The SAR-580 Facility – System Update

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***Abstract*- This paper discusses the Environment Canada SAR-580 system: its capabilities, acquisition hardware upgrades, processing system advances and recent acquisitions.**

I. INTRODUCTION

Since 1996, Environment Canada (EC) has owned and operated the SAR-580 airborne Synthetic Aperture Radar (SAR) facility which consists of a twin-engine turboprop Convair-580 platform fully instrumented with navigation and sensor facilities including SAR. Details of the original SAR architecture and capabilities are available in the open literature [1], [2] and this paper provides a short summary on recent upgrades to the both the hardware (HW) and software (SW) associated with acquisition and processing systems.

The CV-580 shown in Fig. 1 is a dedicated aircraft built in 1953 with approximately 27000 total flying hours and was originally purchased in 1974 by the Canada Centre for Remote Sensing (CCRS) and configured for research in SAR. It has a flying duration (limited by take off weight) of approximately 5 hours, and typically acquires data at 23,000 ft at approximately 250 knots. The CV-580 has three radomes: one in the nose which contains a weather search radar; one on the belly under the tail which contains a pair of dual-polarized X and C-band antennas; and third radome on the starboard side at window level which contains a single H-polarized C-band antenna. There are two X-band and C-band receivers that can operate at either 6 or 15 m range resolution. The SAR HW can be configured for work in four major modes : X/C dual polarization, C-band full polarimetry, C-band across-track interferometry, and, C-band along-track interferometry [9]. Most recent acquisitions have been in support of advanced spaceborne SAR applications using the along-track interferometer for associated RADARSAT-2 GMTI work or in polarimetric mode associated with ENVISAT and RADARSAT-2 multi-pol and polarimetry.

Fig. 1. Tail section of Convair –580 showing SAR radomes.

Table I is a summary of the overall flying activity in recent years. With restricted flying budgets, most acquisitions do not involve long transits and have tried to utilize sites within easy access of the Ottawa-based hangar facilities of EC. This has included numerous sorties to the Mississippi (Ontario) watershed, agriculture, forestry, GMTI and snow surveys at sites in the Ottawa Valley. More extended missions have included agriculture work in Indian Head, Saskatchewan area; The Grand Banks and Scotia Shelves for targets at sea; the Gulf of St Lawrence for sea ice; and, coastal monitoring in Québec and Nova Scotia. Major customers for the facility are: the Canadian Space Agency, National Defence, Canadian Ice Service, Transportation Safety Board and CCRS.

This paper reviews upgrades to the overall acquisition and polarimetric SAR processing systems. Work on the GMTI processing is reviewed elsewhere [10] and is therefore not repeated here.

TABLE I. RECENT ACTIVITY WITH THE SAR-580 FACILITY

Year	Flying Hours (hr)	SAR Hours (hr)	Distance flown (nm)	Area Imaged (km^2)
1998-1999	100.6	60.0	15000	0.56×10^6
1999-2000	92.5	51.9	12975	0.48×10^6
2000-2001	46.7	17.0	4250	0.16×10^6
2001-2002	45.7	27.9	6975	0.26×10^6

II. ACQUISITION SYSTEM UPGRADES

A. *Recording Verification Facility*

Although fully compressed data are available in real-time during the acquisition, the advantage of flexible post-flight azimuth signal processing including motion compensation meant that range-compressed data must be recorded at 6-bit quantization in I/Q format. In the SAR-580 system, the ground-sampling rate is held constant so that the PRF and data rates vary significantly and were a challenge since the rates could be as high as 70 Mb/s. A custom formatter interfaced to a *Kodak* instrumentation cassette recorder is used for data acquisition. Post-flight playback is done on another PC-based system with custom interface boards and a *Sony* DIR-1000L recorder.

In normal operation, the Bit Error Rate (BER) is typically 10^{-9} but this does not necessarily guarantee successful data recovery. To provide immediate feedback on the integrity of the recording system, the read-after-write capability of the *Kodak* recorder is used to compare recorded information against what was intended and this

Fig. 2. Recording system. The formatter and verification unit is at the front at the bottom.

includes the frame synchronization and a number of important fields in each record. With this tool, our success rate in this critical path of the data flow has been improved enormously. The recording system including the upgraded formatting unit is shown in Fig. 2.

B. SAR Real Time image printer

The SAR Azimuth Processing Unit was designed to output a serial byte stream suitable for the EDO-Western dry silver image recorder, which is now obsolete. An alternate was found with an *EPC Labs* model HSP-100 greyscale printer that uses paper or white film media. An interface was built to accept and buffer the continuous data stream for compatibility with an off-the-shelf high-speed digital I/O card.

Image data can be printed, recorded directly to hard disk and 8-mm digital tape in real-time on a PC platform running Windows® 2000 professional. The real-time printer can handle and print up to 64 grey-levels in real-time. The software interface allows the user to do post flight image printing at up to 256 grey levels on film.

In addition, post-flight JPEG image conversion into a number of scenes with/without decimation, tape copy to disk, disk or tape playback with full printer control is also available. This unit is shown in Fig. 3.

C. CIS facility for real-time review and downlink

In 2001, real-time downlink capacity was added to the system by the Canadian Ice Service (CIS) as part of their backup contingency. A similar capacity was tested in 1995. With this facility, real-time processed imagery together with appropriate ancillary information can be directly downlinked to ships in ice-infested waters.

III. PROCESSING SYSTEM UPGRADES

The main investigations using the SAR-580 system have involved the C-band along-track interferometry and full polarimetric modes. Work on the data recovery and processing has evolved considerably in the following areas: Stripping, Direct gain adjustment, Geocoding, GPS processing, Motion-compensation verification and, Systematic calibration and system monitoring.

As explained above, the hardware and software of the 120 mm cassette (See Fig. 2.) playback system was designed and built at CCRS in 1993 and based on the evolving PC server HW. Stripping rates of only 8 Mb/s were obtainable at that time with the newly emerging NT OS and raid disks. By upgrading the host server to a Dell Power Edge 4200, the rates have quadrupled to match the rates of the custom HW boards in the system, thereby removing a significant bottleneck in the processing chain.

Polarimetric SAR processing [7] is done using a software suite known as POLGASP developed at CCRS. Originally conceived for flight lines with constant gain, this restriction proved unrealistic for acquisitions over scenes with wide dynamic ranges or containing point targets [6]. SW upgrades included changes to remove gain changes on a range line by range line basis using embedded ancillary information. (Provided that simultaneous changes are made in the two receive channels, relative phase errors cancel and are unimportant.)

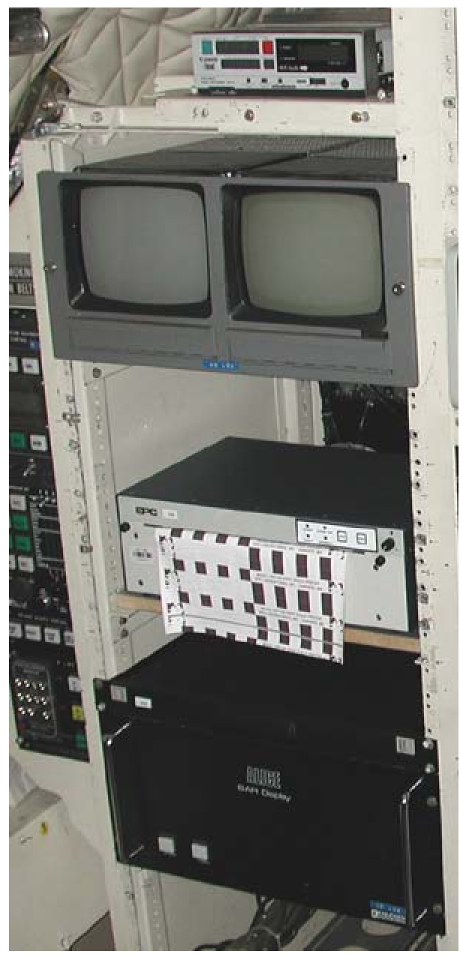

Fig. 3. Real-time image display and printer. At the top are scrolling full-image and blow-up screens. The new printer and display/formatter are below.

A. *Geocoding*

Because the one-look range and azimuth sampling are 4 m and ~0.4 m respectively and delivered in a slant-range presentation, the polarimetric, complex floating point output from the system is both awkward and voluminous. Efforts have been made to resolve these issues with special efforts to preserve the polarimetric properties of the data. The package known as GEOCOR [11] was modified to accept the Stokes Scattering Operator (SSO) matrix generated [8] from the basic processor solve for the ground pixel geometry using a model for the system together with dynamic navigation parameters, DEM and ranging information. The result is then coded into JPL SIR-C format realizing another volume reduction.

Fig. 4 is an example of the final calibrated imagery from the north coast of Prince Edward Island collected for sea-ice and coastal-erosion study.

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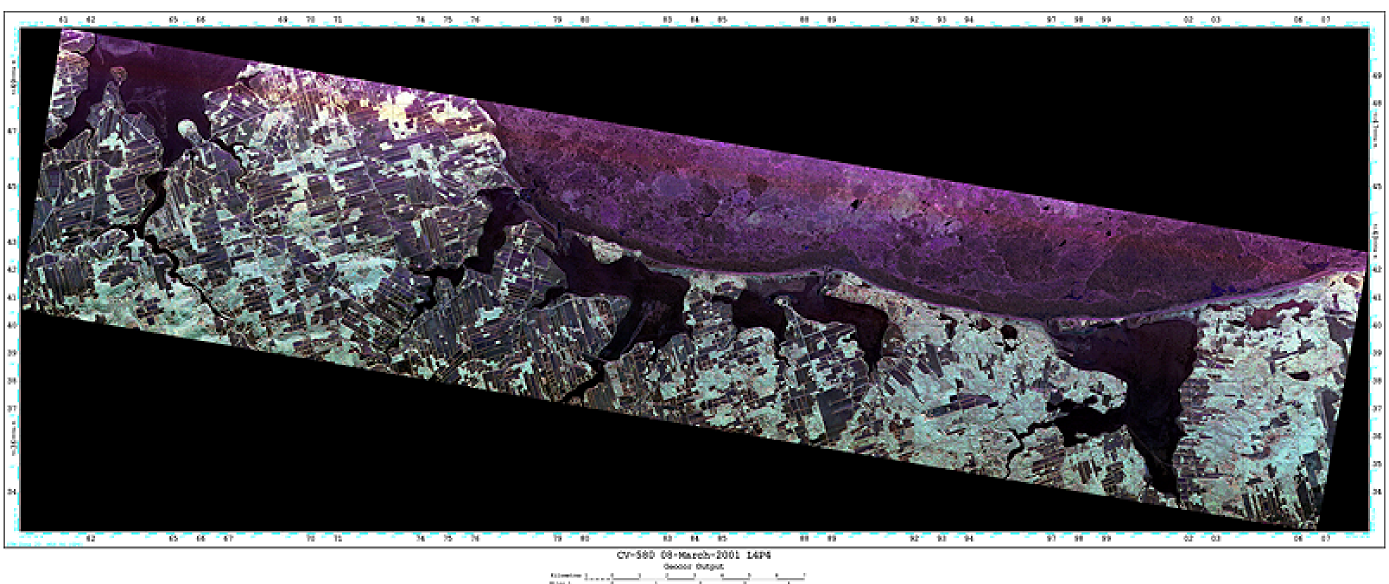

Fig. 4. Geocoded image of PEI. Data were taken on March 8, 2001 in polarimetric mode. In this rendering, the polarimetric channels were detected and presented with the colour scheme [HH, HV, VV] for [red, green, blue]. The aircraft was looking on-shore from the top of the image and travelling basically west to east looking starboard. Calibration devices were deployed in beach area; however, at the resolution allowed here, these devices are not visible. The data were acquired for a number of purposes including shoreline erosion and sea-ice signature work. The flight-line segment shown is approximately 50 km in length with only the near half of the range swath displayed.