Radarsat: The Antarctic Mapping Project

Science Requirements and Related Documentation

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Section III

3) Scan Results File generated within 12 hours of acquisition and/or receipt at ASF; the oldest data on hand will receive the highest priority. There must be capability to generate scan results files from data using standard beams 1-7 and extended beams 1-4 (ASF)

8) ASF must process full-res, quick-look images of all Radarsat standard beam (SB1-3) data acquired over the Antarctic coast within 12 hours of acquistion/receipt. ASF should have the capability to transfer any of these image data for subsequent manipulation by the RAMP team. (ASF)

9) Provide for local storage of all coastal, standard-beam images at full-resolution: provide capability for electronic side-lap (sliver) checking; provide capability to create hardcopy (paper) products of all coastal data. (JPL)

Project Summary

On November 4, 1995, the Canadian RADARSAT was carried aloft by a NASA rocket launched from Vandenburg Air Force Base. Radarsat 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 will have enhanced flexibility to collect data using a variety of swath widths, incidence angles and resolutions. Most importantly, for scientists interested in Antarctica, the agreement for a U.S. launch of RADARSAT includes a provision for rotating in orbit the normally right-looking SAR to a left-looking mode. This 'Antarctic Mode' will provide 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. This is an unprecedented opportunity to finish mapping one of the few remaining uncharted regions of the Earth. The completed maps will also provide two important benchmarks for gauging changes of Antarctica's ice cover.

The preparation of a digital mosaic of Antarctica is being conducted under a NASA Pathfinder Project awarded to the Byrd Polar Research Center of The Ohio State University. The primary goal of this proposal is to compile digital SAR mosaics of the entire Antarctic continent using a combination of standard and extended beams during the "Antarctic Mode" of the Radarsat Mission. Preliminary agreements with the Canadian Space Agency call for the first Antarctic Mapping Manuever to occur in March, 1997. A mission plan to coordinate that complex acquisition and downlinking of Antarctic data is being developed by NASA’s Jet Propulsion Laboratory. The Alaska SAR Facility (ASF) will be used as the primary data collection site supported by collections at the Canadian Gatineau and Prince Albert Ground Stations. ASF will process data into images which will be sent to OSU for compositing into map products using state-of-the-art equipment to be designed by Vexcel Corporation of Boulder Colorado. Calibration transponders

have been constructed and installed in the Antarctic by the Environmental Research Institute of Michigan (ERIM) with logistical support from the Office of Polar Programs of the National Science Foundation. Ground control point data is being provided by the Defense Mapping Agency, the British Antarctic Survey and the German Institute for Geodesy. Final products will be distributed through the ASF and the National Snow and Ice Data Center which are both NASA Data Archive Centers. The mosaics and ancillary information will be prepared on CDROM and will be made available to the science community through NASA DAACs.

Science opportunities envisioned for the program are summarized on the accompanying table. These include studying the dyamics and variability of the Antarctic Ice Sheet including studies of regions like the Wordie Ice Shelf and the Larsen Ice Shelf which have recently experienced unexplained and nearly catastropic retreat. Geologic applications include large scale mapping of faults, volcanic features, and mountain building processes (particularly the Transantarctic Mountains. Finally, there is simply the unprecedented opportunity to use these digital maps in studies of many previously unexplored areas of the Southern Continent.

RADARSAT

THE ANTARCTIC MAPPING PROJECT

SCIENCE OPPORTUNITIES

GLACIOLOGY

- Ice sheet/stream flow regimes (fast glacier flow, relict features, outlet glaciers

- Stability of West Antarctic Ice Sheet (grounding lines, surface velocities)

- Ice sheet mass balance (calving rates, ice sheet margins, topography)

- Surface melt regimes

GEOLOGY

- Uplift of the Transantarctic Mountains (Fault and lineament mapping)

- History of subduction beneath the Antarctic Peninsula

- Geologic mapping (Sirius Formation)

- Vulcanology

GEOMORPHOLOGY

- History of glaciation (moraines, raised beaches)

EXPLORATION

I. SCIENCE REQUIREMENTS

1. Two, complete mappings of Antarctica at 25 m resolution are called for during the Radarsat mission; a two to three year time interval between mappings is desirable. (CSA)

2. Each mapping should occur during the austral cold season (between March 15 and October 30). The second mapping should occur at the same time of year. (CSA)

3. The imaging geometry should be the same for each mapping. (RAMP)

4. A viewing angle between 20 and 30 degrees is required for as much of the ice sheet as possible; higher incidence angles are acceptable toward the pole. (RAMP)

5. Primary mapping data should be collected in the ascending mode with data collection starting over the interior ice sheet. (RAMP)

6. The instrument should be operated at a fixed gain. (CSA)

7. Map products should be supported by additional data including the incidence angle, azimuth, surface elevation, calibration data and ASF image ID. (Vexcel)

8. The map product will be in Polar Stereographic projection as used for SSMI. (Vexcel)

9. Projection parameters and other information used to register each image in the mosaic must be preserved including a pointer from any portion of the mosaic back to the original imagery. (Vexcel)

10. Geolocation accuracies of +- 100m (pending quality of DEM and availability of GCPs) and distortions in the imagery of less than 50 m in 100 km (JPL). This requires ground control points distributed around the continent. (RAMP)

11. A relative radiometric accuracy of 1 dB and an absolute radiometric accuracy of 2 dB is required.

12. Maintain an archive of valued-added products, eg. GCPs, orthorectified images, improved SAR imaging parameters. (RAMP)

13. Preliminary map products should be routinely distributed to the Antarctic Mapping Advisory Group (AMAG) for review.

14. The final map product should be validated by the AMAG and ready for distribution within 1.5 years of acquisition. (RAMP)

II. North-Looking Data Requirements

1. Acquire sufficient data in RAMS format for testing RAMS. (RAMP)

2. Acquire north-looking data to verify assumptions in South Looking plan. (RAMP)

3. Verify operational readiness of active radar transponder. (RAMP)

4. Establish IFSAR and Stereo capabilities of Radarsat. (Vexcel)

5. Map perimeter as contingency for South mode data losses. (RAMP)

6. Map all viewable area in north mode (complete image, stereo, IFSAR coverage); image coverage should be repeated seasonally. (RAMP)

7. Data collected in support of items 1, 2, and 3 must be processed within 5 weeks of acquisition. Data collected in support of 4, 5, 6, and 7 should be processed as resources permit. (ASF)

III. RAMP AMM Operational Requirements

1) ASF must acquire, receive, record and duplicate all RAMP data either received directly by ASF or other ground receiving stations.

2) ASF should be prepared to use either ASF receiving antennas in the event of ground station failures.

3) Scan Results File generated within 12 hours of acquisition and/or receipt at ASF; the oldest data on hand will receive the highest priority. There must be capability to generate scan results files from data using standard beams 1-7 and extended beams 1-4 (ASF)

4) Immediate transmission of scan results files to RAMP mission planning computers. (ASF)

5) McMurdo Ground Station Data Quality Monitoring (DQM) results and data reports (coordinates and time) transmitted to ASF within 12 hours of acquisition. (MGS)

6) There must be on site expertise at ASF for interpreting scan results and DQM files during AMM; on site expertise in SAR processing and system engineering is also required. (JPL)

7) Gatineau and Prince Albert signal data sent to ASF to arrive within 2-days after acquisition. (CSA)

8) ASF must process full-res, quick-look images of all Radarsat standard beam (SB1-3) data acquired over the Antarctic coast within 12 hours of acquistion/receipt. ASF should have the capability to transfer any of these image data for subsequent manipulation by the RAMP team. (ASF)

9) Provide for local storage of all coastal, standard-beam images at full-resolution: provide capability for electronic side-lap (sliver) checking; provide capability to create hardcopy (paper) products of all coastal data. (JPL)

10) It is desriable for ASF to process once-per-day or on a best effort basis, full-res, quick-look image of South Pole starting with commissioning phase. (ASF)

11) Provide work area at ASF with phones and ethernet access for 6 visitors, and wall space to mount 243 quick look images. (ASF)

12) ASF will make image processing and visualization tools available for inspection of AMM full resolution data. (ASF)

13) Software required at ASF during AMM: SPA; EOSMENU; GPCT; ScanRes; SPAtoSAP;SAPtoSPA. (JPL)

14) Any orbit corrections must made prior to the AMM data acquisition. (CSA)

15) A calibration plan must be implemented by ASF and CSA for the AMM.

IV. RAMP Requirements for Radarsat Precision Processor

(see Vexcel RAMS Functional Requirements Document)

ASF will process the data to have the following characteristics:

1) slant-range

2) skewed

3) 25 meter azimuth pixel spacing

4) natural, 4-look range pixel spacing

5) 16 bit unsigned

6) process at fixed gain

7) process all standard beams and the extended beam(s) that cover South Pole.

V. Post AMM RAMP Requirements

1) ASF calibrated-data processing to begin 6 weeks after the end of the AMM and to be completed within one year of the AMM. (ASF)

2) AMM data must be processed on the precision SAR processor using precision orbit data. (ASF)

3) All processing is “frame” based. (ASF)

4) Data products to be delivered to BPRC on DLT tapes (uncompressed and at highest density allowed by device). (ASF)

5) DLT to contain N separate tar files, each tar file containing SAR leader and data files with all leader files preceding all data files - no VDF files required. (ASF)

6) Data from one orbit saved as a sequence of frames; all frames processed contiguously and provided as 1 tar file. (ASF)

7) Data processed and provided in RAMP requested order. (ASF)

8) ASF to provide radiometrically calibrated data (1 dB relative, 2 dB absolute)

VI. North-Looking, Post AMM Data Requirements

1) collect and process any contingency data resulting from South-looking mode gaps.

2) CSA and ASF to identify and exchange calibration data sets.

3) Continue routine acquisition, processing, and calibration of seasonal north looking data.

VII. AMM Preparations Plan

The AMM Preparations Plan highlights activities and milestones required prior to and during the AMM.

1.0 Mission Plan

RAMP has sent the preliminary South Looking Data Acquisition Plan to CSA. The final plan awaits a decision on the RAMP start-date. Once an approximate date is selected, the plan will be migrated in time to choose a precise start time. The Antarctic Manuever will take place approximately 10 days prior to the start of the mapping mission. RAMP will use the time interval between the manuever and the start of the mapping mission to acquire layover and shadow fill data on an opportunity basis. RAMP will also verify which extended beam is required to image the South Pole during that interval. The initial installment of the north-looking plan in support of RAMS testing requirements has also been sent to CSA. North looking plans in support of other North looking data requirements will be sent to CSA by October, 1996.

Calibration data acquisitions over Delta Junction, the Amazon, McMurdo and the South Pole for all RAMP beams have been incorporated into the South looking plan. Acquisitions over the CSA calibration sites still must be incorporated by CSA into the acquisition plan.

We require working level reviews of the plans at CSA leading up to a readiness review scheduled to occur about 1 month prior to the antarctic manuever.

2.0 Operational Preparations

We plan a ‘dress rehearsal’ of ASF operations 3 months prior to the mapping mission. We plan to test tools specified under the RAMP requirements document, evaluate communications links within ASF and to CSA, within CSA and to PAS and GAT. We will also install RAMP specific mission planning tools at ASF. Logistical preparations include establishing tape courier and customs procedures, and setting up charge accounts for transferring data via custom package service.

System support for RAMP will be delivered to ASF by JPL. Systems must be installed, tested, and operational prior to the arrival of the AMM Team at ASF.

Tapes must be staged at Gatineau and McMurdo prior to the AMM. These preparations are in progress and that enough tapes will be staged at McMurdo to accommodate the loss of both tape recorders contingency.

3.0 Transponder Preparations

The McMurdo Transponder is operational. Test data must be collected over the site during the summer of 1996. Temperature data for diagnostic purposes have been ftp'd from MGS to ERIM. This should continue on a monthly basis.

The South Pole Transponder is in storage at the South Pole. Personnel presently at the South Pole have been trained on installation and operation. Spare parts are available. The Transponder must be erected, turned on and serviced (including initializing the temperature recorder) starting one month prior to the AMM. Temperature data must be routinely ftp'd to ERIM once the transponder is erected.

Additional training for rotating South Pole and McMurdo station personnel will be required because slippage in the AMM schedule. Replacement parts and other expendables, eg. batteries, will have to be shipped to McMurdo and South Pole.

4.0 AMM Team

The AMM team consists of those individuals directly involved in AMM implementation. Team members external to ASF include: Ken Lord and Jean Muller from CSA; Frank Carsey, John Crawford and engineering support personnel from JPL; Ken Jezek and Katy Noltimeir from BPRC, Robert Thomas, Martha Maiden and Prasad Gogineni from NASA. JPL and BPRC Team members are expected to deploy to ASF and GAT about 1 week prior to the Antarctic manuever.

5.0 AMM

The AMM will be carried out under the AMM acceptance plan and acquisition plan. Calibration is the responsibility of CSA and ASF.

VIII. AMM Data Acceptance Plan

During the AMM commissioning phase, RAMP will evaluate the data quality and provide a recommendation to CSA whether to proceed with the mission. Recommendations will be based on three general properties of the data:

1) radiometric accuracy and dynamic range (comparisons with calibration data obtained prior to the AMM) (if we do not have absolute calibration we can use natural targets: +10dB over percolation facies: -15 to -20 dB over dry snow, these targets have a 25 - 30 dB typical dynamic range; Amazon rain forest)

2) orbit and pointing accuracy: is the orbit and instrument pointing angle as predicted to assure that the mission plan can be satisfied (overlapping coverage at the coast).

3) qualitative comparison with N-looking Radarsat and ERS data.

The following plan provides details on how the decision will be made.

1.0 Prior to AMM and prior to rotation to SL mode:

Verify by analysis and by test where possible that all the data analysis tools are ready for processing the S. Looking mode. This includes: SAR processor test: tools to produce high res images; image processing tools (histogram, inspect value of individual pixels, interpolate interior coordinates from 4 corner points, verify image overlap). Verify that computer code for loading data will properly differentiate between north and south looking mode data.

Collect data over distributed and point target calibration sites to establish a baseline for calibration comparisons prior to S. Looking mode (S1-S7, EH3-EH5 data of Amazon rain forest, interior Wilkes Land, Antarctic Peninsula, CSA calibration arrays, Delta Junction Corner Reflector Array, McMurdo Transponder).

Collect sample data sets of the Antarctic to verify that the sensor parameters are being set properly, i.e., gain, data window position, PRF, etc and that the data acquisition geolocation meets the expected performance.

2.0 Prior to AMM following rotation to SL mode:

Verify that the calibration is still valid by processing data from the Amazon, over corner reflector sites and over Antarctic Transponders.   This should be done by CSA and ASF. ASF and JPL must verify operation of the SAR Processor and related systems.

Verify the orbit location and pointing geometries by collecting and processing data over sample sites including the South Pole. Determine uncertainty in data geolocation and assess the impact on the data acquisition plan. Verify performance of each primary beam including EH beams used to image the pole.

Verify processing related parameters to include making sure that the data can be processed with sufficiently small azimuth and range ambiguities, and acceptable impulse response.

CSA to provide updated SPA configuration file to include updated swath widths.

3.0 During AMM:

Process coastal and South Pole data sets and process them to ensure that the sensor parameters are properly set, the geolocation is meeting spec and that the image quality is as expected.

Monitor mission performance with daily processed images of the McMurdo and South Pole Transponders.

Quick-look process all coastal data and verify image overlap.

4.0 Post AMM and Before Rotating to North-looking mode:

Repeat calibration sequence to get second cal point.

Preparation of the the analysis tools is the most important activity for the acceptance plan. Separating SAR processor (ASF) from sensor-related problems will be the most difficult part of the task.

IX. RAMP Contingency Plan

We examine eight scenarios requiring a contingency plan. These are: loss of a limited number of passes that can be recovered during the AMM; loss of the on board tape recorder; loss of a ground receiving station; loss of primary beam 2; loss of EH4; reduced SAR availability; fluctuation in AMM start time; unexpected swath-width reduction. These options are considered under the general policy of maintaining the integrity of the primary mission plan.

1.0 Assessment of the potential data loss that can be recovered later in the AMM

1.1 Amount of Data likely to require contingency planning

We assume that 5% of all AMM passes will be lost and a contingency plan will have to be invoked to reaquire same. The following table summarizes current acquisitions plans and estimates of data lost under a 5% assumption and in priority order

Data Collection	Total Acquisitions	Total Minutes	Average Minutes
Mosaic Collection	261	630	
South Pole Transponder	163	163	1
McMurdo Transponder	12	12	1
EH 4 Spokes	7	35	5
Layover fill	120	214	
Off-continent calibration	42	56	1-2 min
Total	609	1143	
5% of Total	30	57	
(Data Acquistions on tape recorder	361)		

2.0 Contingency Planning Assumptions

The first objective is to minimize the likelihood that it will be necessary to extend the mission in order to reacquire lost data. We do this by:

i. assuring that all data collections within the Pole Hole are acquired within the first 7 days;

ii. acquiring as much data outside the Pole Hole as early in the mission as possible, especially data collections that require long swaths;
iii. guaranteeing that acquisitions late in the mission are downlinked to ASF.
iv. planning a maximum SAR on time of 12 minutes per orbit. (Our current maximum requirement is 10 minutes per orbit. After the first 100 orbits, our maximum SAR on time is 8 minutes.)
v. develop a suite of plans around the sub-repeat cycle.

By so structuring the acquisition plan we minimize the chances for extending the mission.

3.0 Contingency Scenarios

3.1 Worst Case

We examine the worst case scenario for data lost during the AMM. We assume that one of the last planned data acquisitions are lost and that those data would have been down-linked to Prince Albert or Gatineau. We assume that it takes 48 (possibly 72) hours to transport data from PA and/or GAT to ASF. We assume 1 day to scan, error detect and replan at ASF. We understand CSA will require 3 days to reprogram the satellite. We can reacquire data anywhere over the continent within 3 days using one of the 7 standard beams. If we limit data collections to only standard beam 2, we reaquire another complete cycle to reacquire data.

Action	Hours
Data Acquisition	0
Delivery at ASF	48
Error Detection and Replanning	72
Reprogram Satellite	144
Reacquire data	216 (this time could be reduced depending on the position of the satellite at the time it is reprogrammed.

Hence a maximum of 10 days beyond the optimal mission are necessary to account for all contingencies in this scenario. 7 days of extended mission are required if the data are lost during downlinking to ASF.

We assume that one attempt will be made to reacquire data. No additional attempts will be made if those attempts require extending the mission.

3.1 Loss of Onboard Tape Recorder

The first contingency is to activate the second tape recorder. We need to determine the time needed to switch to redundant OBR.

If both recorders are lost, we can only acquire real-time data downlinked to the McMurdo SAR Facility. It will be necessary to procure and ship additional tapes to MGS sufficient to complete entire mission; ASF has initiated this action

There is a remote possibility that other Ground Receiving Stations will be operational during the AMM. BPRC will determine whether either the German O'Higgins or new portable stations will be deployed in Antarctica during the AMM (October, 1996).

3.3 Loss of a Ground Receiving Station

The following options require further investigation:

3a. Loss of Prince Albert: Convert currently scheduled, single PAS downlink into two passes. One, 5 minute pass will be downlinked to ASF. The remaining 2.5 minutes will be downlinked to Gatineau. This results in an 11 second gap over the Antarctic which needs to be replanned at orbit 113. Verify with CSA that this is possible

3b. Loss of Gatineau: replay data into Prince Albert. Revs such as 9,10, 11 must be real-time down-linked to McMurdo. We still need a complete plan which identifies Gat data that can be acquired at PAS and which must be downlinked real time. This plan is impacted by the start time of the mission.

3c   Loss of ASF: A brief inspection of the current mission plan indicates that 62% of the first 100 data acquisitions can be downlinked to either GAT or PAS. We still require a detailed analysis of how the remaining 42% of the passes can be recovered. Some coastal data could be acquired at MGS in the North-looking mode. Losing ASF would impact the mission by eliminating essential data verification activities. ASF should make preparations to use the second receiving antenna in the event of a failure of the primary antenna.

3d. Loss of MGS: In this event, there are unrecoverable descending layover fill data. The contingency is to use ascending layover fill data. The other impact of MGS loss is on flash hits of the transponders. The contingency is to load South Pole and McMurdo Transponder Hits onto the taperecorder and downlink in the Northern Hemisphere.

3.4 Beam 2 Backup

Standard beam 2 has these properties:

incidence angle 24.2 to 31.3 degrees, 100km swath, 25 m/12.5 m

AMAG recommends standard beam 1 as the primary backup (19.6 degrees to 27.1 degrees) and standard beam 3 as the secondary backup (30.5 degrees - 36.9 degrees)

SB1 will enhance tonal variations due to slight topography over the inland ice sheet. It will reduce shadow but it will enhance layover. It is most similar to the ERS incidence angles.

SB3 will reduce tonal variations due to slight topography over the inland ice sheet. It will reduce layover but it will enhance shadow. It is most similar to the JERS-1 incidence angles.

3.5 Loss of Extended Beam 4. Analysis of available data suggests that the far edge of EH3 may image the South Pole. Invoking EH3 requires an assessment which includes topography and better knowledge of the beam properties. This information is a requirement of the commisioning phase.

3.6 Unexpected reduction in swath width

Extend the program until slivers are filled. Implications on the mission cannot be assessed until receipt of AMM commisioning phase data.

All contingency options still require a final check using the CSA Swath Planner Application Tool.

4.0 Procedure for Invoking Contigency Plans

We still require a process for determining whether a contigency needs to be invoked. A strawman approach is as follows.

1. A data problem is identified by the AMM team at ASF.

2. A plan detailing the problem and invoking a contigency option is developed and sent to
CSA within 24 hours of the identification.

3. CSA and NASA reviews the contigency plan and concurs with the plan or provides the AMM team with an alternative suggestion.

X. Mission Planning Objectives and Requirements

1. North Looking Mode

The primary objectives of North-looking mission planning are to provide data for testing algorithms and for verifying acquisition strategy assumptions. North mode data will also serve as a backup in case only areas south of 78 degrees latitude are imaged during the AMM.

1.1 Acquire sufficient data in RAMS format for testing RAMS. (RAMP)

Long, contiguous swaths are required to test: radiometric balancing algorithms, orthorectification algorithms, block adjustment algorithms, and data ingest functions.

1.2 Acquire north-looking data to verify assumptions in South Looking plan. (RAMP)

RAMP requires 10% overlap of images especially near the coast. We require acquisition of multiple adjacent swaths to verify the accuracy of orbit propagation software. This should be done early in the mission and could be done in concert with objectives 1 and 2 above.

Long, contiguous swaths are necessary to are needed to verify the accuracy of the SPA generated plan and to verify absence of slivers.

1.3 Verify operational readiness of active radar transponder. (RAMP)

Several observations of the McMurdo transponder using the different RAMP beams are required.

1.4 Establish IFSAR and Stereo capabilities of Radarsat. (Vexcel)

Four test sites are selected to verify IFSAR and stereo capability: Ross Island (location of McMurdo Station), Anvers Island (where Palmer station is located); all of King George Island (test of overlapping swaths), and the eastern edge of Lambert Glacier including Gillock Island. Data pairs using beams 2 and 6, 2 and 7, 1 and 6 and 1 and 7 were determined to be necessary to check stereo capabilities. Coordinates are:

Anvers Island
65 S 65 W
65 S 62.5 W
64 S 65 W
64 S 62.5 W

Ross Island

77 S 170 E
77 S   167.5 E
78 S   167.5 E
78 S   170 E

Lambert Glacier

70 S   70 E
70 S   75 E
72 S   75 E
72 S   70 E

King George Island (center point)

58 W
62 S

1.5 Map perimeter as contingency for South mode data losses. (RAMP)

1.6 Map all viewable area in north mode (complete image, stereo, IFSAR coverage); image coverage should be repeated seasonally. (RAMP)

1.7 Data collected in support of items 1, 2, and 3 must be processed within 5 weeks of acquisition. Data collected in support of 4, 5, 6, and 7 should be processed as resources permit. (ASF)

1.8 North-looking mode data will be required to choose the instrument gain setting for south-mode acquisitions.

2.0 South Mode Planning

2.1 Data should be collected with ascending orbits. This enables optimal imaging of the Transantarctic Mountains. Acquisition should begin over the ice sheet..There should be at least 10% overlap between adjacent frames.

2.2 Image South Pole Station on every possible orbit. These data will be used for ground control and radiometric calibration.

2.3 Data should be acquired to compensate for layover and shadow in the basic data set.

2.4 Data ‘spokes’ should be collected that use EH4 to connect data swaths acquired from the pole to the coast.

2.5 Pending north mode tests, we will need to acquire and process stereo data. Our first objective is to acquire data over the stereo polygons but still contend that complete stereo coverage would vastly improve the utility of the final CD-ROM product.

2.6 mosiack with the ‘rose’ pattern for standard beams and single extended beam to fill the remaining data gap around the pole.

2.7 Acquire long swaths that map much of the continent early in the mission.

2.8 optimize data collection south of 78 degrees early in the mission and also provide the best geodetic control by acquiring long swaths that intercept the coast and terminate well in the interior.

2.9 All data takes must be longer than one minute and separated by at least 11.5 seconds.

2.10 Majority of the data must be downlinked to ASF.

XI. Calibration/Validation Objectives and Requirements

1.0 RAMP Calibration/Validation Requirements

Radarsat Antarctic Mapping Project calibration specifications are summarized in table 1.

Table 1
RAMP Calibration Requirements

Geolocation Error:	+- 100 m (pending accuracy of DEM)
Geometric Distortion:	no more than 25 m in 100 km
Radiometric Calibration:	1 dB relative and 2 dB absolute accuracy.
Beams to Calibrate:	All standard beams; extended 3 and 4.

ASF will provide RAMP with radiometrically calibrated data at the level specified in table 1 and with a geometric accuracy not to preclude further processing to the specified geometric accuracies. A global network of sites will be required to fulfill these requirements because there will be at most one radiometric calibration site in Antarctica. The calibration plan should also take into account the antenna patterns for all the beams to be used standard beams 1-7 and extended beams 3,4.

The calibration plan will be developed and executed by ASF/JPL in coordination with CSA and RAMP. Calibration complications include the effect of sun angle (and therefore the heating/cooling of the instrument) changes for the Antarctic mode collection. CSA analysis has shown that this may warp the antenna in the azimuth direction. There may be other effects on the operating point of the xmitter/recvr electronics.

2.0 Approach

Conduct four measurement sequences: i) just prior to the maneuver; ii) just following the maneuver; iii) following the Antarctica mapping but still in the south looking mode; and iv) following return to normal right looking mode. A 5th calibration test mid-way during the mapping would be desirable.This will allow for: 1) CSA to document the effects of the maneuver on the system; and 2) RAMP team to calibrate the system over the life of the 18 day mapping mission. .

The measurements should minimally include the following. 1) Ground receivers (NASA, CSA, other) to measure the azimuth pattern (degree of warp in the antenna and whether we need to modify the ASF SAR processor bandwidth). The azimuth pattern is expected to change for S.-looking mode. This pattern distortion may affect the PRF requirements or the processor bandwidth requirement for this data set. 2) Transponders or corners reflectors to measure the elevation pattern (from which we can derive the absolute gain).

We need this to estimate SNR and derive an absolute calibration of the data. 3) Analysis of internal calibration data (i.e., Radarsat built-in test equipment) to detect variation in operating conditions.

For the first two measurements, we require 2 observation sites at different latitudes. We assume that NASA will operate a calibration site in Alaska and that CSA will have at least 1 site available for this purpose. We assume that CSA would be responsible for analysis of the built-in test equipment data.

These pre-mission calibration data should be expedited through the SAR processor and to the calibration engineers for analysis, to ensure that performance is acceptable prior to starting the mapping campaign.

3.0 RAMP Specific Calibration Activities

3.1 Geolocation and radiometric calibration target at pole.

An active transponder is ready for deployment at the South Pole. A second transponder is in operation at McMurdo Station. The transponsder will improve knowledge of the impulse response function - This would define resolution, ISLR and absolute gain. It could be used by ASF in the processing to check their performance as well as the quick look during the mission. The impulse response function of the data is expected to be distorted. We would like to have a measure of this imbedded in the data if possible to ensure that the data are optimally processed. It is essential to include other calibration targets distributed around the globe in the plan.

South Pole calibration data acquired over the South Pole with EH 4 will be extrapolated to the rest of Antarctica. The procedure will be to acquire long spokes of EH4 data extending from the Pole to the coast and intersecting standard beam data collections. Overlap across many beam 2 tracks will be used to test for geometric accuracy. Beam 4 observations of distributed target areas would be used to check the elevation pattern relative to beam 2. Transponder data will provide data on the radar performance over time. Relative intercomparison with beam 2 data could be accomplished by inspection of overlapping swaths.

3.2 Selection of Distributed Target Sites in Antarctica

We should measure the sigma nought of homogeneous sites in Antarctica during the North and South Looking modes. We can use this for absolute calibration and elevation antenna pattern. Azimuthal scattering properties of the ice sheet may complicate its use as a natural calibration target. Work by Rott and by Early using the ERS-1 scatterometer show that perimeter regions (Amery Ice Shelf, 69.5 deg S, 71.3 deg E) are uniform with respect to azimuth angle and are areas of strong backscatter (0 dB). However these areas experience tremendous swings in backscatter once melt begins. Areas of strong katabatic winds have a strong azimuthal variation and should be avoided (the flanks of the East Antarctic Plateau). The Dome C area (75 S 130 E), and the Siple Station area (75.9 S, 83.9 W) show weak azimuthal dependence and are areas of low backscatter (-20 db).

3.3 Corner Reflectors

The British Antarctic Survey has installed corner reflectors constructed by ASF and positioned with information to be provided by JPL. The locations are:

(1) Haag Nunatak S77 03 W77 51. Reflector to be established on rock and position established by tape and compass with respect to a GPS survey point nearby (say within 10 m)..

(2) SkiHI S74 58, W 70 46. This is staging post used every year.

(3) Rothera Station

(4) Additional corner reflectors were deployed by the Institut fur Angewandte Geodasie on Berkner Island, Neumayer Station, Heimefronfjella (Neuschwabenland), Schirmacheroase, Wohlthatmassiv.

3.4 Geo-referenced Digital Satellite Image Data

Geo-referenced images provided by the IFAG could serve as ground control in the mosaicking process of the Radarsat image data. IFAG has geo-referenced Landsat data of a huge area ranging from 5 deg East, covering western Neuschwabenland, Coats Land, Filchner- Ronne-Schelfeis and entirely the Antarctic Peninsula (the latter area covered by TM); and each pixel of this huge area could be used as control.

3.5. Station Maps

Station maps of international stations have been obtained from the SCAR library. These will be used to provide additional geometric control (figure 1).

3.6 Automatic Geophysical Observatories

The US and British Antarctic Programs have or will be deploying Automatic Geophysical Observatories across the continent. These typically comprise an enclosed van for equipment and personnel and other ancillary structures. AGO sites are shown in figure 3.

3.7 DMA Geometric Calibration.

We will use landmarks such as existing structures (need maps of all the stations), natural features that have been surveyed and ground control point data from DMA. Approximately 150 GCPs distributed in 3 concentric rings will be requested. but have not written it down yet. This is based on the assumption that we have 25 radargrammetric blocks to control. The perimeter each of these blocks is about 1000 km. We want 3 GCPs in each. This is 75 GCPs separated by about 350 KM. At ~65 degrees is a second ring with 2 GCPs per block (50 GCPs) separated by about 250 km. The inner ring is where the rose pattern starts ~74 degrees, I want 1 GCP per block which is 25 additional GCPs separated by about 200 km. The total is 150 GCPs.

4.0 Issues

4.1 Update on the expected performance/problems from Antarctic mode (last input was for warping of antenna, loss of gain, increase in azimuth beamwidth as major issues).

4.2 Azimuth pattern - Distortion in this pattern is the major concern for the Antarctic mode. We need to measure this using ground receivers. We need to request CSA help to make this measurement for us. It does not need to be done in Antarctica. It does need to be collected and analyzed in the day we rotate the S/C.

4.3 How will CSA calibration results be incorporated into the ASF calibration plan? Which CSA sites will be used when and how are they to be equipped?

4.4 How will this data be used to calibrate the output products. Will this information be fed back to the SAR processor to update the product calibration or simply put into a database

4.5 We would expect the results of these and other internal calibration information to be fed back into the processing of the image data to ensure consistency of the data from the North to the South looking mode.

4.6 The new precision processor is scheduled to go on-line at the time of the RAMP mission. Delays in the installation and validation of this processor would significantly effect the RAMP processing as we cannot mix data from 2 processors. The geometric and radiometric calibration plan for this processor must consider the RAMP activity.

RAMP Operational Interfaces