Chapter 2

AIRSAR Operations Overview

Functionally, a typical AIRSAR operations year can be divided into four main parts: (1) mission planning, (2) instrument maintenance and upgrades, (3) mission and flight operations, and (4) data processing and distribution. In reality, mission planning for the next year (and to some degree even flight operations for the next year) takes place at the same time as data processing and distribution for the previous flight season. In this chapter, we shall give a brief description of the AIRSAR organization and discuss the general AIRSAR operations in more detail.

2-1 AIRSAR Organization

The AIRSAR program at JPL forms part of the larger Airborne Instruments Program, which, in turn, is part of the Office of Space Science and Instruments. The pure AIRSAR organization is further subdivided into a number of smaller subgroups, each with a specific function. These subgroups fall in more than one line management group at JPL, and even span two different divisions. Figure 2.1 shows the organizational chart of the AIRSAR effort at JPL. The individuals indicated in each of the blocks are responsible for that particular function in the AIRSAR organization.

2-2 Mission Planning

An AIRSAR operations year starts when users file their flight requests with NASA Headquarters and NASA's Ames Research Center (NASA/ARC). Typically, flight requests must be submitted during summer. Since the DC-8 aircraft is a general-purpose flying laboratory, a number of different instruments are scheduled to use the DC-8 every year. Assigning the times at which different instruments can be accommodated on the DC-8 is the responsibility of NASA and NASA's Ames Research Center. Once a time period for the AIRSAR system has been allocated and flight requests have been received and approved, the planning of the flight campaign or mission can start.

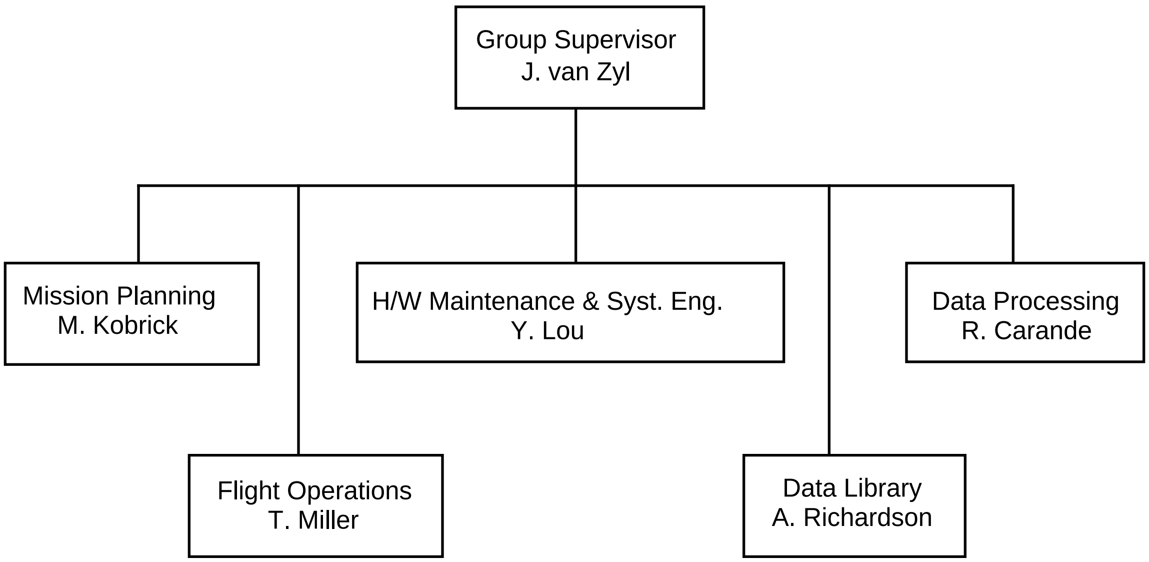

Figure 2.1. *Block diagram showing the AIRSAR organization and the individuals responsible for different functions.*

The primary purpose of the mission-planning phase is to ensure that both the AIRSAR hardware and the DC-8 are utilized optimally based on the received flight requests. This involves extensive discussions between the AIRSAR program and the mission managers at Ames Research Center, although the primary responsibility for defining the missions ultimately lies with Ames.

Once a mission has been planned, and the necessary flight hours have been approved by the various program offices at NASA, specific flight lines for the various experiments are defined by the AIRSAR Mission Planner (Dr. Mike Kobrick). These flight lines are drawn up using information in the flight requests, as well as information obtained through contacts between the AIRSAR Mission Planner and the various Principal Investigators. Pre-mission operations are considered complete when a preliminary data acquisition program, complete with preliminary SAR flight lines, has been defined. This preliminary data acquisition plan is then forwarded to the NASA/AMES navigation and flight planners.

The goal is to produce a reasonable data acquisition plan about 1 month before the first flight of an AIRSAR campaign. This means that the JPL mission planning has to start at least 2 to 3 months before the first flight of a season. It is therefore clear that it is crucial that investigators provide their inputs in a timely manner to allow the AIRSAR personnel sufficient time to plan the flight operations phase of the campaign.

2-3 AIRSAR Installation

When not being used to acquire data, the AIRSAR system is maintained in a laboratory at JPL. Approximately two weeks before the start of a campaign, the AIRSAR system is shipped to NASA's AMES Research Center in Mountain View, California for installation on a DC-8 aircraft. The aircraft is maintained and operated by personnel from AMES Research Center.

2-3-1 DC-8 Interfaces

The DC-8-72 is a standard commercial transport aircraft that has been modified to act as an airborne laboratory. There are facilities for power, intercom and air-to-ground communications, aerial photography and video, instrumentation racks, a digital data stream of ephemeris information, as well as safety gear, a microwave oven, a coffee/tea maker station and rest rooms. Custom mounted hardware options are available both inside the cabin and on the skin of the aircraft. A staff of design engineers and a full sheet-metal and machine shop exists to support modifications and installations on the DC-8.

2-3-2 NASA/ARC Support

The program manager of the DC-8 at AMES is John Reller. He, along with the Medium Altitude Missions Branch (MAMB) chief, Earl Petersen, assigns a Mission Manager (MM) to act as the coordinator for all AMES services to the Principal Investigator for each approved experiment. The AIRSAR program is fortunate to have had Leo DeGreef as the MM for every deployment since 1988. Additionally, an Assistant Mission Manager is tasked to further support the experimenters. AMM's John Wang and Ed Mellenger have been delegated to the AIRSAR program in the past. These managers detail the workers (usually NSI contractors) to implement the needs of the experimenters.

2-3-3 Installation

Approximately three weeks before the start of a campaign, a pre-ship review is held at JPL to ensure that the AIRSAR system is ready to acquire data during the up-coming campaign. After the pre-ship review, the AIRSAR instrument is packed in a 40' trailer and transported to NASA/ARC where it is received by local laboratory supervisor, currently Calvin Kahl. JPL employees, with the AMES laboratory supervisor's assistance, unload the equipment from the van to the hangar where laboratory space is made available for all experimenters. The AMES laboratory supervisor will provide a fork lift, storage space if required and any other type of logistical support. Once the racks are weighed and inspected, they are mounted inside the DC-8 by a crew from the sheet metal shop. A ``load master'' is designated who acts as the liaison between the experimenter, MM's and everybody else who has an interest in the program. Any hardware that is connected to the DC-8 must be installed by the load crew. This includes all external antennas. However, the AIRSAR project insists that all cables be connected by a JPL employee.

2-3-4 Interfaces

Electronic technicians assist in the cabling of the various DC-8 interfaces. Currently, Jim Horvat is the lead man. The interfaces include video cables, switches and monitors (if required) as well as serial data lines, all of which originate from the Data Acquisition and Distribution System (DADS). There are three video lines: (1) a video camera pointing at 45 degrees on the left side, (2) a summary page of ephemeris data from various sensors and sources (such as the Inertial Navigation System) on the DC-8, and (3) a track plot showing the path of the DC-8 which is updated continuously throughout a data flight. The AIRSAR records DADS data via a 9600 BAUD serial line into the Digital Annotator subsystem where it is merged with the subcommutated header. These data are very important to the operation of the AIRSAR system since DADS is the sole source of pressure and radar altitudes, and the DME updated INS position information is the most accurate available. Susan Cherniss is the Sterling Software representative at AMES who is responsible for the DADS system. It is possible to request modifications to the DADS data stream to fulfill unique experimenter requirements.

Good communication between the flight participants is essential to the success of a mission. There are a variety of systems available on the DC-8 such as a two channel intercom system, a Public Address facility and UHF/VHF radio equipment in the cockpit. Headsets are liberally placed throughout the cabin for use by experimenters and crew members. The AIRSAR system also has air-to-ground communications equipment in the form of a FliteFone and a UHF transceiver.

In-flight changes are made due to Air Traffic Control (ATC) vectoring, weather, equipment failure and as a response to requests by the Principal Investigator. In order to ensure that these changes have minimal impact on the planned data acquisition, a group of experts are available during normal data flights. These include an MM, an AMM, a pilot and co-pilot, flight engineer, navigator, aerial photographer, one or more electronic technicians, a DADS operator and possibly a ground-crew member. The AIRSAR crew includes the Mission Planner, the operations manager, an Aircraft Flight Correlator (AFC) operator, one or more support engineers and an High Density Digital Recorder (HDDR) operator. Usually, seats are available for additional interested parties, such as P.I.'s.

The skin of the DC-8 is littered with AIRSAR system antennas. The forward most antenna is the circularly polarized GPS antenna which is mounted in the Zenith 1 port on an aluminum plate. The MM has the capability to close the shutter over this port, thus blocking the satellite signal. The FliteFone antenna is mounted in a forward nadir port usually used as an optical port for a video camera. The forward L- and C-band SAR antennas are mounted just in front of the leading edge of the wings and are connected to the AIRSAR system antenna relay chassis by a low-loss semi-rigid cable made by Prodelin. The P-, L- and C-band SAR antennas mounted aft of the trailing edge of the left wing are the standard SAR mode antennas used in both transmit and receive modes. The transmitter subsystems are located as close as possible to these antennas to minimize cable losses. The GOES antenna (time code) is mounted in the 62 degree port number four. The VHF communications antenna is mounted in nadir number five. Figure 2.2 is a photograph of the DC-8 in flight and Figure 2.3 shows the aft P-, L- and C-band antennas.

Figure 2.2. *The AIRSAR system is flown on board a DC-8 aircraft, shown here in flight, operated by NASA's AMES Research Center, Mountain View, California.*

Figure 2.3. *This photograph shows the aft AIRSAR P-, L- and C-band microstrip patch array antennas. The P-band antenna is mounted on the left, with the C-band antenna mounted above the L-band antenna on the right.*

2-4 Flight Operations

One of the most important phases of an AIRSAR campaign is the flight operations when the SAR data are acquired on a day-by-day basis. Generally, a strawman flight plan for a given flight day is defined by the AIRSAR Mission Planner (Dr. Mike Kobrick) and passed on to the NASA/AMES navigators the day before the actual flight is to take place. This allows the NASA/AMES navigators to generate an official flight plan and to file the flight plan with the relevant authorities for approval. In some cases, such as on deployments away from Moffet field (especially on deployments in foreign countries) flight plans may have to be filed well in advance of the actual flight date and last minute changes are not possible.

The flight plan for a typical day consists of a number of data takes, lasting several hours in total. Each data take is described by a flight line consisting of a start way point, a stop way point and a desired altitude. The way points are defined in terms of the DC-8 ground track, so acquiring data over the same experiment site at different incidence angles will have different way points for the different data takes. Also, the altitude requested is based on the elevation of the primary experiment site and the incidence angle at that site requested by the investigator. In almost all cases, the flight plan also includes way points that describe how the DC-8 would fly from one experiment site to another. Clearly the flight plan is a very important document, as it is used by the DC-8 pilots, the NASA/AMES mission managers and the AIRSAR flight crew as their work plan for that day. Figure 2.4 shows the lines flown on a typical day with the way points numbered.

Figure 2.3. *Flight lines flown on a typical AIRSAR data acquisition day. A total of xx data lines were flown. The way points are numbered in the order in which the lines are flown.*

As mentioned before, a typical flight day consists of a number of different data takes. A typical SAR data take starts about 1 minute past the start way point and stops about 1 minute before the end way point. This is done to ensure that the plane is flying straight and level during data takes. A typical data take starts with a few seconds of recording calibration data, including pre-chirps and receiver noise only (see Chapter on System Tests and Calibration), followed by the actual SAR data recording. Data are recorded on any one of three High Density Digital Tape Recorders during operations. Data are recorded at a rate of 10 MBytes per second on the HDDT while the recorder runs at 3.05 m/sec (120 inches per second), allowing us to store about 2 GBytes of data on a single HDDT. The high-density digital tapes (HDDTs) are valuable objects, since they are the only records of the actual data recorded. A missing HDDT effectively means that the data were never recorded. Their value are increased by the fact that typically data from more than one data run are recorded on the same HDDT. During data acquisition, a flight log is kept by the AIRSAR personnel indicating the number of the data tape on which data for each run were recorded. During all operations, the AIRSAR system is operated by the AIRSAR Operations Group Leader (Tim Miller) using an HP 9000 control computer.

In addition to normal SAR data acquisition, baseline test data are also recorded on a regular basis, typically once each day on which data are recorded. This test data are analyzed later to ensure that the AIRSAR system is performing nominally. These tests, and their use, will be described in more detail in a later chapter. Flight operations are complete when all HDDTs have been shipped to JPL for further data processing. At the end of the flight season, the AIRSAR flight crew, with the help of all the support people at AMES mentioned in the section on installation, remove the AIRSAR hardware from the plane. The hardware is packed into the AIRSAR trailer and driven back to JPL, where it is unpacked and placed in the AIRSAR laboratory to be maintained and repaired for the next flight season.

2-5 Data Processing and Distribution

After the flight season, all HDDTs recorded during the campaign are played back and one of the twelve channels of data (usually LHH) is processed using the real-time processor available on the Flight Correlator. This and other data processors will be discussed in more detail in a later chapter. The output produced in this fashion is called the survey image product and contains all the data recorded on the tape, including the calibration data recorded prior to data recording for each data take. These products are sent to the investigators to be used for selecting areas to process in more detail using the AIRSAR frame processor. The goal is to send all survey products to investigators within three months of the end of an AIRSAR flight campaign. One copy of each of the survey products is also stored in the JPL Radar Data Center for archival purposes.

Upon receipt of the survey products, the investigator selects an area to be processed by the frame processor, fills out an AIRSAR Frame Processor Request, and sends the request back to the AIRSAR Mission Planner (Dr. Mike Kobrick). (A filled-out copy of a processing request is included in Appendix A.) This request is passed on to the AIRSAR processing queue manager (Yunling Lou), who enters the request on the queue and sends the investigator a note confirming the receipt of the processing request. All the processing requests are combined and placed in a queue and processed one after the other. To distribute data as quickly as possible to as many investigators as possible, the queue is set up in the following way. The top priority request from each investigator is processed first, one investigator per processing night. Once this is achieved, the second priority request from each investigator is processed and so forth. Thus, if N investigators submit requests, each investigator will receive one frame product after N processing days.

It is therefore clear that it is crucial for investigators to indicate the order in which they want their requests processed. Also, for large experiments involving a large number of investigators, we request that a single person coordinate the processing requests from all the involved parties before returning these requests to the AIRSAR program. All processed frame products are turned over to the JPL Radar Data Center for distribution to the relevant investigators. Figure 2.5 shows the data flow from the time flight requests are submitted to the time frame products are sent to investigators. All frame products are also archived in the JPL Radar Data Center. To request data that have been processed, interested parties should contact the JPL Radar Data Center.

Figure 2.4. *AIRSAR data flow from the time flight requests are submitted to the time frame products are sent to the investigators.*

Two other sets of information are also archived in the JPL Radar Data Center. After the flight campaign, detailed flight logs of each data acquisition day are printed by the AIRSAR Flight Operations Group Leader and passed to the Radar Data Center. These logs contain information about the flight lines, radar parameters used during data acquisition, HDDT numbers and other general comments on the state of health of the AIRSAR system. In addition to the flight logs, the AIRSAR Mission Planner also generates a Data Digest for each flight campaign. The digest contains a day-by-day description of the flight operations, maps of the flight lines, lists of HDDTs and a copy of the flight logs as an appendix. A limited number of these digests are printed and are available for distribution to the public through the JPL Radar Data Center.

Unfortunately, the processing of the AIRSAR data into frame products still takes longer than what we would like to see. Currently, a maximum of ten frame products can be produced by the AIRSAR frame processor per week. Since most investigators request overlapping near and far swath frame products, this means that a maximum of five investigators can be served per week. With the number of approved investigators reaching 75 for the 1991 flight season, it means that it may take as much as 15 to 20 weeks to process one frame product for each investigator. Adding to this the three months it typically takes to derive the calibration parameters necessary to use in the frame processor and to get processing requests back from investigators, this means that it may take as much as 8 months after the end of the flight campaign before all investigators will have received one frame product for analysis.

We are currently working towards improving this situation. Three separate avenues are being explored simultaneously. First, we are trying to schedule the AIRSAR calibration flights as early as possible in the flight season. In theory this means that we should be able to derive the calibration parameters to be used in the frame processor soon after the first data flight, which, in turn, means that we should be ready to start frame processing even while the flight campaign is being conducted. Secondly, we will try to do survey processing during the flight season, which means that investigators can request frame products sooner than in the past. Thirdly, we are developing a frame processor which should increase the throughput of the system. This new processor will run on newer MicroVax systems with greater reliability than the much older Vax 730 system currently used for the frame processor. By duplicating the processor hardware, we can effectively double the throughput of the system. The aim is to have three copies of the processor running simultaneously, which should allow us to produce on the order of 500 images per year, about 2.5 times the throughput of the current system. Unfortunately, the full system will probably not be available until at least 1992.