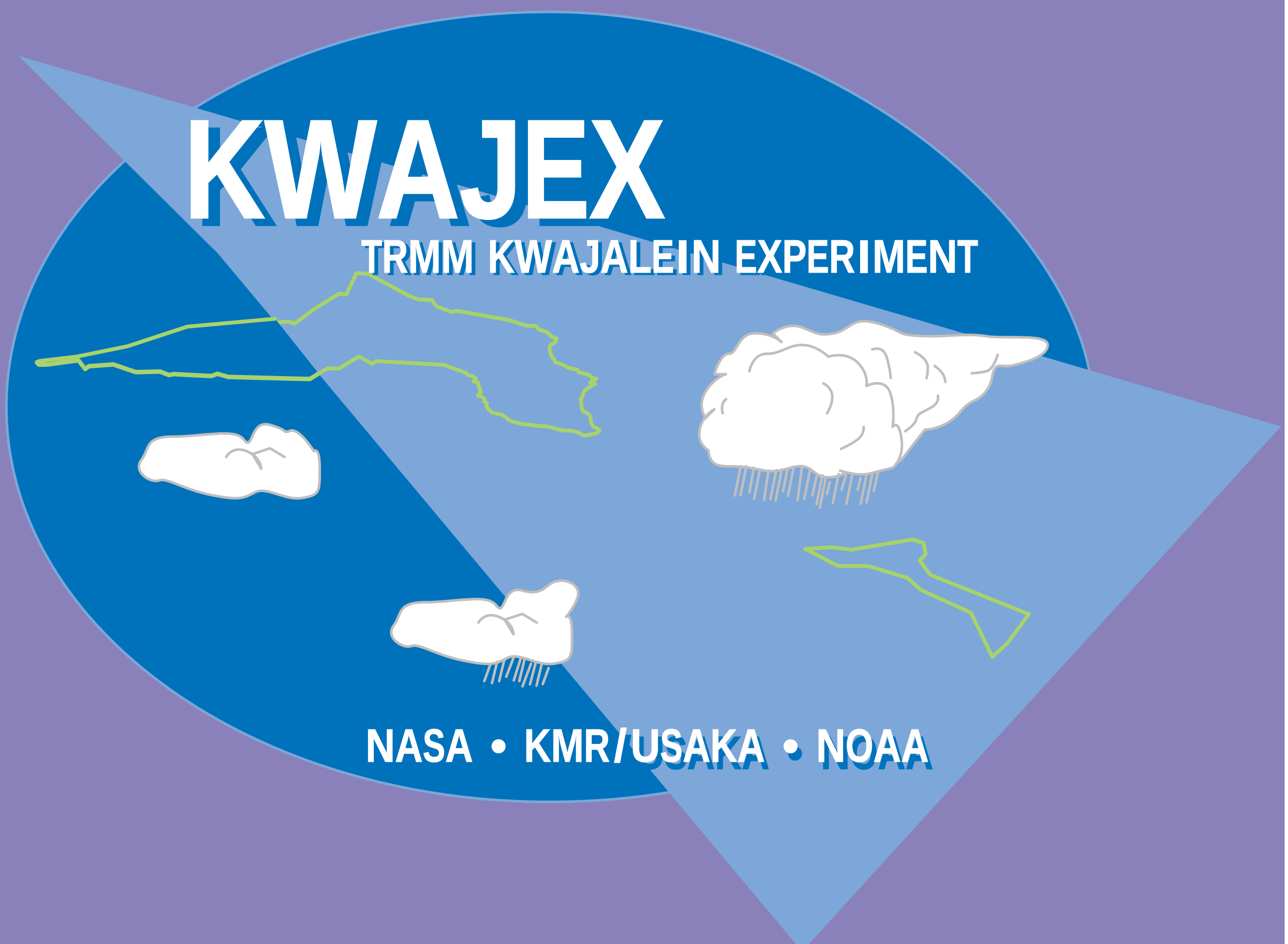
KWAJEX

Experimental Plan



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KWAJEX Experimental Plan

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Purpose of this document

This document presents the experimental design for the NASA Tropical Rainfall Measuring Mission (TRMM) field campaign centered on the permanent TRMM Ground Validation (GV) site on Kwajalein Island in the Republic of the Marshall Islands. The Kwajalein Experiment (KWAJEX) is unique among the planned TRMM field campaigns in that it is the only one to be conducted over the tropical open ocean. While there are similarities in the scientific issues over land and ocean, there are also differences in the issues and their priorities over the ocean. The experimental plan presented in this document forms the second part of the KWAJEX program scientific documentation and details how the experiment will be carried out. The what and why of KWAJEX are presented separately in *KWAJEX: Scientific Overview and Objectives* dated 24 February 1999. The U.S. Army Kwajalein Atoll (USAKA) Kwajalein Missile Range (KMR) support requirements are detailed in the Universal Documentation System (UDS) requirements documents prepared by Carl Sweetland, Professional Universal Documentation Services: the basic *Program Introduction/Program Requirements Document* (May 1998), Revision 1 (2 August 1998), Revision 2 (1 September 1998), and the *Operations Requirements Document* (2 April 1999).

Chapter 1: Operations Overview

KWAJEX will take place 23 July-15 September 1999. Experiment instruments and operations will be focused on six islands and one ship (Fig. 1), and will involve three aircraft. Appendices 1-3 list the instruments on the NOAA Ship *Ronald H. Brown*, the NASA DC-8, the University of North Dakota Citation, the University of Washington Convair-580, and on each island.

1.1 Monitoring

Periods of intensive observations are best interpreted in the context of longer term baseline observations. In this way, the nature of changes to the environment and precipitation structure sampled during intensive observation periods can be placed into perspective as perturbations from the longer time scale means. It is envisioned that collection of the baseline or "surveillance" data will be continuous during the field campaign and that periods of intensive data collection will be timed to coincide with precipitation events near Kwajalein.

The primary objective of the baseline sounding and radar observations will be to monitor the environment and to detect precipitation in the vicinity. This information will be useful both in terms of initializing models and for forecasting precipitation events so that intensive data collection resources such as aircraft will be able to be deployed in the right place at the right time.

Models require environmental information often 24 hours or more prior to the event they are simulating in order to "spin up". Thus it is not always obvious when the data are collected whether they will be used for model initialization. Monitoring of atmospheric structures such as easterly waves requires regular upper-air soundings over a wide region both upstream and downstream of Kwajalein. Upper-air soundings will be launched from the island sites between 23 July-15 September including periods when the ship is in port.

1.2 Intensive Observation Periods (IOPs)

Intensive observation periods (IOPs) are when the radar ship is in position within the KWAJEX area. During these periods upper-air soundings will be launched every 3-12 hours depending on conditions (See Section 4.1 for details of the sounding launch schedule). The Kwajalein Island S-band and ship C-band radars will continuously scan in a manner to facilitate collection of dual Doppler data (See Section 5g). The NOAA Ship *Ronald H. Brown* has allocated 50 days at sea and 25 days in port during its stay in the Kwajalein area. The continuous days at sea will be broken into two periods separated by 4 days in port at Kwajalein.

Aircraft operational periods (AOPs) will occur within IOPs and are defined as any time one or more KWAJEX aircraft conducts a scientific mission. The Citation and Convair aircraft will be available for operations both day and night. The DC-8 is only available for operations during daylight. Back-to-back aircraft missions may be required for aircraft with short duration ($\leq$4 hours). Minimum precipitation criteria for aircraft deployment will be defined by KWAJEX project management for TRMM satellite overpass and non-overpass situations. These criteria will be less stringent for overpass situations. TRMM satellite overflights with significant overlap with the GV region will be defined as potential AOPs. Aircraft will be deployed at least an hour prior to the satellite overflight if precipitation conditions warrant.

1.3 KWAJEX office space locations

Most of the Project offices, workspace, and meeting rooms will be located in Bldg. 1009 on the north side of the runway on Kwajalein Island (Figs. 2 and 3). Building 1009 is the primary office space for KWAJEX. Two small trailers will be set up next to the Aeromet offices on the south side of the runway to house the KWAJEX Operations Center. Both Aeromet and the Operations Center house 24-hour operations. Aeromet has operational responsibilities to KMR and it is important that they be able to work without undue interference from KWAJEX personnel. Similarly, the Operations Center is focused on the day-to-day coordination issues with the ship and sounding sites. In order to minimize distractions for scientists on shift in the Ops Center and at Aeromet, unless invited, KWAJEX personnel not assigned to the Ops Center are asked to refrain from visiting the Ops Center and the Aeromet offices. Ops Center shift scientists are requested to restrict their interactions with Aeromet personnel at the office to the designated Aeromet radar scientist and project forecaster.

1.4 Communications

a. KWAJEX network

The KWAJEX network will support local internet access to KWAJEX computers on-island in Bldg. 1009 and the KWAJEX Operations Center. Different components of the network will be set up and maintained by different groups. The Project Office is responsible for the portion of the network in Bldg. 1009. Aeromet is responsible for coordinating the network connection between the Ops Center and Bldg. 1009 with KMR and for the connections to the workstations and displays they provide. The Project Science Coordinator in coordination with Aeromet is responsible for the network within the Ops Center trailers.

b. Project email

The Project Office will set up and maintain an email server for project personnel. Email addressed to KWAJEX personnel will be bundled for transfer by a computer at NASA Ames. Similarly, outgoing email will be bundled by a Project Office computer in Building 1009. Project email will be exchanged between Kwajalein and NASA Ames a few times per day on a schedule TBD with KMR. Given the limited network bandwidth to Kwajalein, KMR will likely impose an upper limit on the total size of the email transfers. In order to keep the total project email byte count within these constraints, it is recommended that participants not forward *all* their usual incoming email to Kwajalein. The Project Office will define guidelines for KWAJEX personnel regarding email and attachments.

c. Telephone

Offices in Bldg. 1009 have telephone lines as shown in Fig. 2. The KWAJEX Ops Center trailers will have phone lines in the two offices and there will be two phone lines in the Ops Center for official project communication.

d. General Internet access

There will be no access to the World Wide Web from the KWAJEX network. General Internet access is via an Internet Service Provider (ISP) accessible via phone line. The cost of "1-800" calls from Kwajalein is covered in the "hotel bill" for calls from individual rooms but not from the KWAJEX office space. The number of phone lines available to the Kwajalein community as a whole is very small. It is recommended that KWAJEX participants limit their Internet access via phone lines to short sessions.

e. Land-Sea communications

An HF radio set has been requested for the KWAJEX Ops Center and the main lab on the NOAA Ship *Brown*. The HF communications system will be tested by the respective engineers from KMR and the *Brown* during the ship's first in-port period 19 -25 July. The engineers from the respective facilities are responsible for the maintenance of their HF systems. HF radio will be the primary mode of communication between the ship and the Ops Center on land and will operate as needed 24 hours a day in a "chat" mode by the scientists on ship and in the Ops Center. Additionally, the ship has the capability to send and receive faxes via INMARSAT and has INMARSAT voice and data lines. The INMARSAT voice-only cost is ~$3 per minute and the INMARSAT data-quality line is ~$7 per minute. Despite the physical proximity of the ship to Kwajalein Island, such satellite calls are not local.

For quality-control purposes, all the ship's daily soundings and a few radar volumes will be sent via ftp from the ship each day to the Ops Center. Because of security considerations on the Kwajalein Mission Support Network, the recipient machine may be either a UNIX workstation on the KWAJEX TRMM network (preferred method) or an Internet-connected mainland computer where the data can be retrieved during regularly scheduled mainland ftp sessions (see Sec. 8.3e).

The current plans do not include any direct communication between the ship and aircraft scientists. Scientific information from the ship will be relayed by the Airborne Mission Coordinator at the Ops Center to the aircraft as needed.

f. Land-Air and air-to-air communications

See Section 7.4c.

Chapter 2: Operations Coordination and Oversight

2.1 Oversight and planning structure

The KWAJEX Scientific Steering Committee will consist of: the Operations Director, Project Science Coordinator, Surface Sites Coordinator, Aircraft Mission Coordinator, Aircraft Chief Scientists, Ship Science Coordinator, and TRMM Joint Science Team Members (Kakar, Wilheit, Smith, Houze, Kummerow, Thiele, Zipser) on island. Since the Ship Science Coordinator will be on the ship and telephone conferencing via INMARSAT will be prohibitively expensive, they will be unable to attend Steering Committee meetings unless the ship is in port. The Project Office will handle logistics and infrastructure issues in support of the project science. Figure 4 shows a block diagram of KWAJEX project management structure.

2.2 Project staff and functions

This section presents a general outline of KWAJEX project staff and their responsibilities. At times during the IOP, two functions may be handled by one person. For functions corresponding to 24-hour operations, several people will be required to provide certain functions over several shifts.

a. Project office

Project Manager

- Coordinates all aircraft logistical support functions
- Point of contact for KMR regarding aircraft operations
- Oversees administration and implementation of KWAJEX computers and LAN physically located in Bldg. 1009
- Coordinates logistics and transportation support for Lae Island and Woja Island sites
- Has responsibilty to obtain appropriate permissions, permits, and memos of understanding with RMI, KMR, and NWS regarding the Lae Island and Woja Island sites
- Administrative point of contact for KMR
- Provides financial oversight for KWAJEX operations
- Creates and disseminates daily operations schedule
- Insures KWAJEX is in compliance with FAA regulations

Logistics Coordinator

- Assists participants with travel and housing arrangements
- Arranges and oversees shipments of equipment
- Coordinates administrative and clerical functions at Bldg. 1009
- Oversees Bldg. 1009 communication system and functions

Data Coordinator

- Responsible for project email
- Oversees data cataloging of all operations
- Monitors daily data receipt
- Designs and maintains KWAJEX operational on-island web pages
- Formats image and text input from Operations Director, Project Science Coordinator, Surface Sites Coordinator, and Aircraft PIs into standardized format web pages
- Prepares for daily transmittal to mainland of subset of web page information
- Produces html daily weather summary pages from information provided by Forecaster

b. US Army Kwajalein Atoll/Kwajalein Missile Range

Kwajalein Missile Range Test Director

- Coordinates KMR departments responding to KWAJEX support needs
- Serves as the **single** point of contact between KWAJEX project and KMR

Aeromet Site Manager

- Point of contact for KMR regarding S-band radar operations
- Coordinates S-band radar calibrations and maintenance
- Oversees administration and implementation of LAN among Aeromet offices, KWAJEX Operations Center trailers, and Bldg. 1009
- Oversees Aeromet-provided computers in Bldg. 1009 and KWAJEX Ops Center
- Supervises Aeromet-provided Project Forecaster

c. Science Operations

KWAJEX Operations Director

- Implements the KWAJEX Experimental Plan
- Convenes and chairs the daily operations planning meeting
- Serves as chair of the Scientific Steering Committee
- Selects Aircraft Mission Coordinator on days aircraft missions are planned
- Monitors a/c missions accomplished and flight hours expended
- Monitors expendable resources
- Maintains near-real time display of status information
- Oversees press/public affairs statements and activities
- Reports to the funding agency

Project Science Coordinator

- Assumes duties of KWAJEX Operations Director at the Director's discretion or in the Director's absence
- Oversees KWAJEX ship-to-land communications
- Oversees KWAJEX Ops Center communications to Lae and Woja
- Oversees off-island ftp communications via KMR Mission Support Network
- Assigns duties of Operations Center personnel

- Supervises preparation of integrated aircraft mission summaries
- Coordinates activities of Surface Sites Coordinator, Ship Science Coordinator, and Shift Senior Scientists
- Oversees administration of KWAJEX computers and LAN physically located in Ops Center
- Science point of contact for KMR

Project Forecaster

- Provides daily forecast support to Operations Director, the daily planning meeting, and the Aircraft Mission Coordinator
- Provides forecast to ship of surface wind, sea, and swell in ship's vicinity for the following 24 hours. A qualitative forecast statement of the likelihood of any significant change in the major forecast elements will be made out to 72 hours
- Coordinates cumulative monitoring of forecast and observed weather conditions
- Selects images and data for daily weather summary pages prepared by Data Coordinator

Surface Sites Coordinator

Prior to commencing field phase:

- Prepare detailed written procedures for upper-air sounding launches including ground checks. This material will be used as a training tool and as a reference manual for the sites. Draft by May 1st, to be distributed to Project Science Coordinator and TRMM FC czar. Final version due on 1 June.
- Determine written and computer logging procedures
- Determine data transmission procedures for each upper-air site
- Write checklist for sonde launch that is referred to for each launch
- Insure ground check instrumentation exists at each site and is calibrated
- Train the sonde launchers

Once the project starts:

- Coordinates operations relevant to surface sites: upper air soundings, profilers, buoys, and mesonet
- Serves as Operations Center contact point for off-Kwajalein island sounding personnel on Roi, Meck, Lae, and Woja
- Prepares daily summary of surface site activity
- Monitors logistics of surface sites
- Monitors personnel schedules and performance at surface sites
- Coordinates timing of sonde launches
- Serve as project point of contact for tethered sonde and coordinates their activities
- Coordinates with 2-D Distrometer scientist
- Monitors sounding quality and deals with problems as they come up

Ops Center Shift Senior Scientist

Leads an 8-hour Ops Center shift team consisting of 2-3 scientists (including the senior scientist). The Shift Senior Scientist has the responsibility to insure the team's main responsibilities are fulfilled:

- Assess quality of real-time S-band reflectivity, Doppler, and dual-polarization data and alert appropriate personnel if there are problems
- Keep detailed log of S-band radar operations
- Ensure that the S-band data are being recorded
- Coordinate and implement dual-Doppler scanning with ship radar
- Communicate with off-Kwajalein sounding stations and obtain their data after each launch
- Produce html mission summary pages for each aircraft mission (see Sec. 8.2)
- Produce daily radar summary html pages of web site
- Monitor Kwajalein Atoll mesonet and alert Aeromet if there are problems

Ship Science Coordinator

- Serve as scientific-operations focal point for NOAA officers and crew
- Serve as scientific-operations focal point on ship for Kwajalein-based project coordinators
- Prepare daily summary of previous day's ship operations and current status
- Assign duties of ship's scientific personnel
- Manage, train, and mentor scientific crew: undergraduates, graduate students, and postdocs

Ship Shift Senior Scientist

In parallel to the structure at the Operations Center on Kwajalein, the ship's scientific work will be performed 24 hours a day in shifts with each shift led by a Ship Shift Senior Scientist. The Ship Shift Team will consist of the senior scientist and an assistant scientist. The Ship Shift Senior Scientist has the responsibility to insure the team's main responsibilites are fulfilled:

- Assess quality of real-time C-band reflectivity and Doppler data and alert appropriate personnel if there are problems
- Keep detailed log of C-band radar operations
- Ensure that the C-band data are being recorded
- Coordinate and implement dual-Doppler scanning with Kwajalein S-band
- Launch upper-air soundings every 3 hours, 24 hours a day
- Once every 8 hours, collect and process water vapor sample for isotope study
- Monitor ship's atmospheric surface and upper ocean data time series and alert appropriate personnel if there are problems

Aircraft Mission Coordinator

Preflight planning:
- Works with Aircraft Chief Scientists representing each aircraft involved in the mission to select initial flight patterns
- Assigns visiting scientists to aircraft as appropriate
- Briefs pilots on scientific objectives and proposed tracks prior to mission

During flights:

- Monitors S-band radar data and aircraft tracks from KWAJEX Ops Center for purpose of directing aircraft to precipitating targets
- Communicates flight track specifications to Aircraft Chief Scientists on each aircraft
- Communicates updated forecast information to aircraft
- Monitors progress of all aircraft during the mission
- Resolves problems that arise such as choice of alternate flight patterns
- Advises aircraft when to initiate, alter, or terminate aircraft scientific operations following takeoff

Post mission:

- Leads scientific debriefing following completion of mission
- Integrates mission logs from each aircraft into written summary of mission objectives and accomplishments to be given to Operations Director

Aircraft Chief Scientists (one for each aircraft)

- Responsible for overall scientific direction during flight
- Works with flight crews to setup and execute flight patterns appropriate for mission
- Point of contact between aircraft flight crews and KWAJEX scientific management
- Primary point of contact for Aircraft Mission Coordinator
- Overall responsibility for scientific data gathering by their aircraft during missions
- Responsible for providing ascii flight track information to Ops Center within 1 hour of landing
- Responsible for providing written mission log and mission objective status to Aircraft Coordinator after each flight

2.3 The daily planning process

Table 1 presents a proposed daily schedule. Based on that schedule the daily planning meeting begins at 8-9 am LT. Modifications to the proposed schedule could occur due to operational or forecast requirements.

Table 1. KWAJEX daily status reports and planning meeting schedule.

Activity	**Local Time**
Ship and Island sites status reports due at Ops Center	6 am
Prep Meeting	6:30-7 am at Aeromet Offices
Daily Planning Meeting	8-9 am at Bldg. 1009
DC-8 Pre-Flight Meeting	2 hours before scheduled aircraft departure time

a. Preparations

Prior to the planning meeting, the Operations Director, Aeromet Site Manager, Project Science Coordinator, Aircraft Mission Coordinator (if there was an a/c mission the previous day), Surface Sites Coordinator, and Forecaster will meet in the Aeromet conference room. There they will assess the status, data, and forecast presentation materials needed for the Daily Operations Planning Meeting and assign responsibilities to insure these materials are available in time.

b. Daily operations planning meeting

The Operations Director will convene and chair a daily operations planning meeting in the large conference room in Bldg. 1009. These meetings will involve the Scientific Steering Committee, the KMR Test Director, an Aeromet representative, a Project Office representative, instrument scientists, and other KWAJEX PIs and observers.

Participants in the daily operations planning meeting will have access to the following information:

- Forecasts
- Reports of prior missions
- Status reports on resource availability
- Progress toward KWAJEX objectives
- Operational status reports on all observing systems, communications, and personnel

Each daily operations planning meeting will commence at 0800 LT and proceed through an agenda that will include the following:

- Summary of previous day's weather and project activities

- Cumulative summary of project accomplishments to date and remaining goals

- Forecast (for that day and outlook for the next few days)

- Status reports from each platform (S-band radar, ship, surface sites, each aircraft)

- Discussion of the Plan of the Day
  - "possible fly" or "definite no fly" decision
  - if "possible fly"
    1) Proposed aircraft operations
    2) Discussion
       - compatibility of proposed operations
       - progress toward KWAJEX objectives
       - availability of human and material resources
    3) set scheduled departure time and begin countdown that will trigger Preflight Meeting
    4) assign Aircraft Mission Coordinator and aircraft scientists

- Operations Director's recommendations for operations for next 24 hours

c. Actions following daily operations meeting

The Operations Director, Project Manager, and Project Science Coordinator will prepare a written mission requirements statement for the KMR Test Director and KWAJEX science operations. The Operations Center will issue a daily operations summary and forecast to the ship and all island sites.

If an aircraft mission is planned, the Aircraft Mission Coordinator and Aircraft Chief Scientists will brief aircraft flight support groups and KMR FAA as to the mission schedule and requirements.

d. Forecasting facilities

Aeromet Inc. will provide a dedicated forecaster to KWAJEX. This person will work at the Aeromet offices and interact primarily with the Project Science Coordinator, Shift Senior Scientist at the Operations Center, and the Aircraft Mission Coordinator. Since Aeromet has 24-hour contractual responsibilities to KMR it is extremely important that KWAJEX personnel not disrupt Aeromet's work at the Aeromet offices. The forecaster will come to Bldg. 1009 for the daily meeting, pre-flight meeting, and as needed for other project meetings.

To facilitate provision of current weather and forecast information to the scientists in Bldg. 1009, the main conference room in Bldg. 1009 will be equipped with a real-time video display showing Kwajalein S-band radar surveillance scans. A Mcidas workstation with GMS satellite data and grid data from the NODDS, ECMWF, and AVN models for the area roughly 10ºS to 40ºN and 155ºW to 135ºE will also be available.

The KWAJEX Ops Center trailer will be equipped with an SGI workstation with radar display and Sigmet software, and a Mcidas workstation with access to the same model and satellite data as in Bldg. 1009.

e. Daily reports

All platforms and sites are required to submit a daily summary of operations including instrument status, frequency of operations, and data acquisition period to the Project Science Coordinator by 0600 am each day so that this information is available at the daily meeting. This status information with the addition of appropriate observer notes will also be submitted daily via the appropriate Chief Scientist/Coordinator to the Data Coordinator for the on-line data catalog. Electronic submissions when possible will speed data ingestion. The Data Coordinator will place this information on the KWAJEX operational on-island web site in a timely manner so the information is accessible to KWAJEX scientists in Bldg. 1009 and the Ops Center.

Accurate information from all observing systems is essential to effective long-term data management. Daily weather information (i.e., geosynchronous satellite), radar operations and aircraft mission summaries, forecast and quick-look analyses, and other information gathered and cataloged during the IOP will be available shortly after the IOP as a summary of KWAJEX operations and a guidebook to KWAJEX data.

Chapter 3: TRMM satellite overpasses

The ground track of the TRMM satellite passes within 250 km of the Kwajalein radar approximately 22 times per month. Of those overpasses only a small fraction pass sufficiently close to Kwajalein to facilitate *possible* intercomparison of the satellite data and GV radar data. Closer overpasses have a larger area of intersection of the satellite swath with the GV region (Fig. 5). The number of *useful* overpasses for satellite-GV intercomparison is an even smaller fraction as three conditions must be met simultaneously:

a close overpass to Kwajalein by the satellite, a rain event within 150 km of Kwajalein, and a functional status of the ground-based radar. The six best overpass events in terms of the juxtaposition of these three criteria for 24 July - 15 September 1998 are shown in Fig. 6. The summer of 1998 was drier than normal at Kwajalein (Sec. 3.3a in *KWAJEX Scientific Overview and Objectives*) so we anticipate a more frequent coincidence of widespread precipitation and satellite overpasses during the project period in 1999.

For planning purposes, the TRMM satellite overflight schedule for the planned KWAJEX period of 23 July - 15 September 1999 is shown in Table 2.

Table 2. Times and distances of closest TRMM satellite ground track to Kwajalein radar for KWAJEX period (23 July - 15 September 1999) based on predicted ground track as of 11 June 1999. Kwajalein local time is UTC+12 hours. Numbers based on orbit computation using TSDIS Overflight Finder.

Date	**Time (UTC)**	**Orbit Segment**	**Range (± 10 km)**
23 July	1206	Northbound	90
23 July	2150	Southbound	250
25 July	2102	Southbound	50
27 July	2014	Southbound	150
28 July	0916	Northbound	170
30 July	0828	Northbound	10
1 August	0740	Northbound	210
1 August	1724	Southbound	130
3 August	1636	Southbound	70
4 August	0538	Northbound	250
6 August	0450	Northbound	50
8 August	0402	Northbound	150
8 August	1346	Southbound	190
10 August	1258	Southbound	0
12 August	1209	Southbound	190
13 August	0112	Northbound	130
15 August	0023	Northbound	70
17 August	0920	Southbound	70
19 August	0831	Southbound	110
19 August	2134	Northbound	210
21 August	2045	Northbound	10
23 August	1957	Northbound	190
24 August	0541	Southbound	150
26 August	0453	Southbound	50
28 August	0405	Southbound	250
28 August	1707	Northbound	90
30 August	1619	Northbound	110
31 August	0203	Southbound	230
2 September	0115	Southbound	30
4 September	0027	Southbound	170
4 September	1329	Northbound	150
6 September	1241	Northbound	50
8 September	1153	Northbound	230
8 September	2137	Southbound	110
10 September	2049	Southbound	90
11 September	0951	Northbound	230
13 September	0903	Northbound	30
15 September	0815	Northbound	170
15 September	1759	Southbound	170
17 September	1711	Southbound	10

Chapter 4: KWAJEX manned platform schedules

4.1 Upper-air soundings

Land-based soundings from Kwajalein, Roi-Namur, Meck, Lae, and Woja will commence for KWAJEX with the 00 UTC 23 July sounding (1200 LT 23 July) in order to provide context for the weather situation on 25 July, the first day of ship operations and possible aircraft operations. Land-based soundings will continue to be obtained while the ship is in port mid-project. Land-based sounding operations for KWAJEX will cease with the 00 UTC 15 September sounding (1200 LT 15 September).

4.2 Tethered sonde

A tethered sonde will operate from 21 July -15 September. See Sec. 6.1a for details.

a. 2-D video disdrometers

An experienced 2-D Disdrometer Scientist will be assigned to mind the 2-D video disdrometers daily from 23 July - 15 September in order to insure high quality data from these instruments.

4.3 Ship

The current ship schedule for the NOAA Ship *Ronald H. Brown* is shown in Table 3. The ship's days at sea are broken into 2 IOPs with 4 days in port approximately mid-project for resupply, restaffing, and shore leave.

Table 3. NOAA Ship *Brown* schedule.

Date	Description
19 July	ar. Kwajalein Island from ARM-Nauru cruise
25 July	lv. Kwajalein Island - start IOP1
20 August	ar. Kwajalein Island - end IOP1
24 August	lv. Kwajalein Island - start IOP2
13 September	ar. Kwajalein Island - end IOP2
18 September	lv. Kwajalein Island for Moorings cruise

4.4 Aircraft

The two of the three KWAJEX aircraft will arrive on Kwajalein Island on a schedule that will have them ready for a potential first flight on 25 July 1999. The first potential flight for the NASA DC-8 is 29 July. Aircraft arrival and departure dates are given in Table 4. Both the Citation and the Convair-580 may leave earlier than indicated if their allocated flight hours are exhausted before the last day of the project.

Table 4. Scheduled arrival and departure dates of KWAJEX aircraft.

Aircraft	arrival date	first potential flight	departure date
NASA DC-8	27 July	29 July	20 September
UND Citation	15 July	25 July	17 September
UW Convair-580	23 July	25 July	16 September

Chapter 5: Radars

Both the C-band radar operations on the ship and the S-band radar operations at the Ops Center on Kwajalein Island will be staffed 24 hours a day. When either radar is down,[1] dual-Doppler data will not be able to be collected and the remaining radar will utilize a single radar scanning mode. When both radars are operational, they will use a coordinated dual-Doppler scanning strategy.

5.1 Kwajalein S-band radar

a. Characteristics

The characteristics of the Kwajalein S-band radar are described in Table 5.

Table 5. Kwajalein S-band radar.

Model	Modified DWSR-93S
Wavelength	10.71 cm
Peak transmit power	500 kW (250 kW horizontal, 250 kW vertical)
pulse duration (usec)	0.72
minumum detectable signal	–108 dBm
antenna gain	~45.1 dB
PRF	variable 396-960 Hz (maximum of 4 specified at a time)
Polarization	Horizontal and vertical
Beamwidth	1.12 degrees
antenna and radome dimensions	Antenna (8.23 m), radome (11.5 m)
Antenna height above msl	24.8 m
maximum scan speed	20 deg/sec
elevation range	-0.4 to 90.5 deg
available radar variables	Z, Vr, SW, ZDR, PHIDP, KDP
Radar processor and software	Sigmet RVP7, RCP02, and Iris software V7.05

The clutter characteristics in the vicinity of Kwajalein Island are such that the radar data within a 15-km range of the S-band are essentially not usable for research purposes. A 15 km radius hole is cut in the TRMM GV products from Kwajalein for this reason.

b. Responsibility for operations

As KMR/USAKA weather radar contractor on Kwajalein, Aeromet Inc. has sole responsibility for operations of the S-band radar. KWAJEX scientists will work with Aeromet personnel to control the radar in a manner that jointly satisfies KMR Operational requirements and KWAJEX scientific objectives. However, Aeromet has ultimate authority over the radar scans and task scheduling.

A critical component of joint control of the radar during KWAJEX is clear and frequent communication between the KWAJEX radar scientists and Aeromet personnel. The need for this communication and the technical constraints associated with controlling the radar

[1] A radar may be down for regular maintenance, calibration, or repair. Obviously, scheduled radar down times should be timed to coincide with periods when there is a lull in the precipitation in the vicinity and should not occur during TRMM satellite overpasses.

are the primary reasons the KWAJEX Ops Center is located next to the Aeromet offices. A continuing dialogue of respective needs and proposed solutions has worked well in designing the nominal GV scan strategy and modifying it as the radar suffered mechanical problems during the last year. Both sides need to carefully listen to each other's concerns and suggest solutions that address the needs of both groups. KWAJEX radar scientists need to keep in mind that the Aeromet personnel have unique skills and experience with the S-band radar that are essential to obtaining a valuable research data set during KWAJEX.

There are three potential workstations for controlling the radar: the SGI workstation running Sigmet IRIS in the KWAJEX Ops Center, the SGI workstation running Sigmet IRIS in the Aeromet offices, and the SGI workstation running Sigmet IRIS in the base of the radar structure. The workstation in the base of the radar structure has an unfavorable noise environment and will be avoided whenever possible. The following guidelines are proposed for joint operation of the S-band radar. These may be modified once the technical details of implementing joint control of the radar are completely worked out between KWAJEX and Aeromet.

- It will always be clear who has responsibility for controlling the **radar scan task schedule**. A physical symbol such as a large wooden key will be moved between the workstations that can potentially control the radar to indicate which one has active control. Workstations without the radar key will only be used to observe radar operations, independent of whether the software they are running technically has permission to modify operations.
- It is anticipated that most of the time, the control of the radar (and radar key) will reside with Aeromet. Only under special circumstances will radar control reside with the KWAJEX Ops Center.
- If weather conditions are such that it is anticipated that the currently employed scan strategy will not change for an hour or more, control of the radar (and radar key) will always reside with Aeromet.
- Both Aeromet and KWAJEX Ops scientists will actively monitor the S-band radar data at all times in order to anticipate their needs for changes in the scan strategy. In this way, each group can provide notice to the other, ideally 30 min or more but at least 10 min, prior to any needed modifications in the task schedule. The purpose of providing this notice of changing requirements is to allow time to discuss and reach consensus on what the change is and exactly when the change will be implemented.
- Depending on the nature of the change in the task schedule and the KWAJEX Ops Center and Aeromet personnel currently on shift, control of the radar (radar key) may or may not shift between the groups. The group with the radar key would implement the agreed-upon change to the **task schedule** independent of whether they initially requested it.
- Control would pass from Aeromet to the KWAJEX Ops Center if the timing of the changes in scan strategy needs to be closely coordinated with the ship radar and the Ops Center personnel present have adequate training with the Sigmet software system.
- If the KWAJEX Ops Center has control of the radar, then control will pass back to Aeromet when changes in scan strategy no longer need to be closely coordinated with the ship or the Ops Center personnel coming on shift do not have adequate training with the Sigmet software system.
- Either Aeromet or the KWAJEX Ops Center can design and define tasks (scan strategies) within agreed-upon naming conventions. KWAJEX Ops Center originated

tasks are subject to the review of the Project Science Coordinator. Note that defining a task defines a set of scan angles and characteristics of the radar such as pulse width, scan speed, PRF, variables obtained, etc. associated with the radar scanning but does not run the task. Tasks have to be defined before they can be scheduled. In this way, new tasks can be available before they need to be scheduled to run.

- It is anticipated that there may be periods when Aeromet has control of the radar and the task schedule needs to be changed frequently to accomodate KWAJEX scientific requirements. In this case, anticipation of the exact time the change will need to be implemented is particularly important. It will be the responsibility of the KWAJEX Ops Center to determine the needed timing of the change, the specific task being requested, and to communicate that requested change information to Aeromet at least 10 min ahead of time.

c. KMR operational constraints

Aeromet has two main operational requirements from KMR that must be accommodated during the KWAJEX period: regular surveillance scans to show precipitation in the vicinity and volume scans over Roi-Namur and Meck that are used as input for lightning warnings. These KMR requirements take precedence over KWAJEX requirements.

Surveillance scans

A long-range surveillance scan of reflectivity to 350 km range is required by KMR on a regular schedule every ~10 min. These data are on video displays at several locations throughout KMR including the FAA tower, Roi-Namur Island, Meck Island, and will also be available in the Mission Briefing Room in Bldg. 1009 and the KWAJEX Ops Center. The KMR users of these data do not necessarily have the training to distinguish real echo from ground clutter and sea clutter, so to minimize these nonmeteorological echoes a single tilt at 1° elevation is used and takes less than a minute to complete. KMR has some flexibility in the exact interval between surveillance scans but requires that it is between 10 - 15 min.

Lightning warnings

As a missile testing range, KMR has facilities on Roi-Namur and Meck islands to the north of Kwajalein which would be dangerous in lightning conditions. KMR requires Aeromet to provide lightning warnings for these islands during the normal workday (daylight) during the week. Lightning warnings are needed 24 hours a day if there is a rocket on the pad at Meck. Based on the current schedule of KMR programs there is a possibility that a rocket may be on the pad for several days during KWAJEX. Aeromet has a software program that it runs on the incoming radar volume data to forecast lightning. This warning appears as a graphic on the video displays of the radar data for the KMR users. If the S-band radar is scanning a 360° volume scan, the lightning warning program will run automatically.

Although potentially feasible, a workaround to provide lightning warnings from the ship radar when the S-band radar is sector scanning over the dual-Doppler lobes would be complex to implement. It was decided at the 5 April 1999 Goddard meeting that the Kwajalein S-band radar would always scan 360° during KWAJEX so that the required lightning warnings are not interrupted.

d. Single radar scan strategy

When the ship is not in position (i.e., while in port) or when the ship radar is down, the Kwajalein S-band radar will scan in a mode similar to the nominal GV scan strategy run the rest of the year. The nominal GV strategy as of February 1999 is documented in Section 3.2 of the *KWAJEX Science Objectives and Overview*. However, this exact strategy was not run for several months due to mechanical problems with the S-band radar that limited the scan speed to 8 deg/sec. These mechanical problems involving the antenna gearing were corrected in late February and the nominal GV scan strategy resumed in March 1999.

In June 1999, the Kwajalein S-band radar will be upgraded to include a second receiver. With dual receivers in place, the previous constraint on dual polarization data collection which limited scan rates to less than 8 deg/sec in order to collect sufficient samples at horizontal and vertical polarization will be removed. The GV scan strategy will able to be simplified since specialized dual polarization scans will no longer be needed. The new GV scan strategy for Kwajalein will be designed via the usual TRMM GV channels in cooperation between Aeromet, the University of Washington, and JCET. The specific strategy cannot be finalized until the radar upgrade is complete and tested so it cannot be included in this document. The probable form of the new GV scan strategy, and hence the non-IOP S-band strategy for KWAJEX is shown in Table 6.

Table 6. Possible task schedule for revised GV scan strategy for Kwajalein S-band.

Scan name	Scan duration based on task scheduler (mm:ss)
surveillance (1 tilt @ 8 deg/sec, 396 PRF)	01:00
RPHASE volume (2 tilts @ 15 deg/sec, 960 PRF)	01:00
volume (17 tilts @ 15 deg/sec, 960 PRF)	<07:00

Processing of GV radar data collected at Kwajalein since 1997 by both JCET and the University of Washington has indicated a high frequency of occurrence of second trip echo. The existing radar quality control algorithms do not completely remove this non-meteorological echo and it is a source of error in the Kwajalein TRMM GV products. Sigmet Inc. has recently implemented a new signal processing algorithm called Random Phase (RPHASE) in its digital signal processor that will automatically detect and remove second trip echo within the unambiguous range of the radar. However, there are apparently some incompatibilities between running RPHASE and collecting dual-polarization data. RPHASE will be tested at Kwajalein in late June and early July and a decision will be made whether it is feasible to use prior to the start of KWAJEX.

e. NOAA Ship *Ronald H. Brown* C-band radar

Characteristics

The basic characteristics of the C-band Doppler radar system on the NOAA Ship *Brown* are shown in Table 7. This is a new, state-of-the-art-radar system installed in November 1998 by NOAA. Of particular note is that the beamwidth of the antenna is 0.95 degrees, providing better spatial resolution at a given range than the TOGA or MIT radars used on ship during TOGA COARE, TEPPS, and SCSMEX. By the time of KWAJEX, the radar system will have been extensively tested by radar engineers and scientists during the JASMINE cruise in May and the ARM-NAURU cruise in June-July. Both these cruises have collection of volumetric Doppler-radar data as a primary objective and the NAURU cruise will also be collecting dual-Doppler data in coordination with the Japanese radar ship *Mirai*.

Table 7. NOAA Ship *Brown* C-band radar characteristics.

Model	REI-55
Wavelength	5.36 cm
Peak transmit power	250 kW
Pulse duration (usec)	2, 1.2, 0.8, 0.5
Minumum detectable signal	–114 dBm
Antenna gain	~44 dB
PRF	variable 250-2100 Hz
Polarization	Horizontal
Beamwidth	0.95 degrees
Antenna and radome dimensions	14 ft parabolic dish, 18 ft sphere
Antenna height above water line	33 m
Maximum scan speed	36 deg/sec
Elevation range	–0.5 to 85 deg
Stabilization	Seapath 200
Available radar variables	Z, Vr, SW
Radar processor and software	Sigmet RVP7, RCP02 and Iris software V7.05

Single radar scan strategy

During periods when the Kwajalein S-band radar is down, the ship C-band radar can either maintain its current dual-Doppler scan strategy or use a strategy similar to the nominal GV scan strategy. The decision regarding which scan strategy to use while the S-band is down will be discussed between in the Senior Shift Scientists on the ship and in the Operations Center and will be a function of the current weather conditions, whether any aircraft are in the air, and the anticipated duration of the S-band radar down period.

Since the ship radar has the ability to operate at a higher PRF than the Kwajalein S-band radar and the ship radar does not have KMR operational requirements, the ship version of the GV scan strategy will be slightly different from that used for the S-band. The volume scans will be designed to top 13 km (usual max echo top height) at 25 km range and yield ~1 km vertical resolution or better at 60 km. The ship's GV-like volume scan will be designed once the revised GV volume scan for S-band is finalized and thus cannot be included in this document. The surveillance scan will consist of a pair of low-level tilts (0.4 and 0.8 deg; Fig. 7). The availability of data from two tilts aids in distinguishing meteorological echo from sea clutter at closer ranges and extends the useable range of the surveillance scan.

Table 8. Scans for GV-like scan strategy for C-band ship radar.

Scan name	Approx. scan duration (mm:ss)
surveillance (2 tilts @ 18 deg/sec, 300 PRF)	01:30
volume (18 tilts @ 22 deg/sec, 1200 PRF)	< 07:00

Table 9. Scan characteristics for GV-like scan strategy for C-band ship radar.

Name	variables	deg/sec	# tilts	# samples	pulse width (usec)	max range (km)	PRF (Hz)	Nyquist velocity (m/s)
Surveillance	Z	5	2	50	2	240[2]	250	NA
Volume	Z, Vr	22	18	55	0.5[3]	125	1200	16.1

f. Ship positioning

The climatology of the GV coverage area around Kwajalein indicates a steep N-S rainfall gradient with more rainfall in the southern half of the circle. The prevailing winds in the Kwajalein area are easterly. Storms can track from any direction but often approach from the northeast. The NOAA Ship *Brown* has a top speed of only half the typical advection speed of storms in the Kwajalein area so it is too slow to chase storms. At the March KWAJEX meeting, two fixed positions were designated for the ship: 40 km to the south of Kwajalein for the first IOP and 40 km to the southwest of Kwajalein for the second IOP (Fig. 8).

g. Dual-Doppler scanning

The KWAJEX period is the only time during the TRMM satellite lifetime that scientific objectives requiring 3-D winds can be addressed at the Kwajalein GV site. To simplify radar operations, the Kwajalein Island and ship radar will be run in a mode to facilitate collection of dual-Doppler data at *all times* both radars are operational.

Five minute volumes

Experience in other field programs over the last 15 years has shown that 5 minutes is a good length for a dual-Doppler volume scan as a compromise between the competing constraints of increasing vertical resolution (more tilts, more time) and decreasing the time to complete the scan. Total scan length needs to be kept short to minimize the degree of storm evolution within the sample volume during the scan. Coordination of the start time of the scans is also very desirable in order to minimize the time difference between the intersection of the beams of the two radars. The radial velocity data along the beams from each of the two radars are used as components of the vector wind in each resolution volume. Ideally, the beams should intersect simultaneously so that they are sampling radial components of the same true wind vector. In convective precipitation regions when the wind direction and speed can change rapidly, even a few minutes of difference can create large errors in the derived winds if the individual beams sample two different true winds in a given resolution volume.

For these reasons, dual-Doppler scans are usually closely matched in length, coordinated in start times, and execute their tilt sequences in the same direction (usually bottom to top). Thus although the top of the volume is scanned ~5 minutes after the bottom of the volume, the lag time between when the beam from radar A and from radar B passes through a given resolution volume at any one level is usually within 30 sec. Different characteristics of the

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[2]Although technically the maximum range of a 250 PRF scan is 600 km, a 0.4 deg tilt will cross the freezing level at 4.5 km at ~225 km range. The beam is ~4 km wide at 240 km range and the center of the beam is at 5 km altitude.

[3] Pulse width may be increased if RPHASE processing is used.

radars may make the optimal scans for each of the two radars different in terms of tilt sequence, scan speed, and PRF. Programs such as the NCAR Scan Optimizer jointly optimize these various constraints for a given region to yield scan characteristics such as tilt sequence and scan speed.

Given the desire for 5-min volumes and the operational necessity to supply KMR with surveillance scans every 10-15 min, it was decided at the April 5 Goddard meeting that a dual-Doppler task schedule be adapted with two 5 min volume scans and 1 surveillance scan repeating every 12 minutes for both radars.

Dual-Doppler scan strategy

At the April 5 Goddard meeting, it was decided that for reasons of practical implementation, ease of analysis after the project, and reducing wear on the radar hardware that 360° scans would be used for the dual-Doppler volumes. As a consequence, although technically feasible, sector scanning will not be used by either radar even during aircraft missions. When selecting between potential 360° dual-Doppler volume scans, the main variable will be the echo top height and hence angle of topmost tilt of the scan. For dual-Doppler processing, the topmost tilt of the volume scan needs to pass above the tallest radar echo in the area of interest.

Based on the hardware characteristics of each radar, the following scan characteristics are suggested for the volume scans:

- S-band Kwajalein radar, PRF of 960 Hz (max PRF), max scan rate 16 deg/sec translates to ~13 tilts in 5 minutes.
- C-band ship radar with PRF of 1200 Hz and scan rate of 22 deg/sec translates to ~17 tilts in 5 minutes.

Volume-scan tilt sequences for the S-band and C-band will be designed using the Scan Optimizer and fine tuned in the field for echo top heights of 6 km, 8 km, 10 km (usual echo top height), and 13 km (max echo top height) at 25 km range. The vertical resolution of the resulting 3-D wind data will be greater for the volume scans with the shallower tops. When dual-Doppler scanning is implemented, the two radars would choose the volume scan appropriate to the echo top height and implement the scans on a synchronized 12-min repeat schedule.

h. Data archival and transfer

S-band radar data will be archived by Aeromet according to usual TRMM GV procedures on exabyte tape. C-band radar data from the ship will be archived by NASA personnel on ship using exabyte tape. At mid-project in port, all the data archived on the ship to date will be transferred to the Ops Center for cataloging.

A few raw SIGMET format files from the *Brown* will be transferred to the KWAJEX Ops Center every day for quality-control purposes via INMARSAT (see Section 1.4e).

Chapter 6: Surface Sites

6.1 Manned

a. Upper air soundings

Table 10. Sounding system type at each sounding site.

Site	System
NOAA Ship *Brown*	Viäsälä GPS
Kwajalein Island	MSS
Roi-Namur Island	MSS
Meck Island	MSS
Lae Island	VIZ GPS
Woja Island	VIZ GPS

The KWAJEX sounding array will consist of sites on 6 islands and the NOAA Ship *Brown* (RHB, Fig. 9). After every launch, each sounding site will transmit their sounding data to the Operations Center. *The frequency and hence sounding launch times for a particular 24 hour period will be determined on a daily basis for each sounding site by the Surface Sites Coordinator.* With the exception of the ship which will always launch every 3 hours, the upper-air sounding launch frequency will vary according to weather conditions, whether an aircraft mission occurs, and by location. Additionally, a 14-day sounding intensive period is scheduled for weeks 6 and 7 of the project (26 August – 8 September) when the frequency of the upper-air observations will be enhanced to 6 per day in the northern portion of the project area. During aircraft missions, sounding launch frequency will be increased to every three hours at Kwajalein, Roi, Lae, and Woja. Forty additional soundings are allocated to each of these islands to cover the additional launches associated with aircraft missions.

Kwajalein, Roi, and Lae Islands

Kwajalein, Roi, and Lae will always launch soundings at simultaneous times. Not counting the additional soundings launched during aircraft missions, the distribution of sounding frequency for Kwajalein, Roi, and Lae is as follows (note times given below are when balloon is at altitude, approximately 1 hour after physical launch).

- 14 days @ 6 launches a day at 0, 3, 6, 12, 15, and 18 LT
- 10 days @ 2 launches a day at 0 and 12 LT
- 31 days @ 4 launches a day at 0, 6, 12, and 18 LT

Meck Island

During the 14-day sounding intensive period on Meck Island, launches will occur every 4 hours. During the rest of the project soundings will be launched every 6 hours. Sounding frequency at Meck will *not* increase during aircraft missions. The distribution of sounding frequency at Meck is as follows:

- 14 days @ 6 launches a day at 0, 3, 6, 12, 15, and 18 LT
- 41 days @ 4 launches a day at 0, 6, 12, and 18 LT

Woja Island

Woja will not participate in the two-week sounding intensive period. However, like Kwajalein, Roi, and Lae, sounding frequency at Woja will increase during aircraft missions to every three hours. Not counting the additional soundings launched during aircraft missions, the distribution of sounding frequency at Woja is as follows:

- 10 days @ 2 launches a day at 0 and 12 LT
- 45 days @ 4 launches a day at 0, 6, 12, and 18 LT

b. Tethered sonde

Three lower atmosphere measuring systems will be operated on Meck Island from 21 July to 15 Sept 1999 by the University of Virginia (UVA) team participating in KWAJEX. The three measuring systems described below are:

a. 2500 cu ft tethered balloon
b. 10 m meteorological tower
c. A vertically pointing Doppler sound detection and ranging system (SODAR)

An MSS rawinsonde system will be co-located at Meck with the UVA equipment but operated by additional personnel.

Two six-person teams are required on site to maintain 24-hour operations. Four people, 2 for the tethersonde, tower, and SODAR (TTS) and 2 for the rawinsonde (RS) are required on site at all times. The UVA will provide four experienced personnel: two senior researchers (Profs. Garstang and Fuentes) and two graduate students. Two additional junior personnel will be required to assist the experienced personnel in:

a. Preparing the sonde/logger for flight
b. Attaching the sonde/logger to the tether line
c. Operating the tether sonde winch

Each of the above operations will be conducted in the presence of an experienced operator. Operation (b) requires handling the balloon by means of 100-ft handling lines. Tension exerted by the balloon (usually is less than a 100-lb pull) needs to be released while the sonde/logger is attached. This is done manually by pulling on the handling lines.

Operation (c), running the tethered balloon winch, consists of simple procedures: turning on the electrical power, controlling the inhaul/outhaul rates by means of a lever and graduated markings, observing the line traveling on pulley/capstan head/fairlead pathways. Training on these operations will be provided prior to conducting profiles.

Characteristics of the tethersonde system

Size: 2500 cu ft, about 30 ft long, 10 ft diameter

Color: Balloons 1 and 2: body white, fins orange
Balloons 3 and 4: body alternating panels of orange and white, fins orange

Balloon #1 will be the primary balloon. Balloons 2, 3, and 4 will only be flown in the event of failure. Any change from Balloon #1 will be given in good time.

Current lighting: White strobe lights, FAA approval #TS0-C85, flash rate of 1/sec, two lights mounted top and bottom of rear vertical (top and bottom) tail fins.

The downwind displacement of the balloon and tether line should typically be no more than 1000 m. This displacement occurs only when the balloon is at altitude, i.e., top of the profile. Profiles will be done routinely once every 3 hours, i.e., the balloon will be displaced downwind as much as 750 m only once every 3 hr and then for only about 5 min. At all other times the balloon and line will be within the 750 m displacement distance. Moreover, such a displacement only occurs with relatively strong winds, i.e., greater than 15 kts. At lower wind speeds the balloon is flying at a higher angle and the displacement is much less, often no more than 100 to 200 m.

There are no radio transmissions from the tethered balloon-borne package. All tethered balloon measurements are recorded on the balloon-borne data logger. The data are retrieved on the ground by hard connection to a computer (PC).

The tethered balloon system consists of a 2500 cu ft helium-filled balloon, an electric-hydraulic winch, 2000 m tether line, a fairlead/pulley system; a sonde/data logger system and associated computer hardware and software to download the data from the airborne logger and to display and store these data.

The line-mounted tethersonde and data logger are lifted by the balloon to a maximum altitude of 1500 m. Under operating conditions the sonde is raised and lowered at a rate of 1 meter per second to an operating altitude of 1200 m. These up/down soundings, referred to as a profile, take 40 min to execute (20 min up plus 20 min down). The sonde is kept at 10 m for 10 min prior to ascent and following descent. The sonde is kept at altitude (top of the profile) for 1 min prior to descent. The total profile takes 61 min to execute. Preparation of the sonde/data logger and downloading, recording, and quality checking of the data prior to and following the profile takes an additional 45 to 60 min. However, three sonde/logger systems are used so that a sonde/logger can be attached to the line immediately following detachment of a loaded sonde/logger. In principle, soundings can be made every 75 min. In practice, soundings are usually made at a rate corresponding to the rawinsonde releases.

The tethersonde profiles will begin operations with profiles corresponding to the times of release of the rawinsondes. As soon as the tethersonde is operating smoothly the minimum profile rate will increase to 8 per day. During selected periods of not more than 72 hours the profile rate will be increased to 16 per day.

During the 53-day experiment the 6 people on the Meck team will be on a 24-hour shift schedule, rotating two people on 12 hour shifts. This will require a 60-hour, 7-day work week every 2 weeks and a 48-hour work week in the third week.

6.2 Automatic

a. Tower and boom associated with tethered sonde

The 10-m tower on Meck Island with associated ground and below-ground measurements is a fully automated system which is operated by one of the four trained UVA staff. Except for occasional maintenance and calibration operations, no assistance is required in operating the tower system.

A vertical pole anchored in the coral will support an 8-10 m boom which extends over the water. The boom will be instrumented with several radiometers, a pair of upward and downward facing pyranometers (cloud and albedo), an upward facing pyrogeometer (downwelling terrestrial) and a net pyrradiometer (total net radiation). These instruments are fully automated and require no additional personnel to support their operation. They will be installed by the tethersonde personnel.

b. SODAR associated with tethered sonde

The SODAR on Meck Island consists of a vertically pointing set of pseudo-electric transducers operating at 2 Khz up to a maximum vertical range of 800 m. The SODAR is fully automated and requires no additional personnel to support the operation.

c. Profilers

A set of profilers (915 MHz and S-band) provided by the NOAA Aeronomy Laboratory (Ken Gage) will be deployed on Legan Island ~33 km from Kwajalein Island at sufficient distance to be covered by the S-band Kwajalein Island radar. These profilers will be in place and operating in early July 1999. The profilers can provide high vertical resolution radar reflectivity and Doppler velocity data. The data from the two profilers can be combined to estimate characteristics of the drop-size distributions with height.

The profilers and other instruments at the Legan site will run automatically with minimal human intervention. At intervals of ~4 days, a KMR engineer trained by the Aeronomy Laboratory during the installation of the equipment will check on instrument status and exchange recording media. A draft written manual on the profilers, including archival procedures, FAQ, and troubleshooting suggestions needs to be provided for the KMR engineer at the start of the profiler installation so that it can be used as a training tool. A final version of the manual should be sent to KMR by 1 June 1999.

Profiler data will be officially monitored via a satellite uplink by the Aeronomy Lab in Boulder and placed on their web site. The Aeronomy Lab will contact the KMR engineer if there are any problems. Since access to mainland web sites by KWAJEX personnel is only via Internet Service Providers accessible by phone line, the profiler data being collected at Legan will not be officially monitored by KWAJEX on-island personnel.

d. Buoys

Two TAO buoys will be deployed by the Pacific Marine Environmental Laboratory in support of KWAJEX. The proposed locations are 8.4843ºN, 167.3384ºE (west buoy) and 8.4843ºN, 168.1255ºE (east buoy) (Fig. 10). The exact locations will be dependent on the bottom survey by the mooring deployment vessel, the NOAA Ship *Ka'imimoana*. The buoys will be deployed on ~30-31 July at the end of the NOAA Ship *Ka'imimoana's* TAO cruise KA-99-04. The costs of the two days at sea will be covered by NOAA. The buoys will be recovered by the NOAA Ship *Brown* at the start of the moorings cruise on 18 and 19 September. TAO buoy data will be monitored via satellite by PMEL. If there are instrument problems PMEL will contact the Project Science Coordinator on Kwajalein who will determine in consultation with the Ship Science Coordinator and the *Brown's* Operations Officer whether it is feasible for the *Brown* crew to repair the buoy.

e. Rain measurements

TRMM GV tipping bucket rain gauges are present on several islands within the Kwajalein area. See *KWAJEX Science Overview and Objectives* Sec. 3.2 for details.

Disdrometers

Several types of disdrometers will be deployed during KWAJEX. Experience with the video disdrometers during the TRMM Brazil field program has shown that they require daily attention by a skilled operator and are not suitable for deployment on remote islands. A Disdrometer Scientist, with an office in Bldg. 1009, will be designated to mind the video disdrometers on a daily basis. The NASA TRMM Office will work directly with the NWS to deploy the APL distrometers on RMI islands (Woja, Lae, and Namu).

Table 11. Disdrometer information.

Disdrometer Type	Locations	PI
Joss-Waldvogel	Kwajalein Island near DC-8 flight ops office	Yuter
2-D Video	Kwajalein Island near DC-8 flight ops office	Kwajewski
2-D Video	Legan Island near profiler	Tokay
APL	Kwajalein, Meck, Legan, Roi, Woja, Lae, Namu, *Brown*	Tokay

f. Surface mesonet

Aeromet operates a network of surface stations providing data on pressure, air temperature, dew point, wind direction, and speed. Mesonet stations are on Kwajalein, Meck, and Roi-Namur islands. These mesonet data will be logged by Aeromet and provided to the DAAC at the completion of KWAJEX.

Chapter 7: Aircraft Operations

7.1 Overview

Three research aircraft will be available for the KWAJEX IOP (Table 12). Information on the instrumentation on each aircraft during KWAJEX is provided in Appendix 2. All aircraft will be based on Kwajalein Island. The primary scientific function of the Citation and the Convair-580 during KWAJEX is to obtain in situ microphysics data. The primary function of the DC-8 is to simulate TRMM satellite overflights and its secondary objective is to obtain high altitude in situ microphysics data. The Citation and Convair-580 will share space in the fixed-wing aircraft hanger and the DC-8 will be parked near Bldg. 1116 near the west end of the runway (Fig. 3).

Table 12. Project aircraft.

Type	Origin	Research Hours	Mission Duration	Restrictions
DC-8	NASA Dryden	NA	4 hours	No night flights[4]
Citation	U. of North Dakota	100	3.5 hours	No flights below 500 ft at night
Convair-580	U. of Washington	100	6 hours	No flights below 500 ft at night

All participants in KWAJEX must remain aware that:

- KWAJEX research aircraft flight missions and operational requirements require approval of the FAA, which has control of the airspace over the KWAJEX area of flight operations.
- All flights must comply with the current FAA regulations, including the pertinent deviations.
- Crew duty and rest periods will be fully observed.
- Certain KWAJEX flight tracks may be restricted by ATC regulations necessitating revisions in the flight plans after filing.

7.2 Aircraft experiment design

a. Priorities

The KWAJEX flight strategy emphasizes collection of data that will directly support the scientific objectives of KWAJEX, namely, the physical validation of TRMM satellite microwave and PR algorithms, GV algorithms, and cloud models over the tropical open ocean. Since TRMM satellite overpasses coinciding with precipitation are rare (Chapter 3), the DC-8 aircraft will fly radar and microwave instruments similar to those on the TRMM satellite to simulate overpasses. The cloud physics aircraft (Citation and Convair-580), equipped with state-of-the-art particle probes, can best provide in situ microphysics data which are vital for physical validation of the TRMM Microwave, PR, and GV algorithms as well as cloud models. The primary source of environmental data for KWAJEX will be non-aircraft observing systems, specifically the frequent soundings from five sites and tethered sonde continuously sampling the boundary layer (Chapter 6).

The specific types of measurements needed to address KWAJEX scientific objectives are summarized in Table 1 of the *KWAJEX Scientific Overview*. Data need to be collected in both convective and stratiform precipitation regions to address the physical validation issues in both types of precipitation.

10 km minimum horizontal dimension of targeted echoes

Although interesting in their own right, radar echoes less than 10 km in minimum horizontal dimension are less useful for satellite validation since they are within the uncertainty of TRMM satellite navigation. KWAJEX aircraft flight sampling will therefore focus on precipitation regions greater than 10 km in minimum horizontal dimension. A

[4]Complete list of flight restrictions are listed in Appendix 4.

forecast for scattered echoes < 10 km in dimension within 150 km of Kwajalein for the next 24 hours would be a criterion for a "definite no fly" decision for that day at the Daily Planning Meeting.

Aircraft sampling with 150 km radius of Kwajalein Island

In order to obtain simultaneous radar data of the aircraft-sampled region necessary to achieve many physical validation objectives, aircraft sampling must be within the 150 km radius region around the Kwajalein S-band radar. Aircraft operations outside the 150 km radius will not have S-band radar support for mission coordination or later data analysis. Since none of the KWAJEX research aircraft is equipped with scanning weather radars, target selection for track Initial Points would be severely hampered when aircraft are outside the 150-km radius zone.

Emphasis on vertical stacks

In order to achieve KWAJEX scientific objectives, nearly simultaneous data for the same region from sensors on different aircraft need to be obtained. In particular, the in situ microphysical sampling (on Convair and Citation) and upward-looking radiometer data (on Convair) needs to be closely coordinated with the downward-looking radar and radiometers (on DC-8). When practical, multiple aircraft need to fly along tracks closely coordinated in location and timing. The nadir data from AMPR and ARMAR is particularly important in addressing several KWAJEX objectives. Because of the importance of nadir-pointing data from instruments on the DC-8, *within safety constraints, coordination in horizontal location of the flight tracks needs to be within 5 km (2.7 nm). The temporal separation between aircraft passing over the same location needs to be less than 5 min within convective regions and less than 10 min within stratiform regions.* For microphysical sampling, slower speeds are preferable to higher speeds. The Convair will fly at 156 knots indicated air speed (~4.8 km/min) when sampling in vertical stacks. It is proposed that the Citation adjust its speed in order to remain as close as possible immediately above the Convair. This will require frequent communication between pilots. The DC-8 will fly at its minimum speed for its altitude (~410 knots true air speed) and execute legs ~ 2.6 times the length of the legs flown by the other two aircraft. It is understood that aircraft speed will need to be fine tuned by pilots depending on aircraft altitudes, etc. Ideally, the DC-8 legs will be timed to coincide with the Citation/Convair position in the center of the Citation/Convair leg. Because of the importance of data obtained in vertical stacks to KWAJEX scientific objectives, whenever multiple aircraft are aloft and jointly sampling, the preference will be to fly in vertical stacks. Experience gained in TRMM Brazil indicates that ascending legs may be preferred for microphysical data collection compared to descending legs.

Aircraft separation and altitude blocks

In order to achieve KWAJEX objectives that require closely coordinated vertical stacks, the primary means of aircraft coordination will be altitude blocks. The proposed altitude blocks for each aircraft are shown in Fig. 11. Two 2000 ft depth "no fly" zones are proposed between 18,000 –20,000 ft and between 33,000-35,000 ft to maintain aircraft separation when all three aircraft are in the air. Under special circumstances, the Citation and Convair can overlap the altitude blocks of other aircraft. To prevent the presence of multiple aircraft at the same altitude, the following guidelines are proposed:

- Aircraft will observe the “no fly” zones between 18,000-20,000 ft and between 33,000-35,000 ft when all three aircraft are in the air (Fig. 11a).
- When only the Citation and Convair are in the air (Fig. 11b), the “no fly” zone between 18,000-20,000 ft is still in effect. The Citation can ascend to its maximum altitude.
- When only the DC-8 and Convair are in the air (Fig. 11c), a “no fly” zone between 25,000-27,000 ft will be observed. The DC-8 will fly above 27,000 ft and the Convair will fly below 25,000 ft.
- Similarly, when only the DC-8 and Citation are in the air (Fig. 11d), a “no fly” zone between 25,000-27,000 ft will be observed. The DC-8 will fly above 27,000 ft and the Citation will fly below 25,000 ft.

The situations depicted in Fig. 11 are generic. Assigned altitude blocks will vary from mission to mission depending on the size of clouds forecast to be present. Actual aircraft altitude blocks for each aircraft will be assigned prior to the start of *each mission* during the pre-flight meeting in consultation with the Aircraft Mission Coordinator, Aircraft Chief Scientists, and pilots. Altitude blocks will be confirmed among pilots prior to any cloud penetrations.

Within other mission constraints, individual aircraft are encouraged to ascend to their sampling altitude at the start of the mission and descend at the end of the mission by executing a spiral out of cloud for the purposes of obtaining thermodynamic data on the environmental air. Alternatively, individual aircraft may choose to ascend to their sampling altitude at the start of the mission and descend at the end of the mission within precipitation while maintaining adequate horizontal separation.

Emphasis on convective sampling

The operational difficulties in collecting in situ data in convective[5] precipitation have made the uncertainties regarding the microphysics, and particularly the ice microphysics, of the convective regions particularly acute. KWAJEX will therefore emphasize cloud physics data collection in convective regions. The target distribution for KWAJEX cloud physics aircraft data collection hours (excluding time associated with ascent at beginning of mission, descent at end of mission, turns, and holding patterns while aircraft coordinate start time of legs) is as follows:

- 60% in convective precipitation regions
- 40% in stratiform precipitation regions

In order to achieve these sampling objectives, within aircraft safety constraints, convective regions will be aggressively targeted for sampling.

The percentage of DC-8 flight hours over convective precipitation will be less than for the cloud physics aircraft. The mission rules for the DC-8 (Appendix 4) restrict overflights over the deeper, more intense convective regions. Any of the aircraft may break off coordinated tracks with other aircraft at the discretion of the aircraft’s pilot or Aircraft Chief Scientist based on input from their own instruments, advice from other aircraft, the Airborne Mission Coordinator, or the DC-8 ground coordinator.

[5] The “convective” category includes both convective cell and transition zone.

Within each type of precipitation region, the time should be divided roughly equally between precipitating regions whose minimum horizontal dimensions are < 50 km and > 50 km. A detailed breakdown is provided in Table 13 below.

Table 13. Target percentage of aircraft sampling hours by precipitation type, precipitation region size, and altitude for cloud physics aircraft.

Precipitation Type	15 dBZ radar echo min dimension < 50 km	15 dBZ radar echo min dimension > 50 km
Convective	30%	30%
Stratiform	20%	20%

The relative scientific priority of microphysical measurement at various altitudes is shown in Figs. 4 and 5 of the *KWAJEX Scientific Overview*. Based on the aircraft capabilities, cloud-physics data collection with the Citation will focus between 26,000-46,000 ft (6 -14 km) altitude and with the Convair-580 from near the surface to 26,000 ft (8-km) altitude (Fig. 11). Within these altitude regions, priority will be given to measurements obtained closer to the freezing level. For the Citation, legs between -10 to -25°C have priority over data collection at higher altitudes. For the Convair-580, the target flight hour allocation will be evenly distributed between the mixed phase layer, the region from just above the mixed phase layer to -10 °C, and the region just below the mixed phase layer.

Tracking progress toward objectives

It is desirable that there be some objective means of tracking progress in achieving the KWAJEX overall target percentages for sampling in convective and stratiform precipitation regions after each aircraft mission. A working definition of convective and stratiform precipitation regions is needed prior to the project for the purposes of keeping track of the number of flight hours in each type of precipitation sampled by each aircraft. This score keeping will aid in focusing aircraft activities on KWAJEX objectives throughout the project as personnel rotate in and out. The running tally will also provide important feedback to scientists in the field regarding whether and how the aircraft patterns need to be modified to better address the KWAJEX scientific objectives.

Since one of the objectives of KWAJEX is to refine the definition of convective and stratiform precipitation in terms of TRMM algorithms, the working definition will have some unavoidable error. To be practical, the working definition must work uniformly for aircraft at different altitudes, and be simple to use to tabulate score after each aircraft mission. A definition based on flight-track vertical velocities may not be representative in a repeatable manner of the velocity characteristics of a particular region between different altitudes, aircraft, and flight legs. The horizontal radar reflectivity pattern is an indirect indication of vertical velocities and is used to classify convective and stratiform precipitation in TRMM satellite and GV algorithms.

It is proposed that a working definition of convective and stratiform precipitation regions for the purpose of keeping track of flight sampling be as follows: A version of the TRMM GV convective/stratiform algorithm compatible with the data types available in the KWAJEX Ops Center real-time data stream will be implemented and run on a low level of interpolated S-band radar data to produce a convective/stratiform map. Although FAA flight track data will be available in real time to the Ops Center, in order to properly score the aircraft sampling, flight track data from the aircraft data systems are needed. Within 1 hour after each flight, the Aircraft Chief Scientist for each aircraft will supply the Ops Center with an ascii file containing the following flight track information in at least 1 min increments: time, latitude, longitude, altitude, LWC, and temperature. The aircraft track produced from these data will be overlaid on the convective/stratiform map using NCAR Zebra software. Ops Center personnel will examine the flight track versus the location of convective regions in the convective/stratiform map. For each 15 min segment of track:

- If the aircraft passes within 5 km of a convective region it counts as a convective sample.
- If the aircraft is within echo > 15 dBZ but not within 5 km of a convective region it counts as a stratiform sample.

Since the primary difference between the convective/stratiform algorithms at the 1994 TRMM GV Algorithm Intercomparison Workshop was along the edges of the convective regions, use of a 5-km buffer region will reduce error in the scoring. Since changes to the algorithm once the project is in progress will necessitate rescoring of aircraft missions, it is proposed that the convective/stratiform algorithm used in scoring be frozen for the duration of the project after the first few aircraft missions. The testing of the scoring methodology with data from first few missions will permit detection and correction of any gross problems. The scoring is not meant to be precise, nor the convective/stratiform classification perfect. It needs to be sufficiently good to be useful in assessing progress toward KWAJEX objectives but not necessarily good enough for research purposes. It is anticipated that after the GV convective/stratiform algorithm is refined based on data collected in KWAJEX, the aircraft sampling may be retabulated for research purposes in terms of time in convective and stratiform precipitation.

Based on the coarse classification of 15-min flight track segments, the Ops Center will also produce tables of allocation of flight time in 5 deg temperature blocks by precipitation type and in-cloud by precipitation type (in-cloud but outside of 15 dBZ echo will be a separate category: anvil). All the derived information on the aircraft sampling will be part of the mission summary prepared after each aircraft mission and accessible over the KWAJEX network web pages.

The target percentages will likely not be met during an individual aircraft mission. However, it is important for the physical validation work that will follow the project that this distribution is achieved or nearly achieved over the aggregate of missions. The Aircraft Chief Scientists and Operations Director will closely monitor the sampling obtained for each mission and the progress toward the overall sampling goals.

Intercomparisons

During mission ascent and descent of the DC-8, occasional coordinated flight legs out of cloud (Visual Flight Rules conditions) with the Citation and Convair-580 at the same altitude may be made for instrument intercomparison purposes within FAA guidelines for horizontal separation.

7.3 Priorities for flight planning to meet scientific objectives

1) Periods of TRMM satellite overflights coinciding with the occurrence of precipitating regions of > 10 km minimum horizontal extent within 150 km range of the Kwajalein S-band radar have the highest priority.

2) The infrequent occurrence of large areal extent precipitation systems (> 100 km horizontal dimension) suggests they should be given the next highest priority. Back- to-back missions may be flown by the Citation and Convair-580 to obtain as much data as possible in these systems.
3) The infrequent occurrence of precipitating systems between 50-100 km in horizontal dimension suggests that they be given third highest priority.
4) The lack of strong diurnal modulation of precipitation in the Kwajalein area during the months of August and September suggests that missions be flown during daylight hours when the DC-8 is available for operations.
5) While an aircraft mission is in progress, priority will be given to aircraft sampling in precipitation occurring within the Kwajalein S-band and the *Brown* C-band radar dual-Doppler lobes and/or the profiler on Legan.

7.4 Mission coordination

a. Aircraft Coordinator

The aircraft coordinator based on Kwajalein Island will have access to the Kwajalein S-band 3-D radar data and real-time aircraft tracks displayed using NCAR Zebra software on a Sun workstation. The aircraft tracks for all KWAJEX aircraft will be ingested into Zebra in real time and be overlaid on the S-band radar data. The source of the flight-track information is a KMR data stream from the FAA radar on Kwajalein. The aircraft coordinator has the responsibility to direct the aircraft to new precipitating targets when their existing targets move out of range of the S-band radar or decay past their ability to be sampled. If the aircraft are deployed in a manner such that their altitude blocks will overlap, the protocols for aircraft altitude changes will be agreed upon by the individual aircraft flight directors and aircraft coordinator prior to departure.

The aircraft coordinator will not act as an air traffic controller. However, the aircraft coordinator will suggest locations for flight track legs based on the pattern of radar data. By making the altitude blocks clearly defined and keeping the flight tracks simple and repeatable, individual aircraft will know where the other aircraft are at all times. In some instances the start times of legs will be suggested by the aircraft coordinator to facilitate simultaneous sampling.

b. DC-8 Ops Ground Controller

During DC-8 missions, a DC-8 Ops Ground Controller will be present in the Ops Center to act as an intermediary between the Aircraft Mission Coordinator and the DC-8 Ground Coordinator.

c. Communication paths

The air-to-ground communication paths for each aircraft are illustrated in Fig. 12. Table 14 shows the aircraft communication channels for each aircraft and the Operations Center. The designated sci-sci VHF frequency is 132.2 MHz which was agreed to by all three participating aircraft in May 1999. The ATC, and pilot-pilot frequencies will be assigned by the FAA at Kwajalein. The DC-8 ground to DC-8 frequency will be chosen from the following list of frequencies provided by KMR[6]: 132.7, 133.2, 133.7, 134.2, 134.7 MHz. Note that non-FAA ground stations cannot transmit at ATC or pilot-pilot frequencies.

Table 14. Project communication.

	ATC (VHF)	Pilot-Pilot (VHF)	Sci-Sci (VHF)	DC-8 grd-DC-8 (VHF)	UHF backup
Citation	X	X	X		
Convair	X	X	X		
DC-8	X	X	X	X	X
Ops Center			X	X	X

The Aircraft Mission Coordinator and DC-8 ground coordinator will sit side by side in the Operations Center during aircraft missions. Each will have a communications console equipped with headphones, microphone, and speaker.

To facilitate communication of flight track information from the Operations Center to the aircraft, a standard form with blanks for each category of information will be developed. The form will be transmitted to the aircraft in a specified order so that a parallel form can be filled out on the aircraft. Standard aviation units[7] will be used in all ground communication with aircraft (ft, nm, knots). Locations will be specified as latitude/longitude coordinates. To simplify communication, the same units and mode of defining the track will be used for all three aircraft. The exact mode of flight track specification will be refined in the field.

d. Role of radars during aircraft missions

At the 5 April Goddard meeting, a decision was made not use sector scans in support of aircraft missions. A 360° dual Doppler scan strategy for the S-band and C-band radars will be used during aircraft missions (see Section 5.1g).

e. Role of upper-air sounding sites during aircraft missions

Upper-air soundings from Kwajalein, Lae, Roi, and Woja will be obtained at three-hour intervals during aircraft missions starting with the first potential launch time after the aircraft are put on alert and ending with the last potential launch time within 1 hour of the last aircraft returning to base. The potential upper-air sounding launch times are such that the balloon is near the tropopause at 0, 3, 6, 9, 12, 15, 18, and 21 UTC. For example, the 3 UTC sounding is launched at 2 UTC.

7.5 Flight plans

Approximately 20 multiple aircraft missions will be flown during the 25 July -15 September period of KWAJEX.

a. Roles of different aircraft in each planned pattern

The Citation and Convair will have microphysics instrumentation that is more sensitive than the DC-8. Therefore, the cloud microphysics aircraft will have the primary

[6] Additional frequencies may be available from KMR upon request if those listed are unsuitable.

[7] For reference: km * (3.28 x 10^3) = ft, km * 0.53996 = nm, km/hr * 0.53996 = knots.

responsibility for microphysics data collection at altitudes below the operating altitude of the DC-8. To achieve KWAJEX objectives, aircraft will be deployed in a manner that permits coincident or nearly coincident sampling of DC-8 ARMAR radar and AMPR radiometer measurements with in situ microphysical sampling by the cloud physics aircraft at lower levels. (See Sec. 7.2a about vertical stacks, altitude blocks, and priorities for sampling.) Microphysical data collection by the DC-8 at altitudes lower than 10 km will primarily occur during periods of aircraft ascent after takeoff and descent before landing.

b. Mission timetable

The constraints on flight crews for alerting and holding each aircraft are given in Table 14 for each aircraft. The flight crew alert period is the time interval between the Aircraft Chief Scientist informing the crew of a mission and when the aircraft is fueled and ready to take off. The maximum hold period is the time interval between the initially anticipated takeoff time and the time when the aircraft can take off and still fly a 4-hour mission (3.5 hours in the case of the Citation).

Table 15. Aircraft mission timetable constraints.

Aircraft	Flight crew alert period (hours)	Maximum hold period (hours)	Flight crew duty day (hours).
DC-8	3	3	<=12 [8]
Citation	2	9	14
Convair	2	9	14

The constraints on flight crews for alerting and holding each aircraft are given in Table 14. The flight crew alert period is the time interval between the Aircraft Chief Scientist informing the crew of a mission and when the aircraft is fueled and ready to take off. It is likely that not all the aircraft missions will begin precisely as initially scheduled. Some fraction of missions will include takeoff times later than initially planned and some will be scrubbed and flown another day. The information in the mission timetable above will aid in developing guidelines regarding when a decision to fly or scrub must be made. The maximum hold period is the time interval between the initially anticipated takeoff time and the time when the aircraft can take off and still fly a 4-hour mission (3.5 hours in the case of the Citation). For aircraft missions involving the DC-8, hold periods must be in increments of 1 hr or more.

c. Aircraft tracks

Multiple aircraft portion of missions

Forecasting for aircraft missions within the 150 km radius area of Kwajalein will be difficult as precipitating systems often move rapidly through the region. The KWAJEX project area is very small compared to the aircraft operating regions used in previous tropical open ocean aircraft projects such as TOGA COARE and CEPEX. Depending on the state of convective activity at the anticipated take off time, the three aircraft may take off in close succession, take off staggered by tens of minutes, or hold.

[8]DC-8 duty day is <= 12 hours on, followed by 12 hours off. No more than 6 consecutive duty days without 36 hours off. Any time ground and flight crews report is a duty day.

For most missions, the Aircraft Mission Coordinator at the KWAJEX Ops Center will suggest track leg coordinates such as center and length or endpoints and starting leg altitude. The Aircraft Mission Coordinator will communicate directly with the Citation and Convair and indirectly to the DC-8 via the DC-8 Mission Coordinator.

Aircraft data collection to address the scientific objectives of KWAJEX require closely coordinated vertical stacks (Section 7.2a). Following the March KWAJEX meeting and subsequent discussions, the proposed aircraft tracks for KWAJEX have been simplified to the patterns illustrated in Fig. 13. The DC-8 has the option of flying in either a bow-tie or line pattern with 90-270 turns (Fig. 13b and c). The Citation and Convair will fly straight line legs with 90-270 turns. Aircraft will fly legs at a constant altitude and change altitude during turns. The length of the leg will be a function of the size of the precipitation region being sampled and vary between 60–120 km for the Convair and Citation. Since the DC-8 travels more than twice as fast as the other aircraft, their legs will be more than twice as long. The altitude step between legs will be a function of the height of the cloud and will be determined mission to mission.

As discussed in Section 7.2a, the flight legs need to be closely coordinated in space and time. Horizontal separation of flight track legs between aircraft needs to be less than 2.7 nm (5 km). Temporal separation between aircraft passing over the same location needs to be less than 5 min in convective precipitation and less then 10 min in stratiform precipitation. This degree of precision in flight track coordination between three aircraft will be challenging to implement.

Based on Kwajalein radar climatology (Sec 3.3 in *KWAJEX Scientific Overview and Objectives*), the expected patterns of precipitation in the vicinity of Kwajalein are: MCS > 100 km in horizontal dimension with well-defined narrow (10-20 km) convective bands and extensive areas of mature convection, narrow convective bands without associated mature convective regions, scattered echoes including some > 50 km in horizontal dimension, and lines of shallow convection (echo top less than 5 km altitude). The larger precipitation systems occur much less frequently than the smaller ones. The basic flight track pattern illustrated in Fig. 13 will serve as the building block for patterns used in all types of precipitation. Depending on the motion, size, and shape of the precipitating region, the straight line leg flight pattern may be repeated in place, move with the system, and/or be combined into patterns such as a triangle to sample horizontally extensive areas of precipitation.

Single aircraft portion of missions

With its longer duration compared to the other aircraft, the Convair-580 is expected to be the only aircraft participating in KWAJEX that will have significant time as the sole aircraft in the air. Based on KWAJEX physical validation objectives and the capabilities of the aircraft, it is suggested that the Convair execute patterns similar to those proposed for it during multiple aircraft missions and focus on data collection in the melting level region in convective and stratiform precipitation since these data are particularly important for TRMM physical validation.

7.6 Mission Summaries

a. Pre-KWAJEX data requirements

Each aircraft will have provided a sample of the ascii flight track information file that will be given to the KWAJEX Ops Center after each mission to Sandra Yuter by 1 June 1999 so that data ingest software can be written and tested prior to the field phase. The ascii files will be in column format with the following fields: yyyy mm dd, hh mm ss, lat (decimal degrees), longitude (decimal degrees), altitude (m), air temp (°C), and liquid water content (g/kg) with data provided at 1 min intervals. Aircraft may provide additional fields in the ascii file for ingest into Zebra and for inclusion in the Ops Center mission summaries in consultation with Yuter.

b. Post-mission data requirements and timetable

Within 1 hour after landing, each Aircraft Chief Scientist will make available to the Ops Center an ascii file of flight level information as specified above. These data are for the production of mission summaries by the Ops Center and scoring of aircraft sampling. The mission summaries need to be produced ASAP after the mission is completed in order to provide timely information for debriefing and mission assessment. If the Aircraft Chief Scientist is unable to provide the flight level data within 1 hour after landing, they should contact the Ops Center regarding the nature of the problem and a determination will be made by the Ops Center Senior Shift Scientist whether to go ahead with mission summary and scoring based on the FAA real-time flight track or delay completion of the mission summary to await the more accurate and complete information from the aircraft data systems.

Within 24 hours after mission completion, the Aircraft Chief Scientist will provide the Aircraft Mission Coordinator with a written mission description for inclusion on the web page on the mission. Status of each major instrument on the aircraft during the mission will be included in the description. The deadline will be relaxed if several missions are flown in close succession. An example of such a description from TOGA COARE is included in Appendix 5.

The mission summaries prepared by the Ops Center will have several components:

- Window dumps of Zebra showing flight tracks of all aircraft overlaid on radar reflectivity patterns at 30 min intervals similar to the mission summaries produced for TOGA COARE (e.g. Fig. 14).
- Mission scoring information: based on coarse classification of 15 min flight track segments, number of hours in convective and stratiform precipitation, number of hours in each 5° temperature block, and number of hours in cloud by precipitation type.
- Written mission descriptions provided by each Aircraft Chief Scientist to Airborne Mission Coordinator incorporated into an overall mission summary.
- Html aircraft mission summary page with links to the above information.

Chapter 8: Data management

Data management functions are summarized in Fig. 15. Since resources in the field will be limited, functions performed in the field will be focused on maintaining high data quality. Preliminary quality control will include visual checks of soundings, time series data, and radar data. A few dual-Doppler volumes will be processed each day and mission summaries with be prepared after each aircraft mission. Data cataloging and additional copies of data will made as resources permit so that investigators have a subset of raw data to take home with them. The final QC and data cataloging of each sensor's data sets will take place at the instrument PI's home institution. Any needed format conversions prior to archival in the DAAC will also be done after return from the field.

8.1 Quality control and calibration

Data are of little use if the measurements are uncalibrated or subject to large random errors. Regular calibration and quick-look analyses will be implemented during KWAJEX to insure that data quality standards are maintained. Prior to KWAJEX the rain gauges in the vicinity will be checked and calibrated by the TRMM Office. The calibration of aircraft instruments will be the responsibility of the associated aircraft PIs. Upper-air soundings will undergo a standardized procedure of ground checks prior to release. A similar procedure will be documented for the tethered balloons.

The NOAA Ship *Brown* will calibrate its radar on a schedule to be determined by the NASA TRMM Office. The Kwajalein S-band radar will be calibrated on a schedule to be determined by the Aeromet Site Manager. Sphere calibrations are the preferred method since they provide an end-to-end calibration of the radar system. Since the response of radar equipment to changes in calibration settings can be nonlinear, it is suggested that any such settings be held constant during the period of KWAJEX. In this way the calibrations will assess the stability of the radar systems, i.e., if any needed calibration adjustment is steady or varies over time.

As resources permit, data will be provided by instrument PIs to the operations center for quick-look analysis in the context of the other collected data. The NCAR Zebra software running on a workstation at the operations center can be used to overlay fields collected by different instruments and platforms and used to check for consistency between data fields.

8.2 Online data catalog

After the field phase of a project is over, a document summarizing the weather conditions each day and the sampling by project resources is usually produced. This project overview document is an invaluable tool for scientists analyzing the data after the project is over. Since post-project analysis funding has not yet been committed, it is proposed that a draft version of this type of overview document be produced as a web document while in the field. Given the diverse nature of KWAJEX resources it is difficult for someone focused on a particular instrument to keep track of what everyone else is doing. The overview document would thus have a dual role for communication between scientists in the field and as a summary of KWAJEX operations. The responsibility for linking and incorporating the html pages provided by scientists into a user-friendly document accessible on the KWAJEX network resides with the Data Coordinator. The Data Coordinator will also produce daily web pages containing a subset of information in the on-island pages for transmittal to a mainland web site subject to KMR ftp limitations.

a. Satellite and model data

A subset of the GMS IR and model data available on the Mcidas station will be incorporated into daily html pages by the Data Coordinator.

b. Radar data

In addition to aircraft mission summaries incorporating radar data and aircraft tracks, the Ops Center will incorporate window dumps of hourly radar data into html pages for the on-line data catalog. This information will provide a quick overview of radar echo patterns in the vicinity each day of the project. When available and appropriate the Ops Center will include radar data from the *Brown*.

c. Aircraft data

Each Aircraft Chief Scientist will serve as the point of contact for the Data Coordinator for html pages featuring data from aircraft instruments. The information provided will include a summary of operations and instrument status. A written mission summary for each mission will be provided by the Aircraft Mission Coordinator to the Data Coordinator for incorporation into the mission summary html pages.

d. Surface site data

The Surface Site Coordinator will serve as the point of contact for the Data Coordinator for html pages featuring data from upper-air soundings, tethered sonde, profilers,[9] and other surface systems as appropriate. The information provided will include summary of operations, frequency of operations, instrument status, and observer notes.

8.3 Computer network layouts and workstation functions

a. AEROMET-KWAJEX LAN

The network connecting the radar and Mcidas SGI workstations supplied by Aeromet to the satellite data and radar data streams is shown in Fig. 16. The set of Bldg. 1009 computers is represented as a single block in this diagram in the TRMM Offices (1009 dashed box). The Ops Center computers are similarly represented as a single block in the TRMM OPCEN dashed box. The "TRMM ethernet" is the KWAJEX LAN between all the TRMM KWAJEX machines and is the physical network that the Building 1009 offices will have connections into.

[9] Since the profilers on Legan are monitored by the Aeronomy Lab in Boulder, they will inform the Surface Sites Coordinator when they have placed html pages for incorporation into the on-island data catalog at the appropriate mainland web site. These pages will be ftp'ed to Kwajalein subject to KMR ftp limitations.

b. Building 1009

Table 16. Mission briefing room equipment.

primary program	Type	source
Sigmet analysis	SGI O2/Indigo2 workstation	Aeromet
Mcidas	SGI O2 workstation	Aeromet
Radar display	video monitor	Aeromet

c. Ops Center

Table 17. Workstations.

primary program	computer type	source
Sigmet analysis and radar control	SGI O2 workstation	Aeromet
Mcidas	SGI O2 workstation	Aeromet
Mission summary and online data catalog authoring	PC (2)	UW
Zebra radar and a/c track ingest	Sun workstation	UW
Zebra display for a/c coordinator	Sun workstation	CU-UW[10]
Zebra display for DC-8 coordinator	Sun workstation	CU-UW
Ops center software support and administration	Sun workstation	UW

Table 18. Peripherals.

type	source
DLT tape on Suns (3)	UW
DAT drive on Sun (UW)	UW
9 or 18 GB disk drives on Suns (3)	UW
DAT tape on SGI (1)	Aeromet
Exabyte tape on SGI	Aeromet
Laser printer	Aeromet
LAN hubs/switches (several)	Aeromet/UW

d. NOAA Ship Ronald H. Brown

The NASA TRMM Office under the direction of Otto Thiele is responsible for all scientific logistics on board the *Brown*. This includes coordinating with all shipboard instrument scientists, and ensuring that all scientific data are of high quality and are archived. See the Cruise Instruction document accessible at trmm.gsfc.nasa.gov/trmm_office/field_campaigns/kwajex/kwajex.html for details.

e. Mainland FTP from Aeromet offices

The Project Science Coordinator will supervise non-email ftp transfer back and forth to mainland computers using KMR Mission Support Network on a TBD schedule.

[10]R. Houze of the University of Washington has arranged with P. Webster of University of Colorado to borrow two CU computers for use during KWAJEX.

Appendix 1

NOAA Ship *Brown* instrumentation for KWAJEX.

System	Measurement	PI
Viäsälä GPS upper-air soundings	tropospheric wind, temperature, and RH	Ship system/Halverson
Scanning C-band Doppler radar	3-D structure of precipitation and velocity	Ship system/TRMM Office, Biggerstaff
IMET	Surface meteorology (wind direction, wind speed,T, RH, pressure, SW flux, rainrate)	Ship system/TRMM Office
SCS	Navigation/siphon and optical rain gauges	Ship system/TRMM Office
Thermosalinograph	Near sea surface temp and salinity	Ship system/TRMM Office
S-band profiler	Precipitation profiles	Gage
Ku-band microwave	Scattering off ocean surface at TRMM PR angle and frequency w/ and w/o rainfall	Plant
Water vapor H and O isotopes	Distinguish evap from rain versus evap from sea water	Lawrence
scanning microwave polarimeters (10, 15 and 37 GHz)	Polarized emission from rain and ocean surface	Post/Westwater
air-sea flux system	Motion-corrected turbulent fluxes	Post/Fairall
ceilometer	Cloud base height	Post/Fairall
915 MHz wind profiler	Lower tropopheric winds	Post/Fairall
5 mm scanning radiometer	Sea-air temp difference and SST	Post/Fairall
water vapor/liquid radiometers (23.87, 31.65 GHz)	Column water vapor and liquid	Post/Fairall
APL distrometer	Drop size distribution	Tokay
disdrometers	Drop size distribution	Nystuen

Appendix 2

Principal NASA DC-8 instrumentation for KWAJEX.

System	Measurement	PI
ARMAR	Downward-looking Ku-band radar reflectivity profile	Durden (JPL)
AMPR	10.7, 19.35, 37.1, 85.5 GHz downward-looking microwave radiometer	Hood (MSFC)
Cloud Physics 2-D Probes	Cloud and precipitation particles	Kingsmill (DRI)
SPEC Cloud Particle Imager	Cloud and precipitation particle images	Lassen (Lassen Inc.)
HIS	Atmospheric temperature and water vapor profiles	Revercomb (U Wisconsin)

Principal Citation Instrumentation for KWAJEX.

System	Measurement	PI
SPEC Cloud Particle Imager	Cloud and precipitation particle images	Stith (UND)
SPEC Hi-Vol Precip Sampler	Cloud and precipitation statistics	Stith (UND)
Cloud Physics 2-D Probes	Cloud and precipitation particles	Stith (UND)
General Meteorology	Temp, dew pt, specific humidity,winds	Stith (UND)

Principal Convair-580 Instrumentation for KWAJEX.

System	Measurement	PI
SPEC Cloud Particle Imager	Cloud and precipitation particle images	Hobbs (UW)
SPEC Hi-Vol Precip Sampler	Cloud and precipitation statistics	Hobbs (UW)
Cloud Physics 2D Probes	Cloud and precipitation particles	Hobbs (UW)
AMMR	Upward looking microwave radiometer	Wang (GSFC)
General Meteorology	Temp, dew pt, specific humidity, winds	Hobbs (UW)

Appendix 3

Kwajalein Island

System	Measurement	PI
S-band Doppler, dual polarization radar	Z, Vr, ZDR, PHIDP[11]	Yuter and Chandra
MSS upper-air soundings	profile of wind, temp, and RH from surface to tropopause	Halverson/Ferrier
Aeromet mesonet	Pressure, temp, dewpt, wind speed and direction	Aeromet
Joss-Waldvogel disdrometer	drop size distribution	Yuter
APL distrometer	drop size distribution	Tokay
2-D video disdrometer	drop size distribution	Kwajewski
Tipping bucket rain gauge	rain rate	Aeromet

Meck Island

System	Measurement	PI
MSS upper-air soundings	Profile of wind, temp, and RH from surface to tropopause	Halverson/Ferrier
Tethered sonde	Profile of wind, temp, and RH from surface to 1.5 km	Garstang
10 m tower	Boundary-layer energy fluxes and microclimate measurements	Garstang
SODAR	Horizontal wind speed and direction, turbulence intensities, thermal structure and mixing depth heights	Garstang
Pyranometers, pyrgeometer, and pyrradiometer	LW radiation and albedo	E. Smith
Aeromet mesonet	Pressure, temp, dewpt, wind speed and direction	Aeromet
APL distrometer	Drop size distribution	Tokay
Tipping bucket rain gauge	rain rate	Aeromet

[11]Data are archived as PHIDP. KDP field can be derived from PHIDP.

Legan Island

System	Measurement	PI
915 GHz profiler	Vertically pointing Z and Vr, and horizontal winds	Gage
S-band profiler	Vertically pointing Z and Vr	Gage
2-D video distrometer	drop size distribution	Tokay
APL distrometer	drop size distribution	Tokay
Joss-Waldvogel disdrometer	drop size distribution	Gage
Tipping bucket rain gauge	rain rate	Aeromet

Roi-Namur Island

System	Measurement	PI
MSS upper-air soundings	profile of wind, temp, and RH from surface to tropopause	Halverson/Ferrier
Aeromet mesonet	temp, dewpt, pressure, wind speeds and direction	Aeromet
APL distrometer	drop size distribution	Tokay
Tipping bucket rain gauge	rain rate	Aeromet

Lae Island

System	Measurement	PI
VIZ GPS upper-air soundings	profile of wind, temp, and RH from surface to tropopause	Halverson/Ferrier
APL distrometer	drop size distribution	Tokay
Tipping bucket rain gauge	rain rate	NWS

Woja Island

System	Measurement	PI
VIZ GPS upper-air soundings	profile of wind, temp, and RH from surface to tropopause	Halverson/Ferrier
APL distrometer	drop size distribution	Tokay
Tipping bucket rain gauge	rain rate	NWS

Namu Island

System	Measurement	PI
APL distrometer	drop size distribution	Tokay
Tipping bucket rain gauge	rain rate	NWS

Appendix 4

NASA DC-8 Mission rules for KWAJEX:

Mission rules for the NASA DC-8 based on information provided at the teleconferenced briefing with Dryden Flight Research Center on 16 Dec 1998.

• Day operations only
• Maximum 4 hour flight
• Ceiling and visibility not less than
    - 600 ft. ceiling
    - 2 mile visibility
• DC-8 Airborne Radar and Visual Observation
    - Avoid areas of building convection
    - Maintain visual meteorological conditions
- DC-8 will depart area if heavy rain or moderate turbulence encountered
• S-band Radar on Kwajalein

- DC-8 communications with S-band radar through DC-8 Ops Ground Controller
- DC-8 will be directed away from any storm with hail detected at any altitude
    - DC-8 will not be directed through areas of:
        • Building cells
        • Reflectivity > 25 dBZ
        • Saddle areas (no rapid escape route)
        • Severe weather shapes

Appendix 5

Example of written mission summary for multiple aircraft mission during TOGA COARE.

PRIMARY OBJECTIVE: Three aircraft mission (42RF, 308D, DC-8) to document Class 2 convection, preferably to include convective cell penetrations in range of ship-borne radars.

ALTERNATE: Class 0/1 BL.

ACTUAL: String of CLASS 1 convection sampled over southern IFA. Initial attempts to set up patterns in immediate vicinity of PRC #*5* at request of NASA were frustrated by isolated and rapidly dissipating nature of convection. Subsequent work concentrated on two E-W oriented bands of convection near 4°S. Coordination was good, though some confusion occurred early between 42RF and 308D in setting up quad-Doppler tracks. Although two-transmitter ELDORA operation was planned, second HPA failed during ground test. Many dual-/quad-Doppler legs were executed by 308D and 42RF, but these were compromised by poor radial velocity data from tail Doppler on 42RF. 308D completed multiple cell penetrations, which included several updrafts and a "warm" downdraft. Second (southern) band exhibited peculiar character of moving southward yet appearing to be supported by inflow on its north side. NASA DC-8 ran a combination of E-W and N-S racetracks bracketing both convective lines, completing a total of six drops. 308D and 42RF executed ascent soundings upon departure from area.

Aircraft	PIs	Takeoff	Landing	Duration
42RF	DPJ, CF, GB, BFS	1809 17 Feb	0307 18 Feb	9.2 h
308D	PL, BG	1901 17 Feb	0117 18 Feb	6.4 h
DC-8	EZ	1848 17 Feb	0214 18 Feb	7.3 h

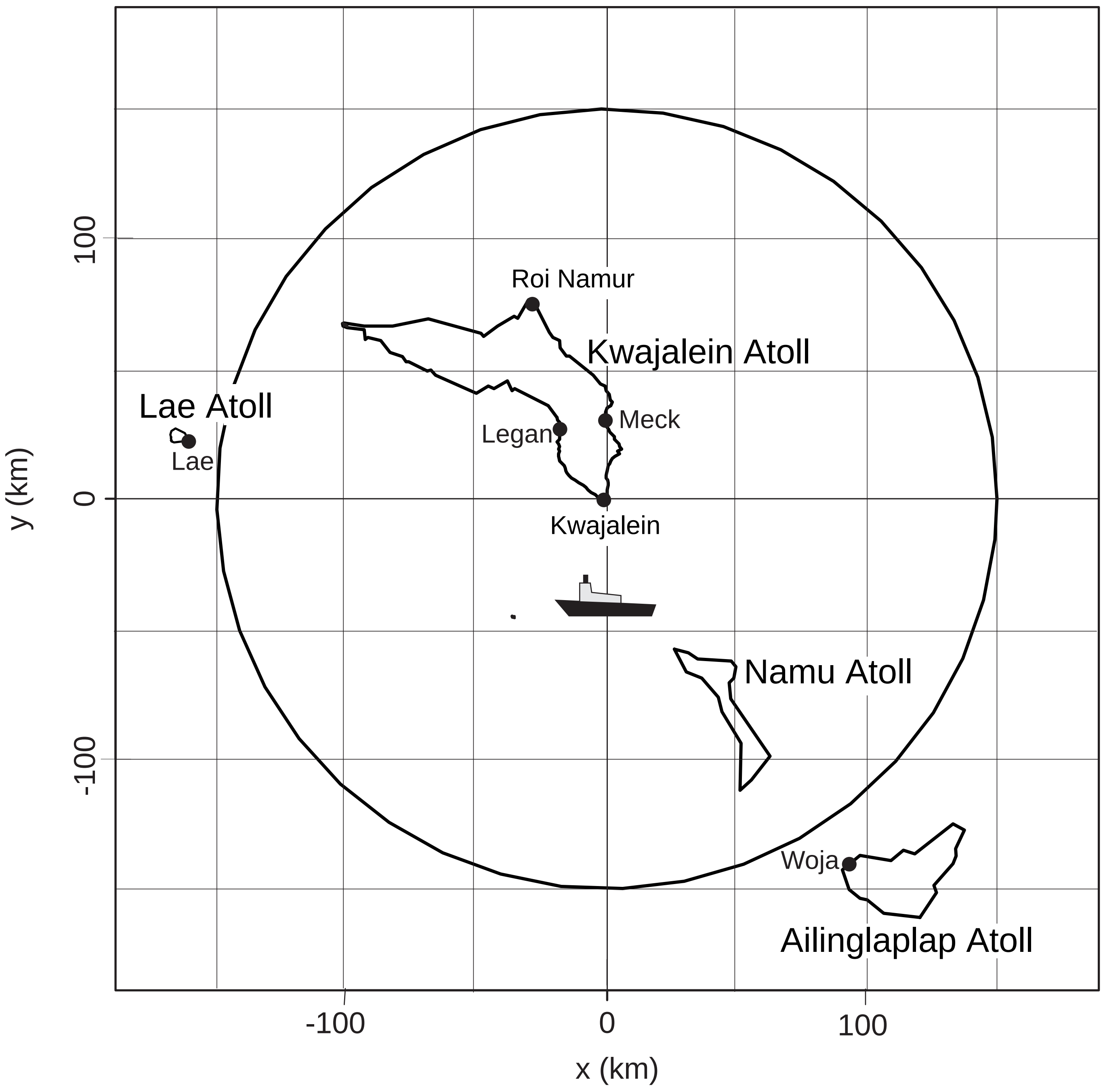

Figure 1. Location of islands with KWAJEX sensors.

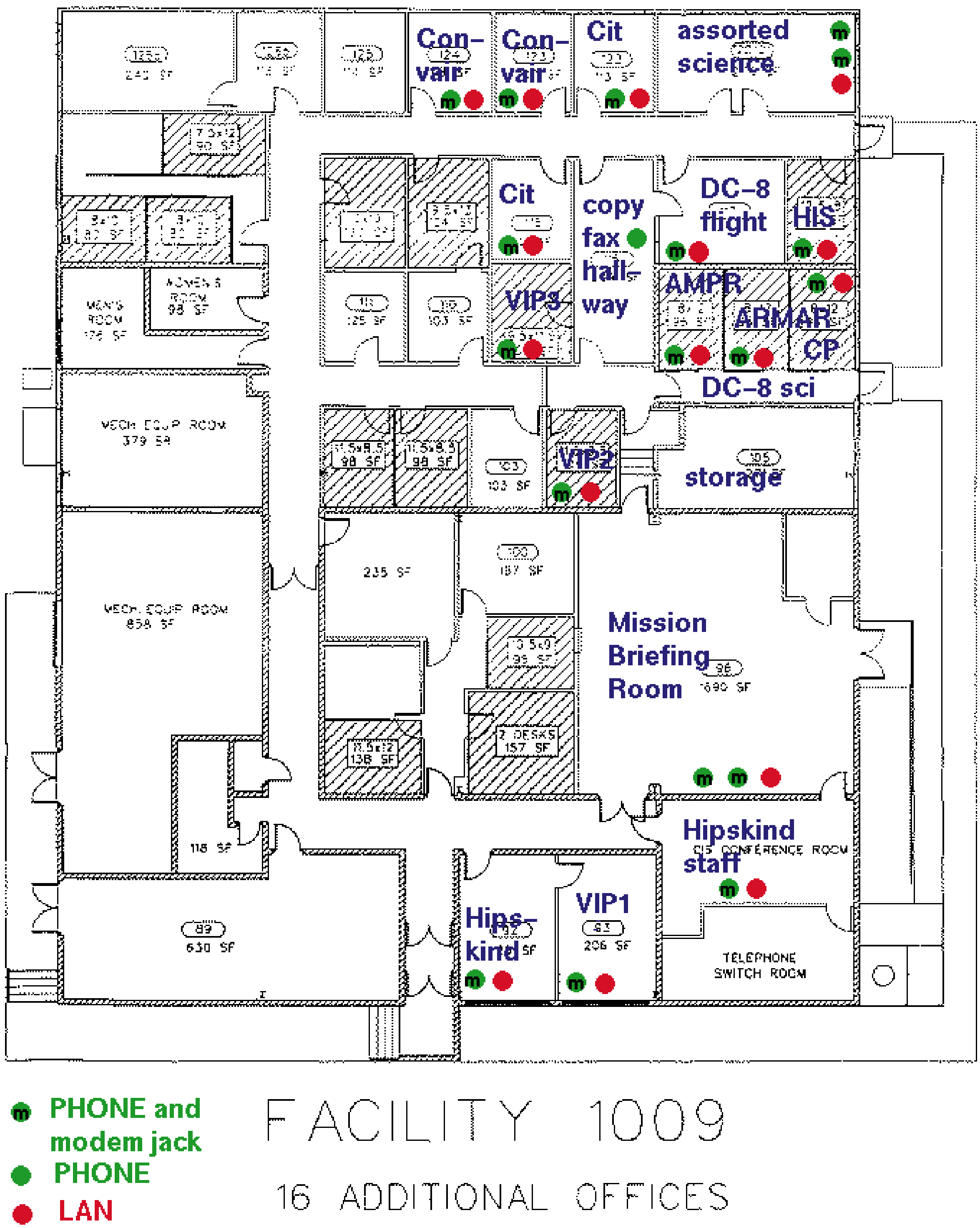

Figure 2. Layout of KWAJEX office space in Building 1009. Proposed office assignments and locations of phone, modem and LAN connections shown.

Figure 3. Aerial photo of Kwajalein Island, US Army Kwajalein Atoll/Kwajalein Missile Range. The locations of several primary KWAJEX resources are indicated. The meeting room and primary office space are located in Building 1009. The fixed wing hangar for the Citation and Convair-580 is indicated as hangar. The NOAA Ship *Brown* will dock at the pier indicated.

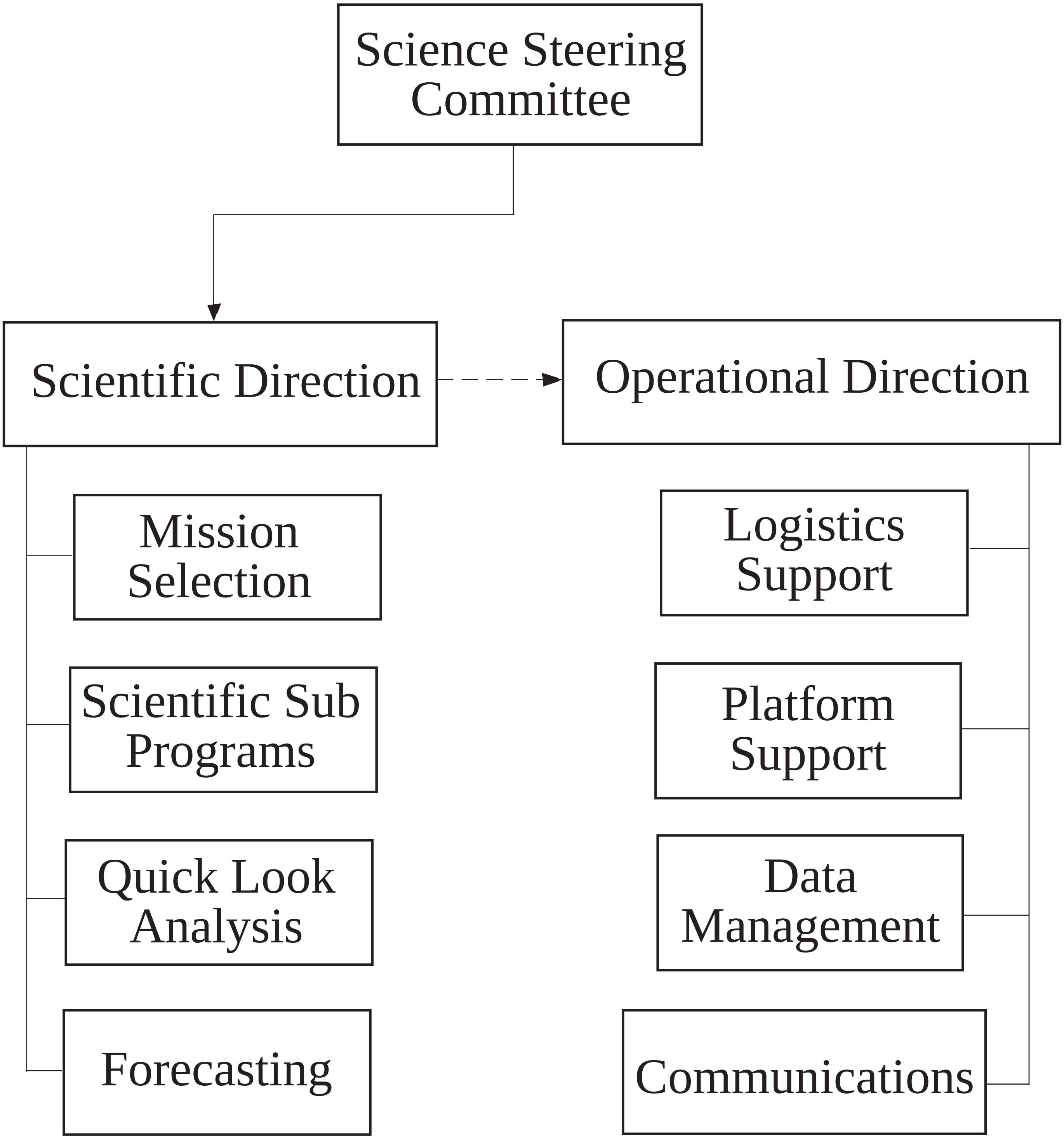

Figure 4. Block diagram of KWAJEX project management functions.

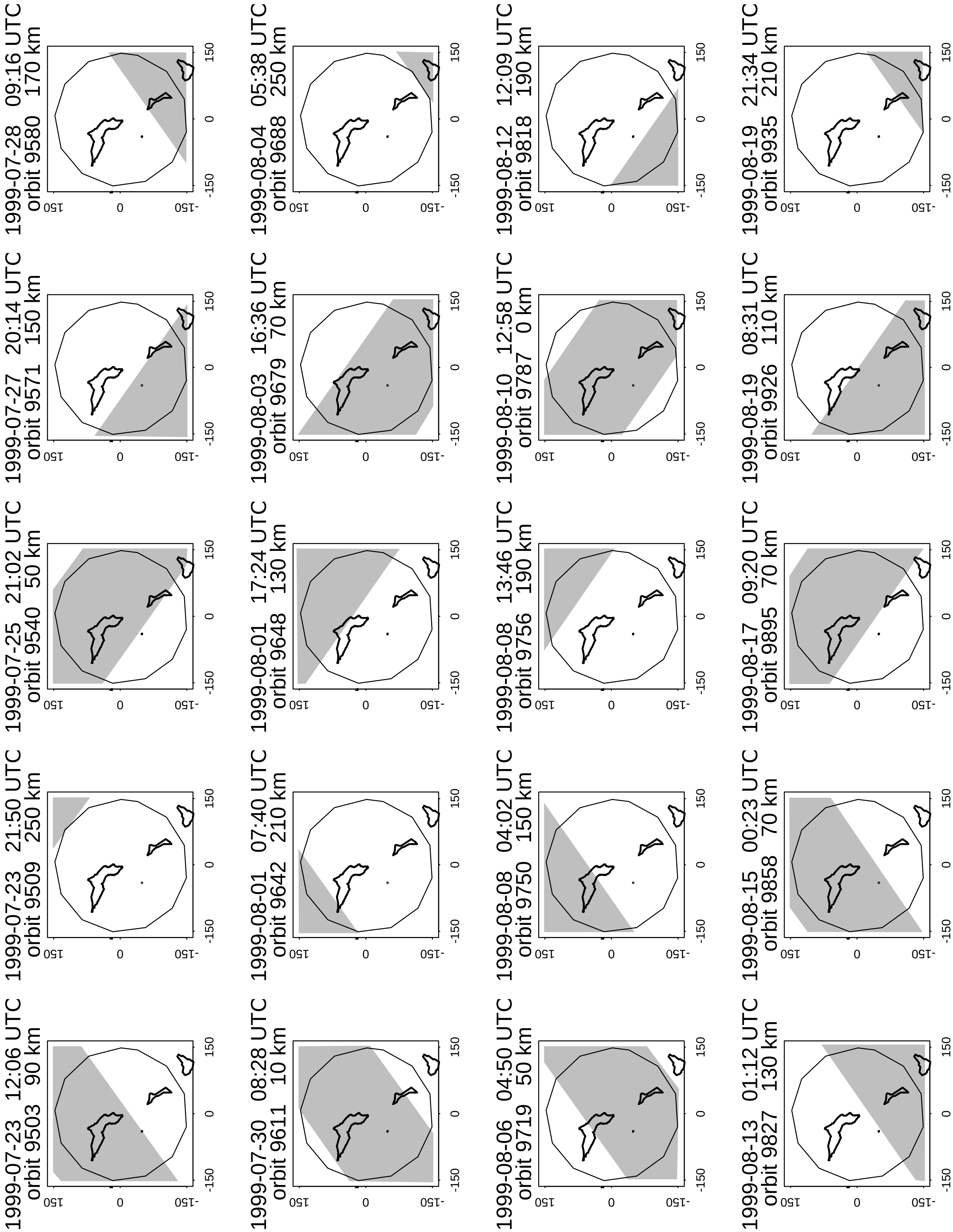

Figure 5. TRMM satellite overpasses over Kwajalein 23 July - 17 September 1999. Swath for TRMM satellite PR instrument is shaded. The 150 km radius TRMM GV area is indicated by the polygon.

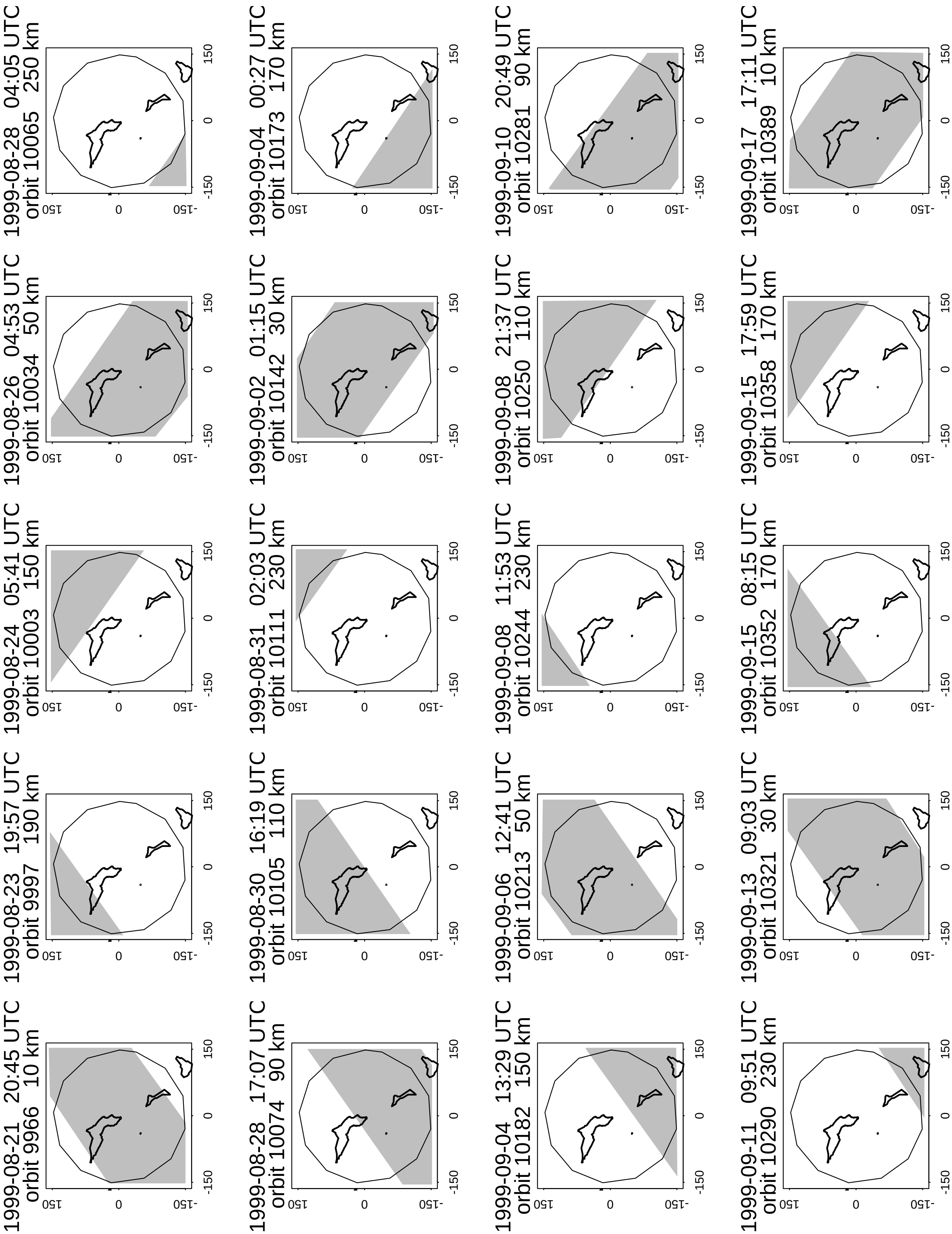

Figure 5. (continued)

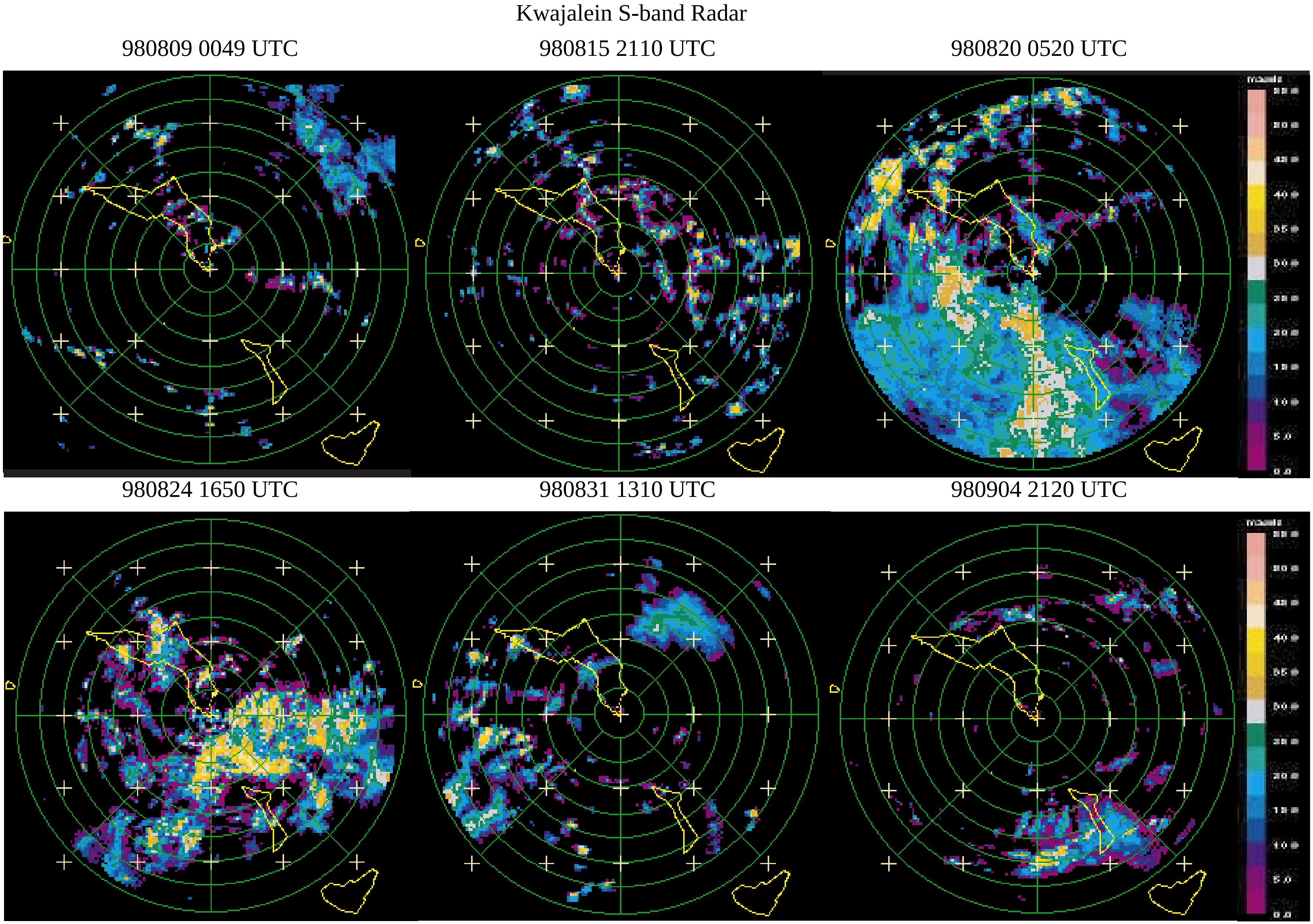

Figure 6. In terms of radar echo coverage, the six best TRMM overpasses over Kwajalein 25 July - 15 September 1998 were (a) 980809 0049 UTC, (b) 980815 2110 UTC, (c) 980820 0520 UTC, (d) 980824 1650 UTC, (e) 980831 1310 UTC, and (f) 980904 2120 UTC.

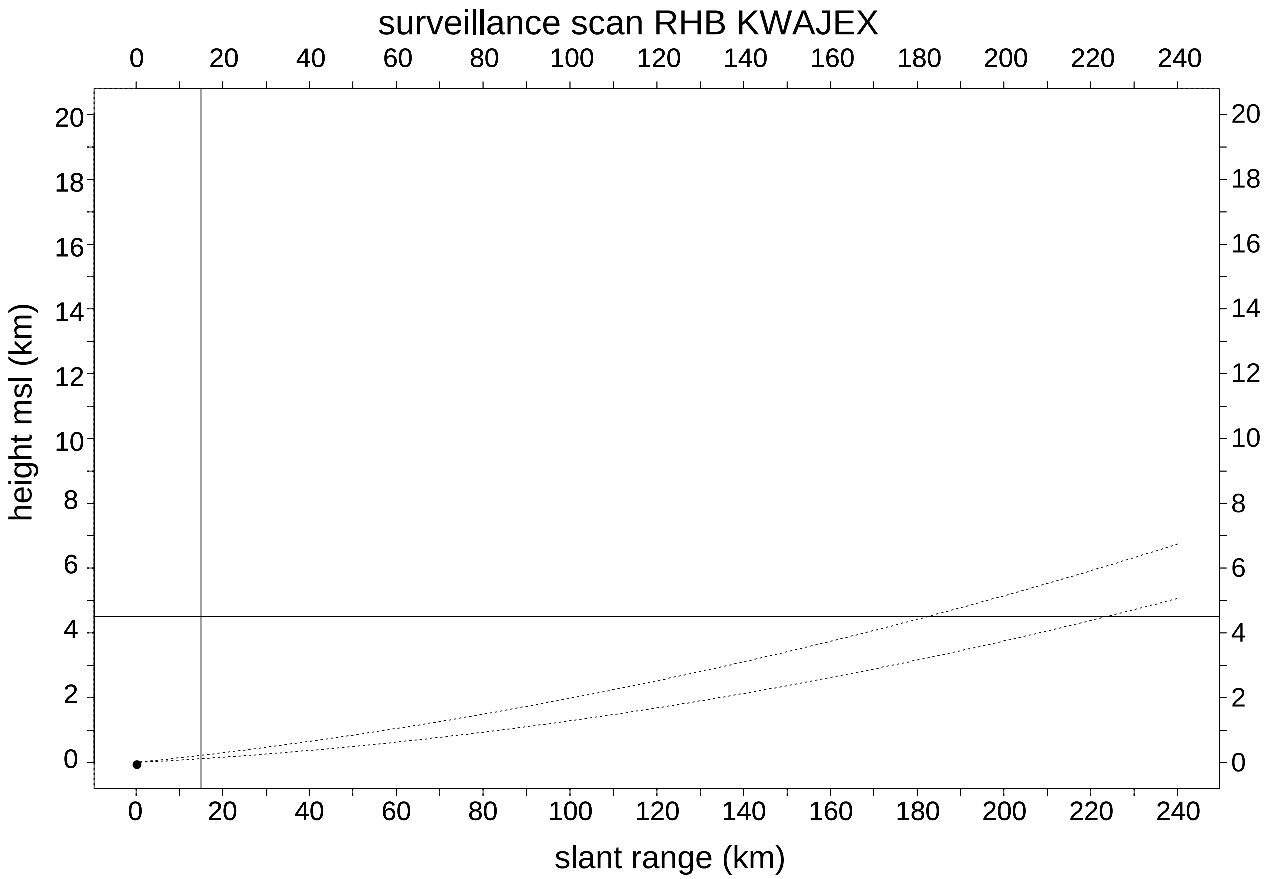

Figure 7. Range-height plot of two tilt surveillance scan proposed for C-band radar on NOAA Ship *Brown*.

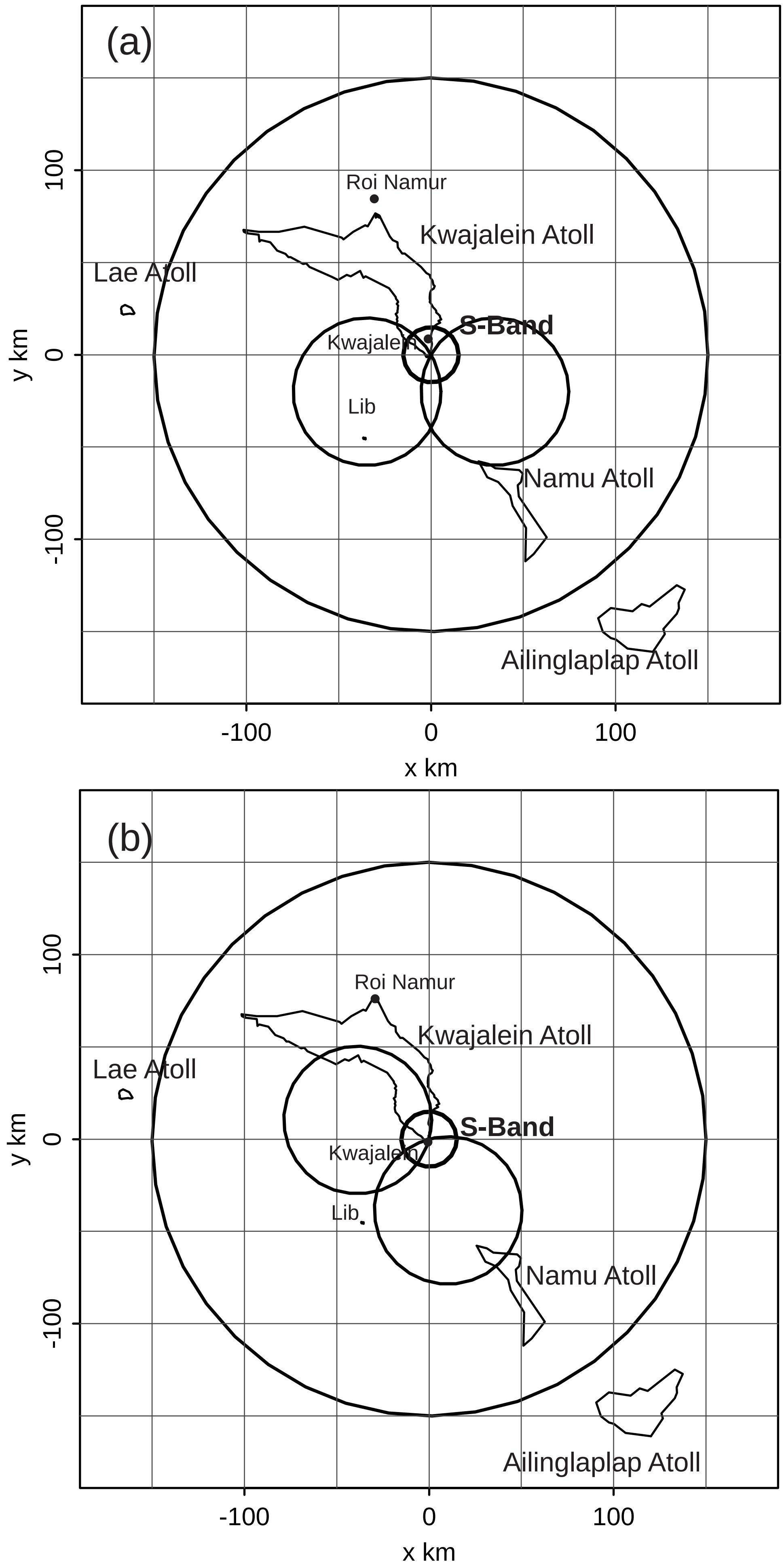

Figure 8. Map showing dual-Doppler lobes when the NOAA Ship *Brown* is (a) 40 km south and (b) 40 km southwest of the Kwajalein S-band radar. The outer circle is the 150-km range ring around the Kwajalein radar. Inside the inner 15-km radius circle, data from the Kwajalein S-band radar are not useable for research purposes.

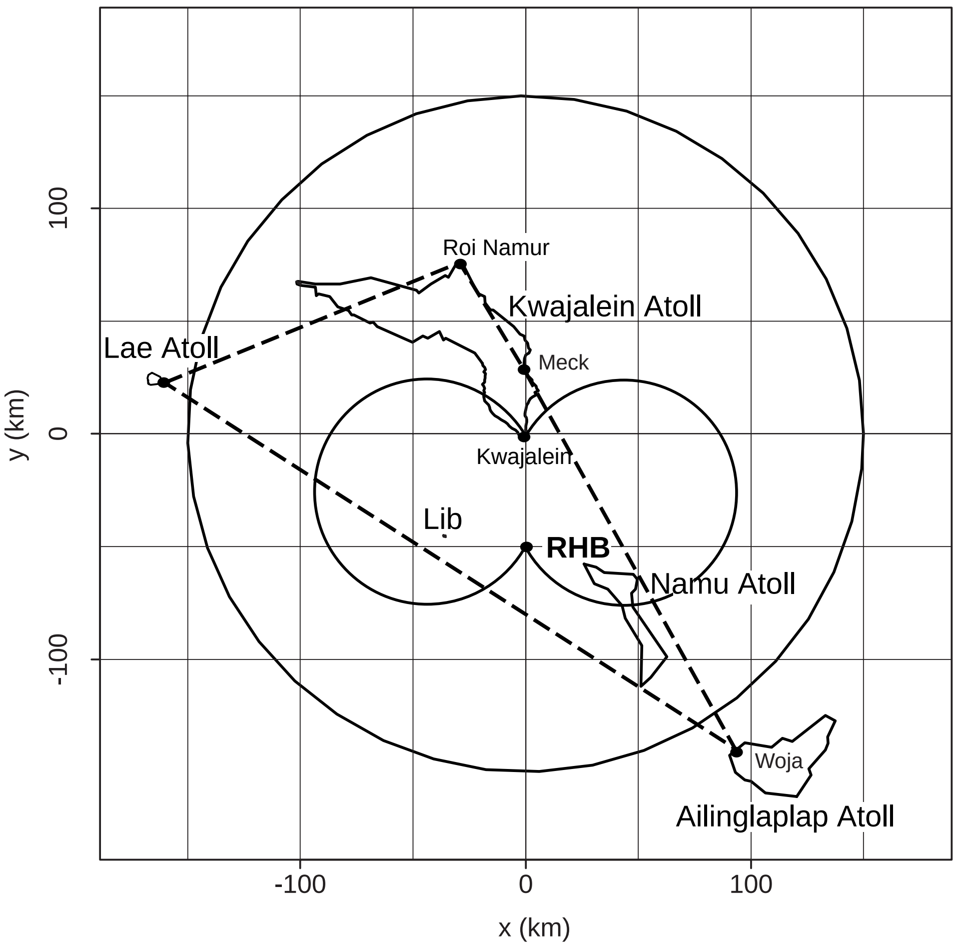

Figure 9. KWAJEX upper-air sonde array. Locations of upper-air soundings launch sites (dots) and the outer boundary of array (dashed line) are indicated.

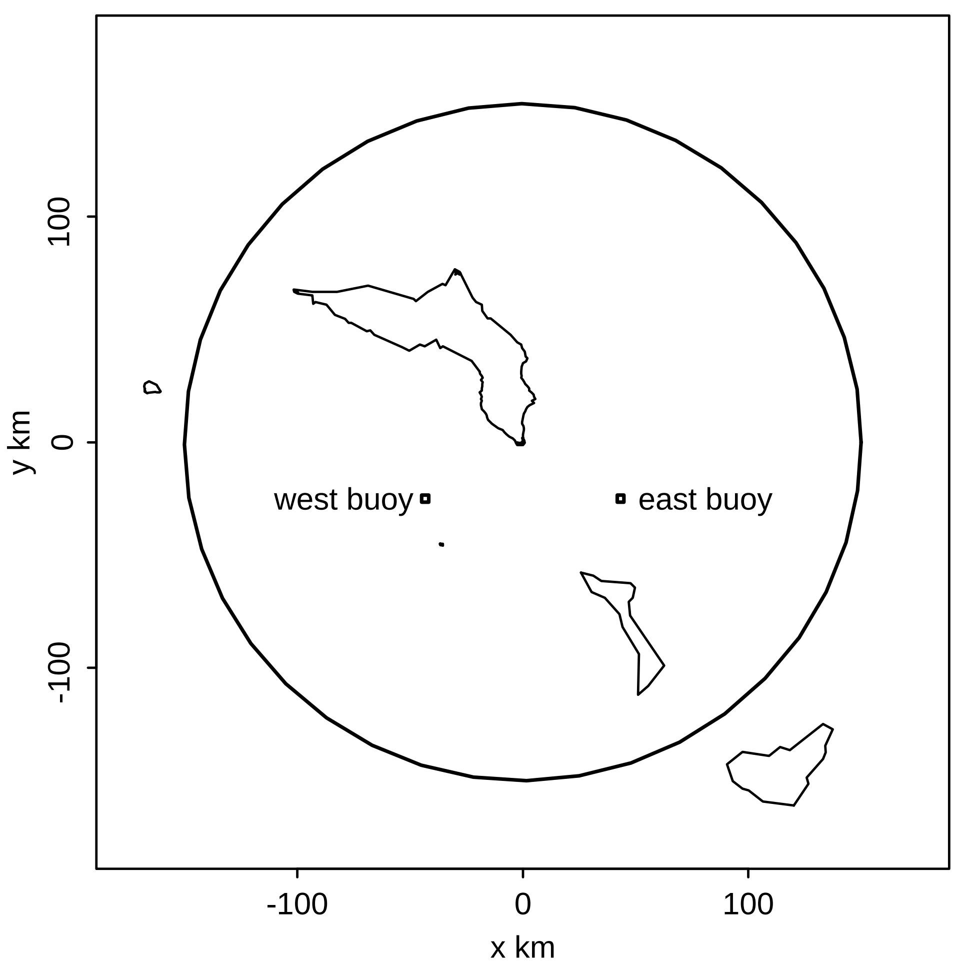

Figure 10. Map showing location of TAO buoys during KWAJEX.

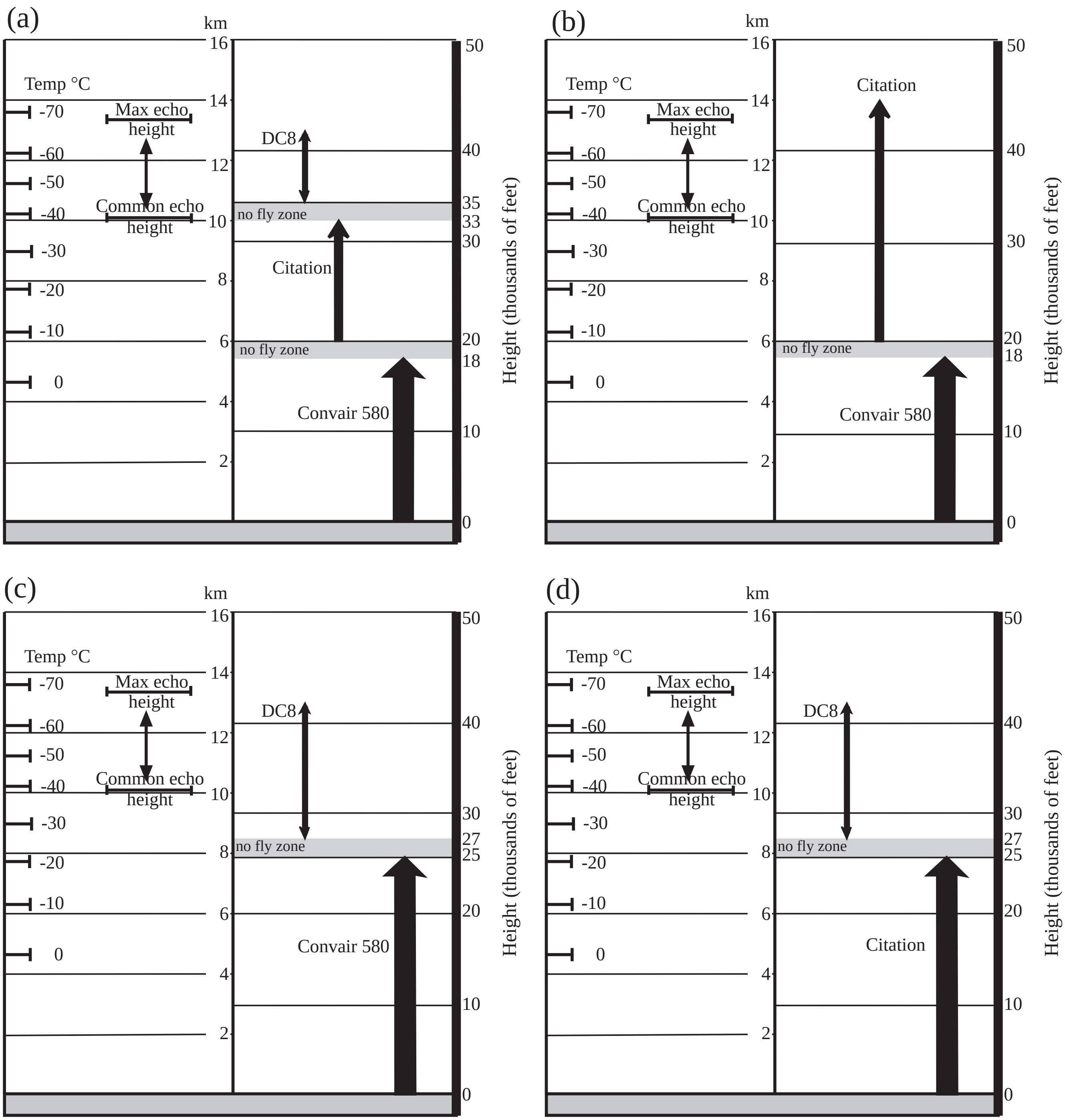

Figure 11. Proposed aircraft altitude blocks for the NASA DC-8, UND Citation, and UW Convair-580. Shaded altitudes indicate "no fly" zones effective during periods when multiple aircraft are in the air. (a) Altitude blocks when all three aircraft are in the air. (b) Altitude blocks when only Citation and Convair are in the air. (c) Altitude blocks when only DC-8 and Convair are in the air. (d) Altitude blocks when only the DC-8 and Citation are in the air. The situations depicted are generic. Altitude blocks for the aircraft will vary depending on the size of the clouds present. Actual altitude blocks for each aircraft will vary from mission to mission. Altitude blocks will be confirmed by pilots prior to cloud penetrations. All panels in vertical view.

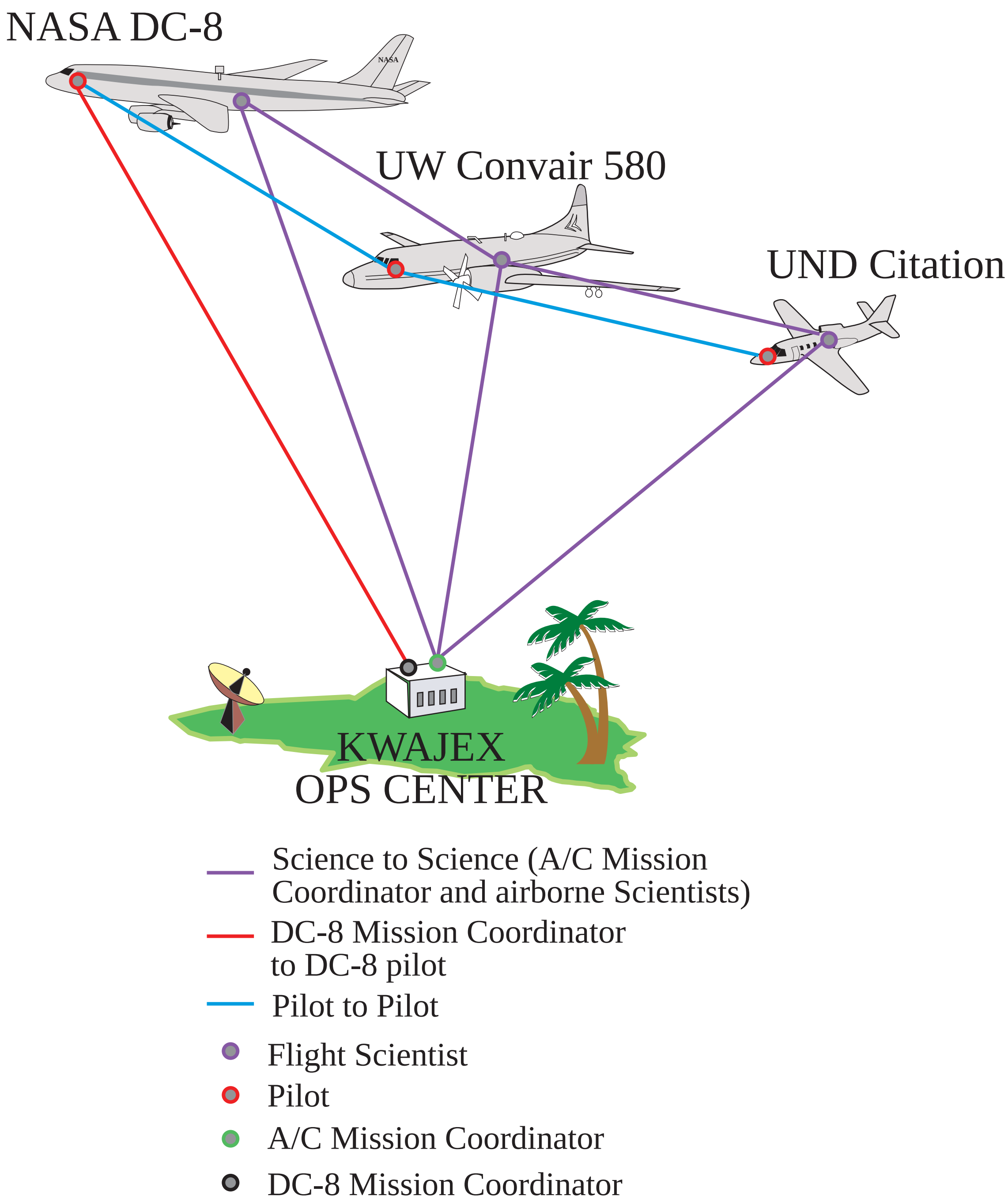

Figure 12. Air-to-ground communication pathways among KWAJEX Ops Center and each aircraft. The NASA DC-8 has two points of contact: DC-8 flight indicated toward the front of the aircraft and DC-8 Science indicated toward the middle of the aircraft.

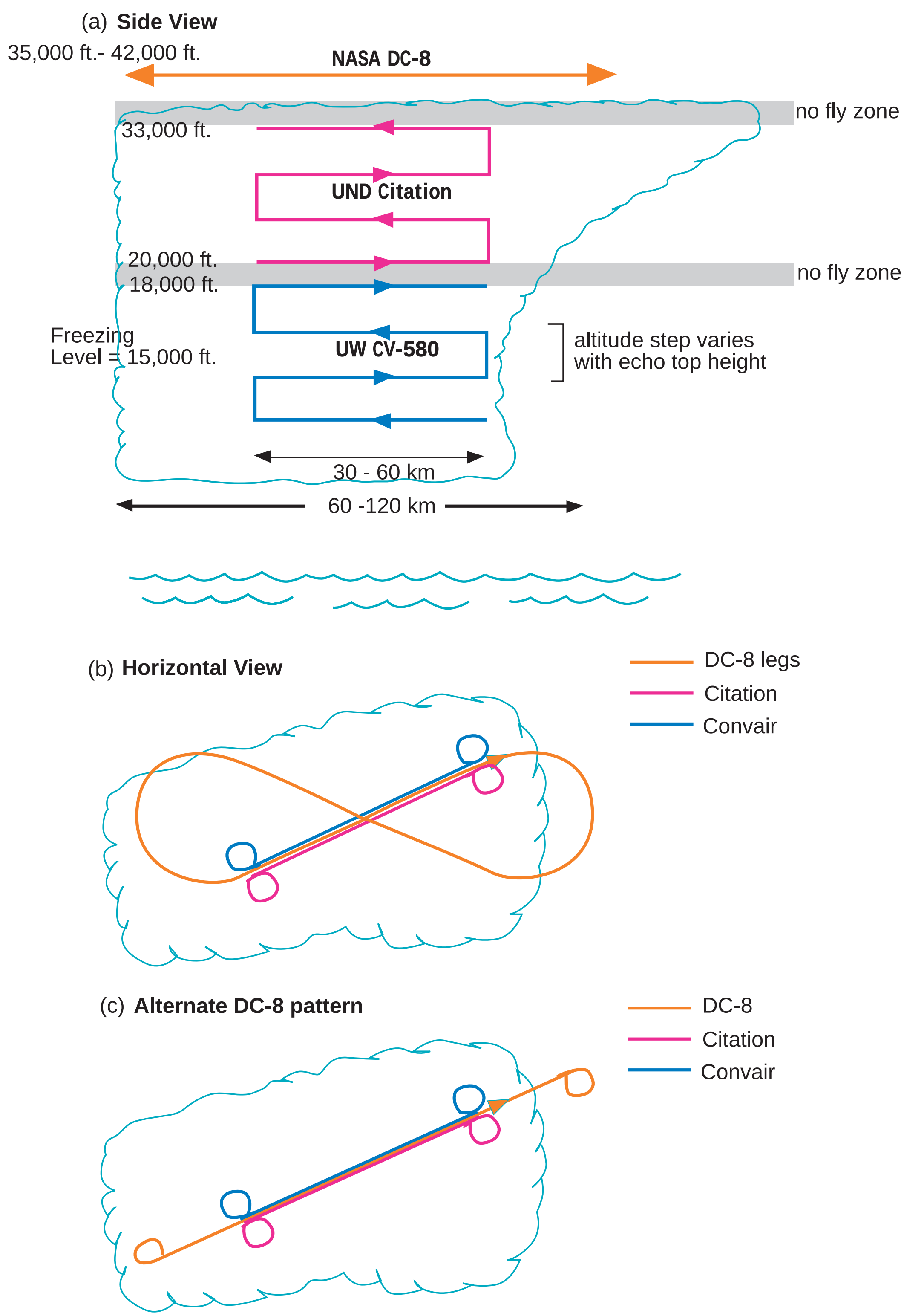

Figure 13. Schematic of proposed multiple aircraft mission flight tracks. (a) Vertical view of flight track pattern showing DC-8 (orange), Citation (pink), and Convair-580 (blue) flight track legs. The altitude steps shown are for illustration. In practice, the altitude steps would depend on the depth of the cloud with shorter steps for shallower clouds. Similarly, the flight track leg length would vary depending on the horizontal dimension of the precipitating region. Gray shaded regions indicate "no fly" zones (see Fig. 11). (b) Horizontal view of flight track pattern with DC-8 flying a 'bow-tie" pattern and Citation and Convair flying straight line tracks. Citation and Convair would employ 90-270 turns at the end of each leg. (c) Horizontal view of flight track pattern with DC-8 flying straight line tracks with 90-270 turns. Citation and Convair flight tracks are the same as shown in (b).

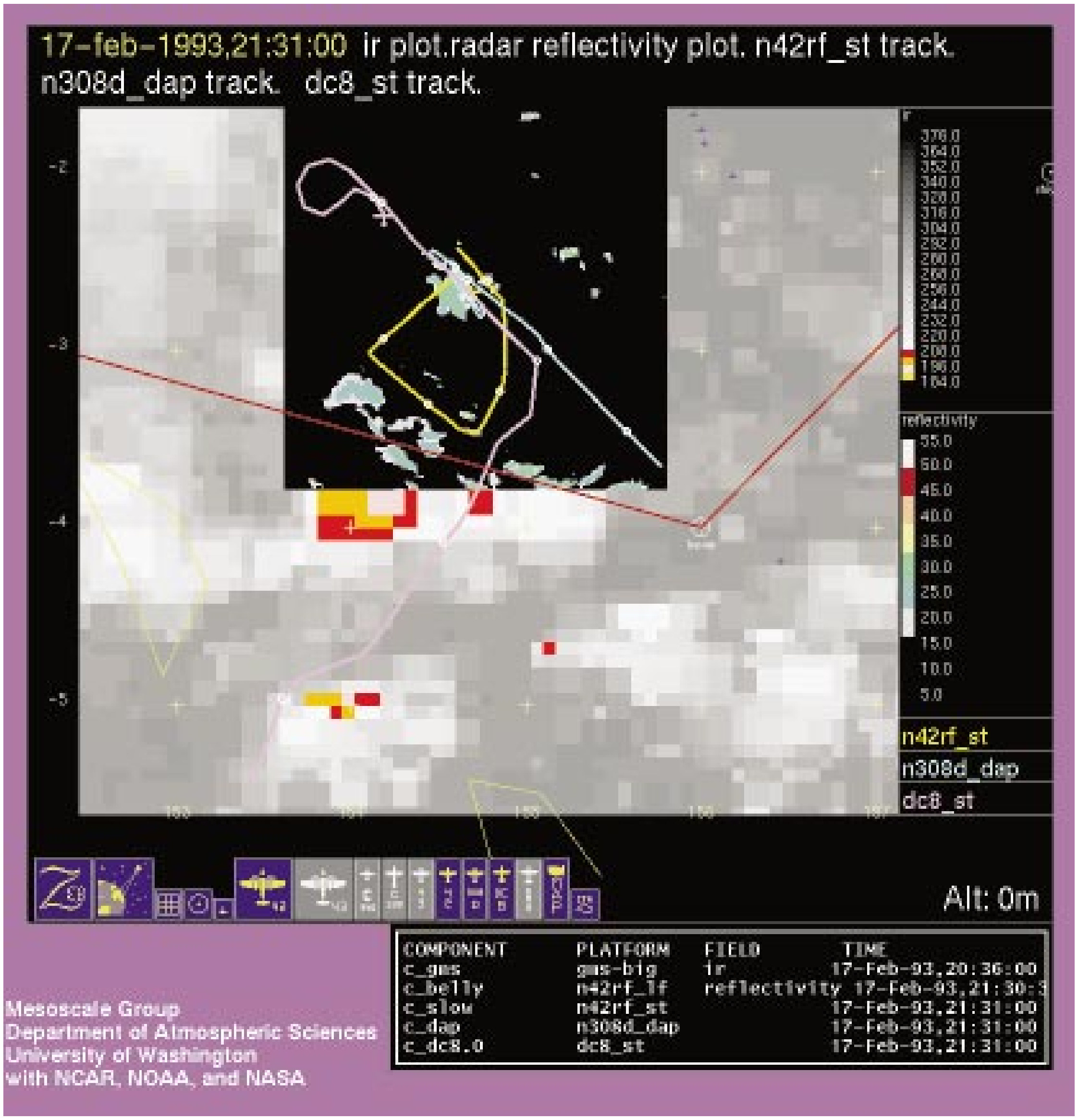

Figure 14. Example of frame from aircraft mission summary loop for multiple-aircraft mission on 930217 during TOGA COARE. Aircraft tracks are overlaid on satellite data and radar data from the NOAA WP-3D aircraft. Aircraft tracks shown are 45 min long and are color-coded by aircraft. Small circles are at 10 min intervals along the track. It is proposed that aircraft mission summaries of a similar nature be generated in the field during KWAJEX.

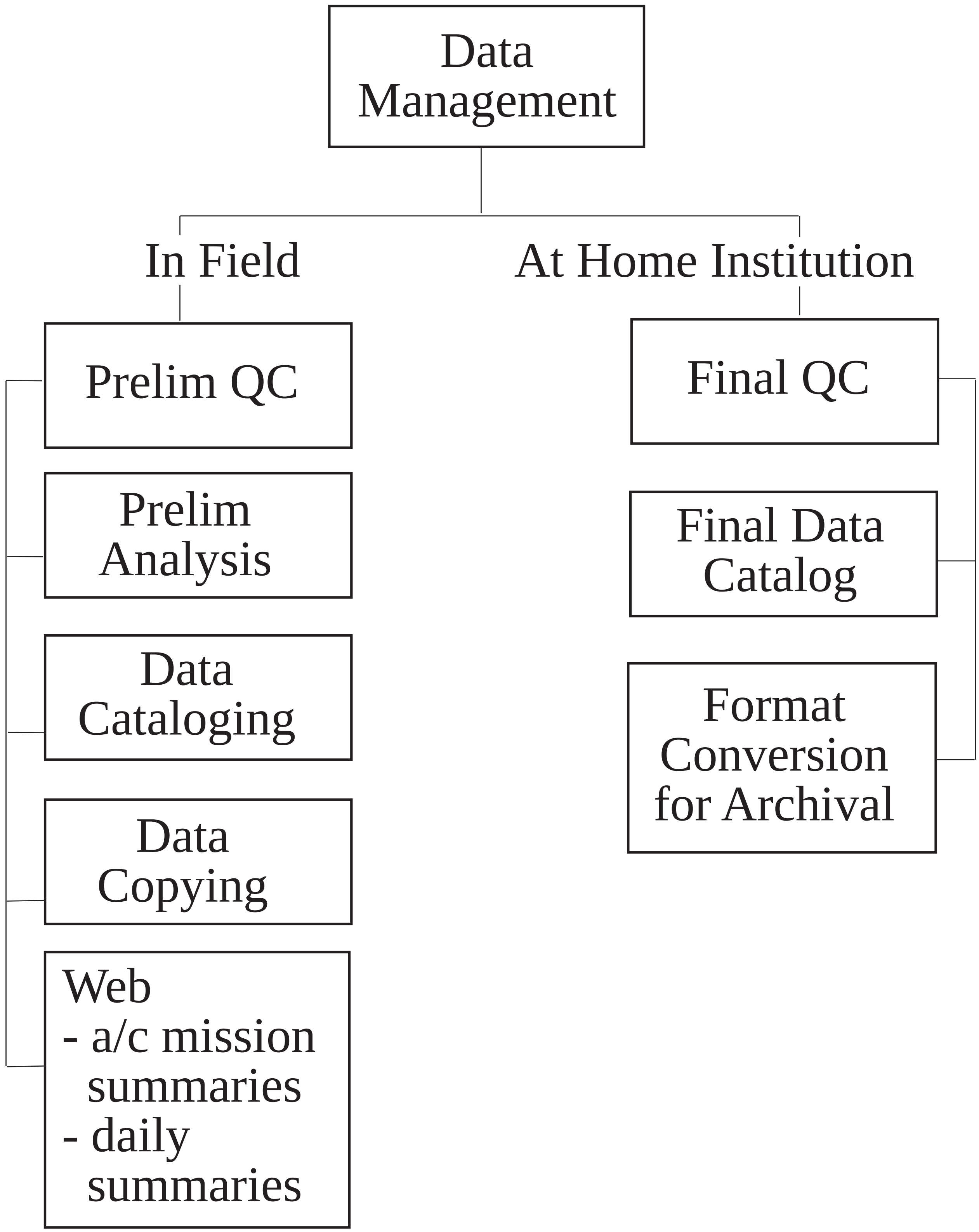

Figure 15. Block diagram of KWAJEX data management functions.

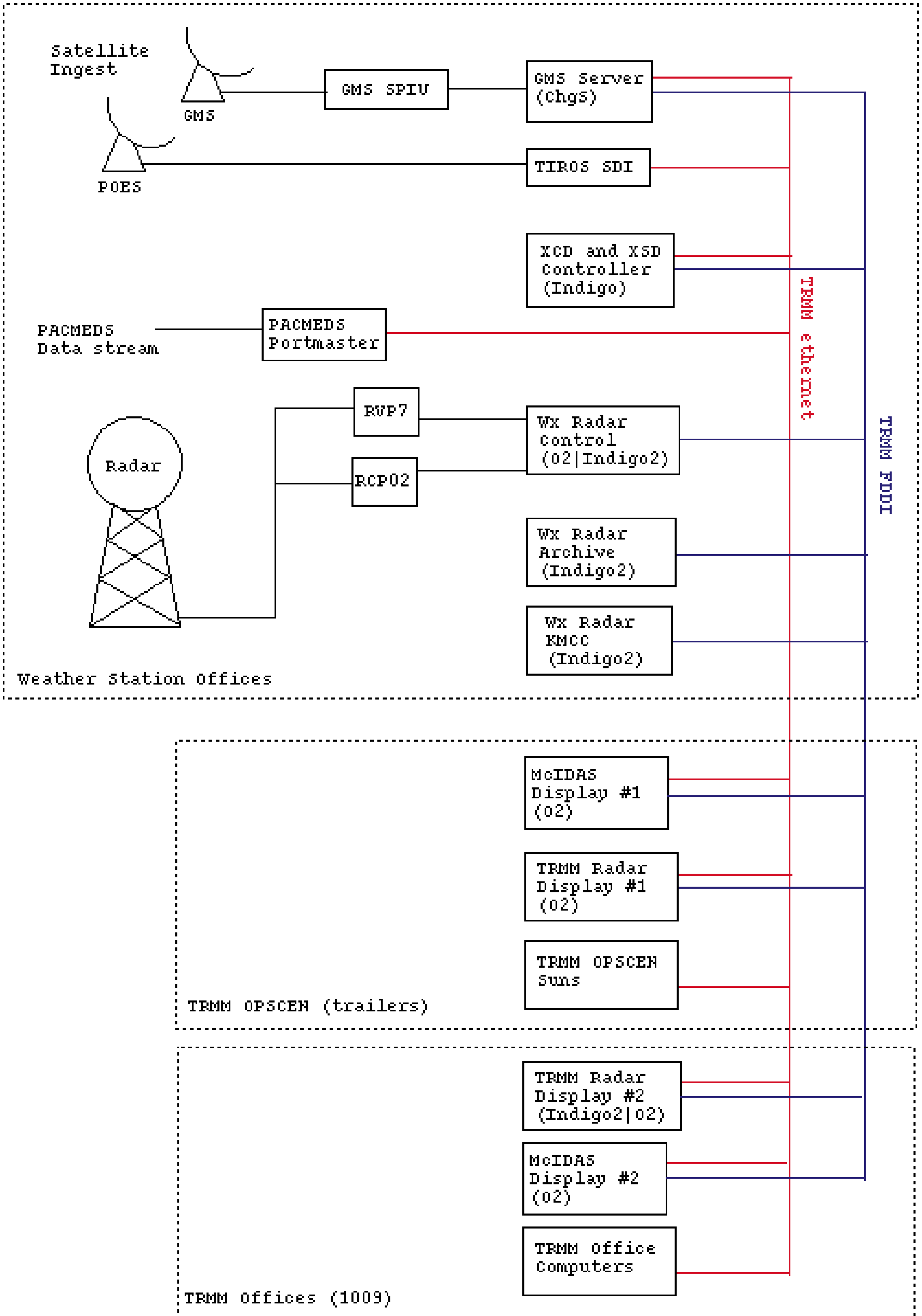

Figure 16. Network layout to support flow of satellite and radar data streams from Aeromet offices to Aeromet-supplied workstations in the Ops Center and Building 1009 Mission Briefing Room, and to the KWAJEX LAN. (Courtesy of K. Swanson of Aeromet, Inc.)