SNAPSHOTS OF ANTARCTICA FROM RADARSAT-1

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INTRODUCTION

Carried aloft by a NASA rocket launched from Vandenburg Air Force Base on November 4, 1995, the Canadian Radarsat-1 is equipped with a C-band Synthetic Aperture Radar (SAR) capable of acquiring high resolution (25 m) images of Earth's surface day or night and under all weather conditions. Along with the attributes familiar to researchers working with SAR data from the European Space Agency's Earth Remote Sensing Satellite and the Japanese Earth Resources Satellite, Radarsat-1 has enhanced flexibility to collect data using a variety of swath widths, incidence angles and resolutions. Most importantly, for scientists interested in Antarctica, Radarsat-1 can be maneuvered in orbit to rotate the normally right-looking SAR to a left-looking mode. This 'Antarctic Mode' provides for the first time a nearly instantaneous, high-resolution view of the entirety of Antarctica on each of two proposed mappings separated by 2 years. The first, Antarctic Imaging Campaign began on September 9, 1997 and was successfully concluded on October 20, 1997.

ANTARCTIC IMAGING CAMPAIGN

The first Antarctic Imaging Campaign (AIC) represents the culmination of many years of planning by Canada and the United States to complete the synthetic aperture radar mapping of Antarctica [1,2,3]. The AIC was made possible by the unique capabilities of Radarsat-1 including an electronically steerable antenna array that provided a range of selectable beam pointing angles. This capability was essential for maximizing the range of the acquisition swaths from the satellite's nadir track. The satellite also has the capability to maneuver in orbit enabling it to change the look direction of the SAR. This capability permitted acquisitions to the Earth's South Pole and represents a technical ability afforded by no other civilian radar.

The AIC relied on real-time, transcontinental coordination of the ground-station network, which also included acquisitions in Antarctica during the early part of the mission. Operational and scientific information were transmitted between the various stations and to mission operations at the Canadian Space Agency in Montreal. The information was key to resolving the limited number of acquisition anomalies that occurred during the mission and quickly grasping scientific opportunities presented as the mission unfolded.

Finally the entire Radarsat-1 Antarctic Mapping Mission Project relied on the participation of many organizations in Canada and the United States and on scientific contributions from the international Antarctic Research Community. The major participants in RAMP are identified in Fig. 1.

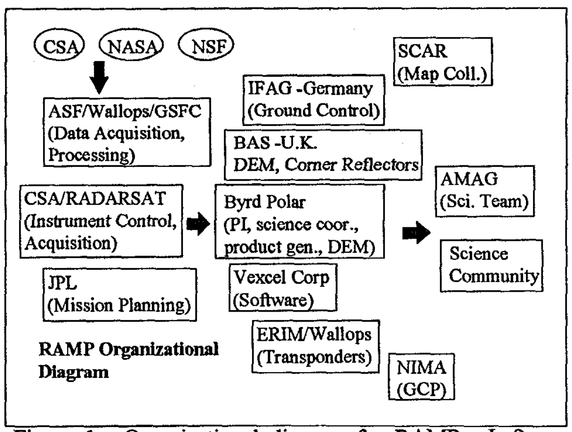

Figure 1. Organizational diagram for RAMP. Left most units are responsible for AIC acquisitions. Middle units are responsible for mosaic development. Right most units are responsible for quality control and science utilization.

AIC CHRONOLOGY

Starting on September 9, 1997, the Canadian spacecraft, Radarsat-1, temporarily ceased normal (right-looking) mode operations and began preparations for the Antarctic imaging maneuver. On September 10, the CSA spacecraft operations team in St. Hubert rotated the satellite 180 degrees from its normally right looking mode to a left looking mode. The procedure included a pitch down to –85 degrees, a yaw around to –180 degrees and a pitch up to 0 degrees to straight and level flight.

The spacecraft was gradually readied for operations on September 11. This included rotation of the solar panels and enabling payload heaters. The first Antarctic Mode image was acquired on September 12 and the first standard beam image of the Antarctic, stored on the on-board recorder, followed soon after. The first radar image of the Earth's South Pole was acquired on September 15 (Fig. 2) and began the final stage of the radar mapping of Earth.

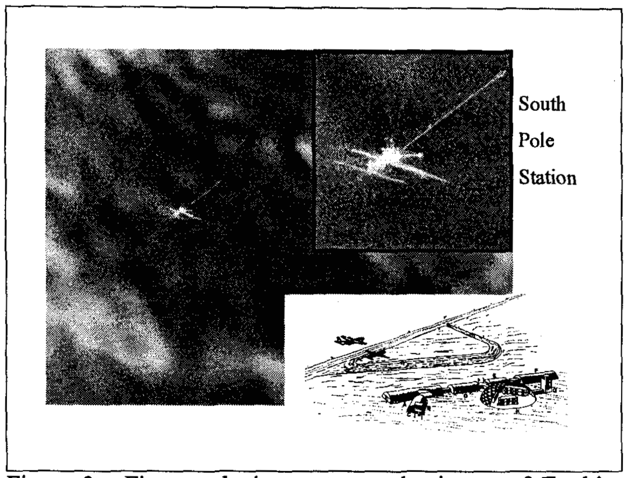

Figure 2. First synthetic aperture radar image of Earth's South Pole showing the location of Amundsen-Scott South Pole Station. South Pole Station is located in the radar clutter in the center of the inset. The central line running roughly from left to right is the current runway. The line segment to the lower left is the signature of the runway abandoned in 1974 and now buried. Old South Pole Station, also buried, is located between the two runways. The long line running to the upper right is a road to an abandoned science site. The road is about 8 km long.

The satellite was cleared for payload operations on September 16 and downlink and processing at the Alaska SAR Facility were confirmed by September 17. Because each of the payload milestones were crossed on schedule and because of the power, thermal and attitude stability of the spacecraft, CSA began to acquire images of the Antarctic on September 19 in support of RAMP. Routine tape recorder downlinking activities began at Gatineau, Prince Albert and the Alaska SAR Facility. Real time downlinks were also recorded at the McMurdo Ground Station.

The pre-AIC acquisitions (Fig. 3) were culled from the nominal plan by relying on the 100 orbit near repeat cycle of the satellite. Acquisitions only imagable in South looking mode and located around the South Pole were identified as the highest priority. The data constituted an important contingency against anomalies encountered later in the mission.

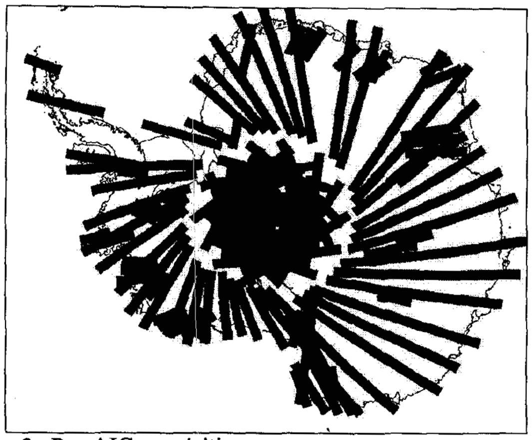

Figure 3. Pre-AIC acquisitions

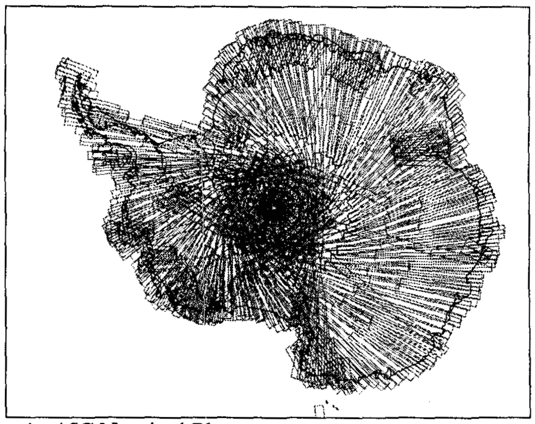

Figure 4. AIC Nominal Plan

The nominal acquisition plan (Fig. 4) started on schedule shortly after noon EST on September 26. The plan was developed by the Jet Propulsion Laboratory and designed to obtain complete mapping coverage within 18 days. The nominal plan proceeded nearly flawlessly through completion on October 14.

An additional opportunity was realized because of the early start on September 19. Radar data, collected after the conclusion of the nominal mission, were acquired exactly 24 days after the beginning of the early start data. This schedule repositioned the spacecraft to within a few hundred meters of its position 24 days earlier. Consequently the data are suitable for interferometric analysis – a demonstrated technique for estimating ice sheet surface topography and surface displacement. Exact repeat data collections started on October 14 and continued through October 20. A map of exact repeat data is shown in Fig. 5. During this period 1 pass of scan sar data was also acquired over the area south of 78 degrees latitude.

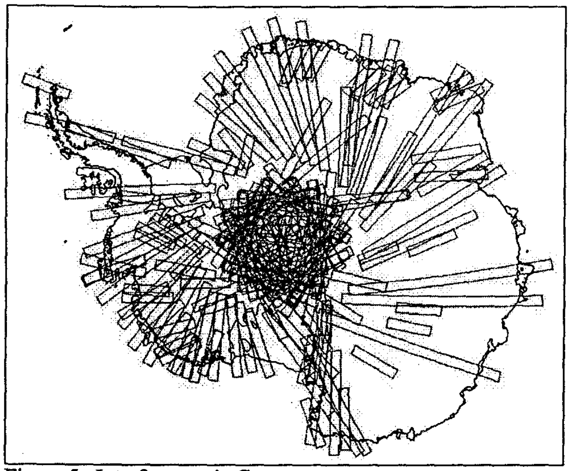

Figure 5. Interferometric Coverage

Preparations to return the satellite to normal operations began on October 20. Arctic mode operations resumed on October 23. Acquisitions for customers resumed on October 26. This occurred 9 days ahead of the planned schedule.

SCIENCE LESSONS LEARNED FROM AMM-1

Key science lessons learned from AMM-1 included verification that September/October timing for AMM-1 was optimal [4]. There was no evidence for surface melting which means that subsequent mappings at the same time of year will better discriminate between long term glaciologic changes and more ephemeral meteorological variations. Timing also proved good for studying coastal processes such as polynas which were easily delineated within the winter sea ice pack. All Radarsat beams provided excellent definition of surface structure. Ascending Standard Beam 2 proved a good choice for collecting data. The fact that the radar passed over the ice sheet onto the ocean also seems to have mitigated automatic gain control artifacts. Extended high-beam 4 data-acquisitions were originally planned to occur only over the southernmost portion of the continent. In fact, passes were acquired from the coast to the pole and data analyzed so far are excellent. This is somewhat surprising because volume scattering from the ice sheet is presumed to be the dominant electromagnetic process initially suggesting that shallow incidence angle beams would be insensitive to the slight topographic variations across the ice sheet. Finally, initial successes to create interferograms and derive surface velocity data are encouraging [5]. Interferometric studies of different areas are needed to determine how effective a 24-day repeat cycle will be for extensive ice motion measurements.

PLANNING FOR AMM-2

The Radarsat Antarctic Mapping Project calls for two complete Antarctic Mapping Missions, goals that are embraced by the Canadian Space Agency, NASA and the Antarctic Science community. Originally, the mapping missions were envisioned to be nearly exact duplicates to highlight change detection studies of the ice sheet. In view of the success of the AMM-1 and the more complete understanding of the potential value of these mapping opportunities, the planning for AMM-2 is being revisited.

Planning for AMM-2 will concentrate on 5 broad goals based on lessons from AMM-1. These are:

1) Establish a second benchmark for change detection studies (3 to 5 year mapping intervals).
2) Increase the overall science payoff through coordination with other complementary programs (IceSat, ERS, ENVISAT).
3) Exploit lessons learned from AMM-1 to highlight Radarsat's unique science capabilities (e.g. INSAR for latitudes south of 78 degrees).
4) Develop a strategy for north mode data acquisitions to complement AMM-2.
5) Encourage broader scientific participation in AMM-2 through the distribution of data from AMM-1.

ACKNOWLEDGMENTS

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