Airport showing the 11 airplanes.*
O *Detected and classified airplanes;* ∆ *Storage box or fuel tank;* □ *Buildings.*
The dihedral target identified in the upper right corner is a possible plane on the runway. Dashed lines indicate locations of buildings and parking lot area.

Acknowledgements

We would like to thank the crew of the CV-580 and our colleagues at CCRS, especially B. Hawkins, for making the acquisition of the C-SAR polarimetric data possible and for their work in the characterization and calibration of this system.

K. Murnaghan, A. Wind, and R. Jean are thanked for their contributions in the processing and calibration of these data.

References

[1] Introduction to Search and Rescue in Canada: http://www.dnd.ca/menu/SAR/eng/sar/index.htm

[2] SARSAT: http://www.dnd.ca/menu/SAR/eng/sar/gicossar.htm

[3] *National Search and Rescue Manual (B-GA-209-001/FP-001, DFO 5449)* Issued on Authority of the Chief of the Defence Staff and the Minister of Fisheries and Oceans, May, 1998.

[4] Dreibelbis, R., D.W. Affens, H. Rais, and A.W. Mansfield, "The Montana Project, " Proceedings *of SPIE Conference on Automatic Target Recognition IX*, F.A. Sadjadi, Ed., SPIE Vol. 3718, 7-9 April, 1999, Orlando, Florida, pp. 221-229.

[5] Sivertson, W.E., Jr., *A Global Search and Rescue Concept Using Synthetic Aperture Radar and Passive User Targets NASA Technical Report NASA -TN- D-8172*, NASA Langley Research Center, Hampton, Va., U.S.A., April, 1976, 29 p.

[6] Wallace, R.G., D.W. Affens, H. Rais, "Beaconless Search and Rescue Overview - History, Development, and Achievements," *Proceedings of Automatic Target Recognition VII*, F.A. Sadjadi, Ed., SPIE Vol. 3069, 1997, pp.162-166.

[7] The work of the SAR^2 Project in the Search and Rescue Mission Office of NASA GSFC can be found at: http://poes2.gsfc.nasa.gov/sar/becnless.htm. A number of publications from this group and related work can be found in *Proceedings of Automatic Target Recognition VII*, (SPIE Vol. 3069), *1997, Proceedings* of Automatic Target Recognition VIII, (SPIE Vol. 3371), 1998, *Proceedings of Automatic Target Recognition IX*, (SPIE Vol. 3718), 1999, and *Proceedings of Automatic Target Recognition X* , 2000 (in press).

[8] The work of the RMC projects can be found in a number of publications including C.J. Cunningham, W. Millett, and P.W. Somers, "Multispectral Satellite Imagery for Search and Rescue," Proceedings *of the 8th CASI Conference on Astronautics*, Nov. 8-10, 1994, pp. 97-99 and K.A.M. Creber, A.R. Green, E.A. Ough, and V. Singh, "A Comparison Study of Data from RADARSAT, Landsat, A Multispectral Camera, A Field Portable Spectrometer and A High Resolution UV-Vis-NIR Spectrometer," *Proceedings of the International Symposium on Geomatics in the Era of RADARSAT*, May, 1997, 5p.

[9] Gilliam, B., S.W. McCandless, Jr., L. Reeves, and B.D. Huxtable, "RADARSAT-2 for Search and Rescue," Proceedings *of SPIE Conference on Automatic Target Recognition IX,* F.A. Sadjadi, Ed., SPIE Vol. 3718, Orlando, Florida, April 7-9, 1999, pp. 189-194.

[10] Jackson, C.R., H. Rais, and A.W. Mansfield, "Polarimetric target detection techniques and results from the Goddard Space Flight Center Search and Rescue Synthetic Aperture Radar (SAR^2) program," *Proceedings of Automatic Target Recognition VIII*, F.A. Sadjadi, Ed., SPIE Vol. 3371, Orlando, Florida, April 13-17, 1998, pp. 185-193.

[11] Livingstone, C.E., A.L. Gray, R.K. Hawkins, P.W. Vachon, T.I. Lukowski, and M. Lalonde, "The CCRS Airborne SAR Systems: Radar for Remote Sensing Research," Canadian *Journal of Remote Sensing*, Vol. 21, No. 4, December 1995, pp. 468-490.

[12] Brown, C.E., M.F. Fingas, and W.C. Bayer, "The Future of the Convair 580 SAR Facility," *Proceedings of the 21st Canadian Symposium on Remote Sensing*, Ottawa, Ontario, June 21-24, 1999, pp. I-463 - I-467.

[13] Hawkins, R.K., R. Touzi, and C.E. Livingstone, "Calibration and Use of CV-580 Polarimetric SAR Data," *Proceedings of the 21st Canadian Symposium on Remote Sensing,* Ottawa, Ontario, June 21-24, 1999, pp. II-32 - II-40.