Tropical Western Pacific Program

Site Science Mission Plan

July – December 1999

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Tropical Western Pacific

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Thomas P. Ackerman and James H. Mather
ARM TWP Site Scientist Office
Environmental and Health Sciences Division
Pacific Northwest National Laboratory
Richland, Washington 99352

and

William E. Clements and Fairley J. Barnes
ARM TWP Program Office
Atmospheric and Climate Studies Group
Earth and Environmental Sciences Division
Los Alamos National Laboratory
Los Alamos, New Mexico 87544

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PREFACE

The purpose of the TWP Site Scientific Mission Plan is to provide information for the planning of scientific activities in the TWP locale. It will update the status of the locale at 6-month intervals with a detailed projection for the next 6 months as well as longer-term views when appropriate. All acronyms used are defined in the Acronym Section.

These plans are available on the ARM homepage at:
www.arm.gov.

Printed copies can be obtained from:

ARM TWP Program Office, D407
Los Alamos National Laboratory
P. O. Box 1663
Los Alamos, New Mexico, 87545, USA
Tel: 505-667-1186, Fax: 505-667-9122
twppo@lanl.gov

INTRODUCTION

The Department of Energy's Atmospheric Radiation Measurement (ARM) program was created in 1989 as part of the U.S. Global Change Research Program to improve the treatment of atmospheric radiative and cloud processes in computer models used to predict climate change. The overall goal of the ARM program is to develop and test parameterizations of important atmospheric processes, particularly cloud and radiative processes, for use in atmospheric models. This goal is being achieved through a combination of field measurements and modeling studies. Three primary locales were chosen for extensive field measurement facilities. These are the Southern Great Plains (SGP) of the United States, the Tropical Western Pacific (TWP), and the North Slope of Alaska and Adjacent Arctic Ocean (NSA/AAO), as shown in Figure 1. This Site Science Mission Plan [RPT(TWP)-010.004] describes the ARM program in the Tropical Western Pacific locale.

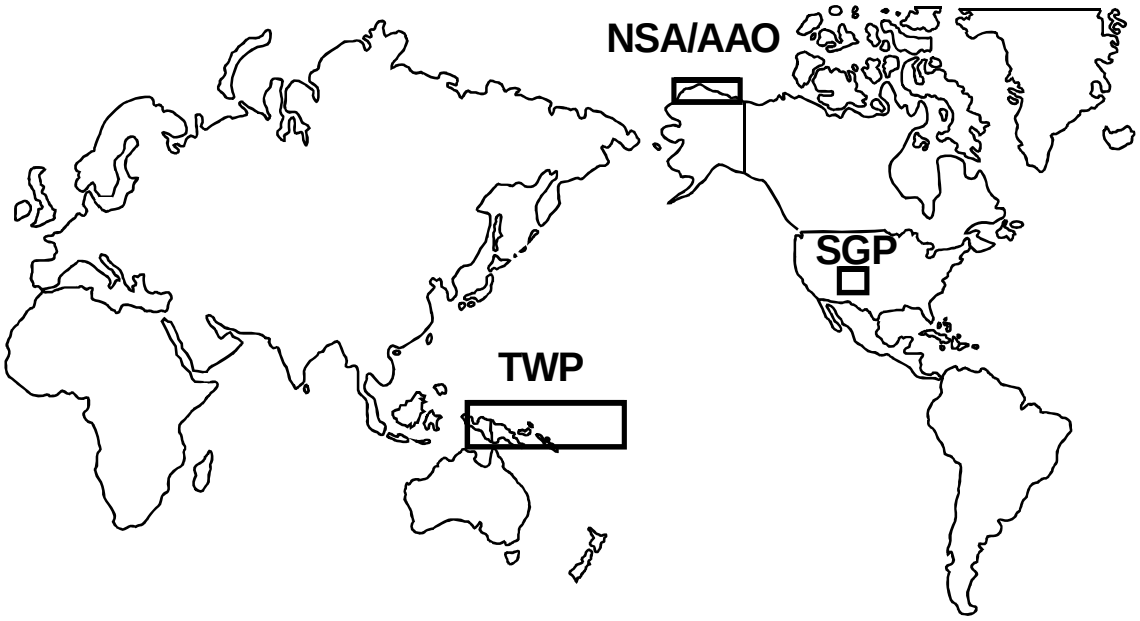


Fig.1. Locations of the three primary ARM Climate Research Facilities.

The Tropical Western Pacific locale is the second site to be instrumented by the U.S. Department of Energy's ARM program. The TWP locale, shown in Fig. 1, encompasses the area from 10°N to 10°S of the equator and from Indonesia to east of the international dateline. The locale was selected[1] because of the existence of the Pacific warm pool, the resulting cloud formations, and its influence on weather and climate throughout the planet. The purpose of the TWP program is to collect long-term data to better understand the effect of tropical clouds on the earth's energy budget. The overall

[1] U. S. Department of Energy (DOE), 1991. Identification, Recommendation, and Justification of Potential Locales for ARM Sites. DOE/ER-0495T, National Technical Information Service, Springfield, Virginia.

science objectives and measurement strategy for the TWP are given in ARM Science Plan[2].

Currently TWP program plans to implement three island-based sites (Fig. 2) with Atmospheric Radiation and Cloud Stations (ARCS) by the year 2001. In addition the TWP program is pursuing ways of obtaining data over the open ocean in the locale with instrumented buoys and ship studies. These data along with satellite data will constitute the basic ARM TWP data set. Intensive operational periods (IOP), campaigns, and collaborations with other studies in the locale will occur as the site matures.

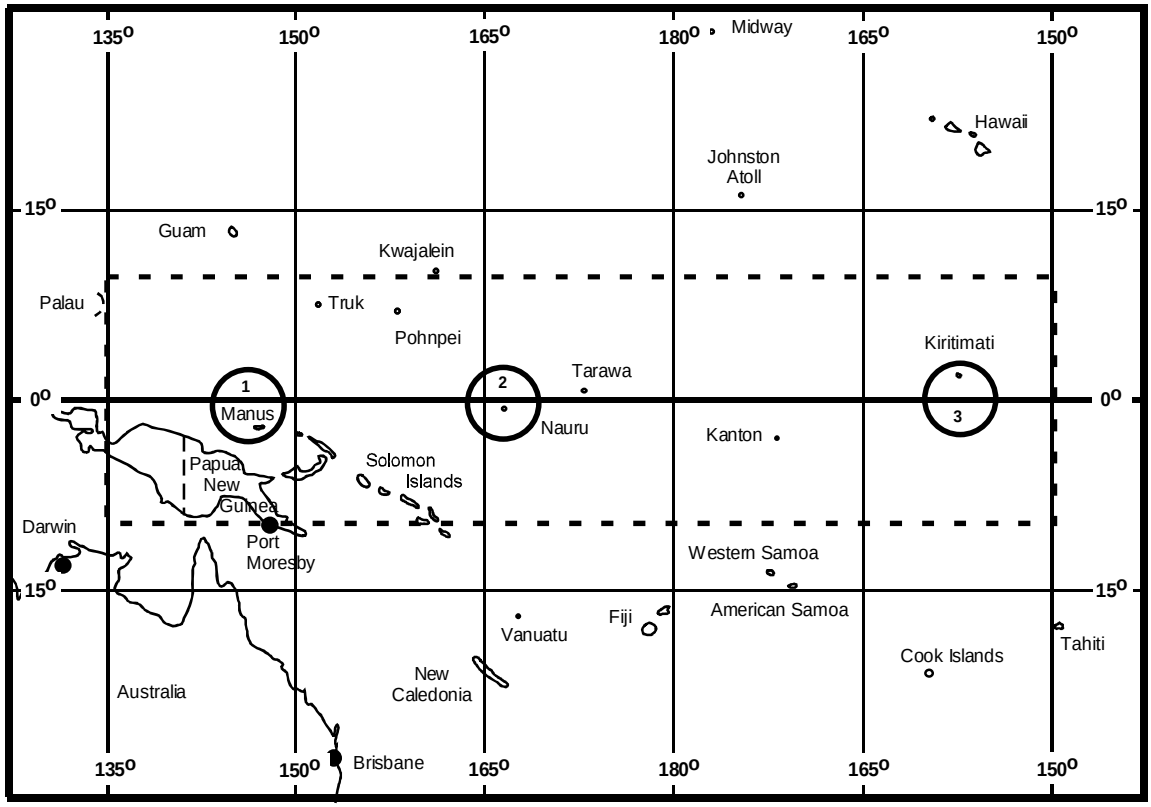


Fig. 2. Equatorial Western Pacific region showing TWP locale (dashed area) and proposed ARCS sites (circles).

[2] U. S. Department of Energy (DOE), 1996. Science Plan for the Atmospheric Radiation Measurement Program (ARM). DOE/ER-670T, National Technical Information Service,

SCIENCE GOALS

The basic science goals of the Tropical Western Pacific component of the ARM program are:

1. Determine the magnitude of the surface radiation budget terms and determine their spatial and temporal variability.
2. Identify bulk and optical properties of clouds in the TWP and how these properties affect the radiation budget.
3. Understand the linkages among sea surface temperature, ocean-atmosphere coupling, surface radiation budget, and tropical convection.
4. Determine vertical transports of water vapor, energy, and momentum in convective cloud systems.

These goals represent a sequence of increasing complexity of knowledge, as well as increasing complexity of measurement. The first is fundamental. We have relatively incomplete knowledge of the surface radiation budget in the TWP, particularly over periods of time longer than a month or a few months. Similarly, high-resolution measurements of bulk cloud properties in the TWP have only been made for short periods of times during campaigns or research vessel cruises. Further, data sets to establish the effect of clouds on the radiation budget do not exist. The third goal seeks to understand the processes in the TWP that connect surface fluxes, sea surface temperature, and convection. These connections are at the heart of meteorology in the TWP and must be well understood for both short-range and long-range climate modeling. The fourth goal represents the linkage between cloud systems and the larger circulation patterns of the region. In addition, it encapsulates cloud feedback processes as they impact the surface radiation budget and sea surface temperature.

The TWP area of interest to ARM is very large, mostly ocean, logistically remote, and operationally costly. Consequently, ARM operations in the TWP will be more limited in scope than in some other locations. Achieving the scientific goals will require a careful blending of long-term, surface remote sensing observations with field campaigns and satellite observations. The Atmospheric Radiation and Cloud Station (ARCS) currently operating at Manus Island, PNG, and on Nauru Island are the first step in the acquisition of long-term data on surface radiation budget and cloud properties. The planned deployment of an additional ARCS on the Kiritimati Island will further enhance this acquisition.

The ARM TWP team carefully selected the ARCS instrumentation to address the issues raised by the first two goals. A list of ARCS measurements and instruments is given in Table 2. Detailed information on the various instruments is available on the ARM homepage: www.arm.gov. The system measures all components of the surface radiation budget. The system currently measures only cloud-based heights and cloud base temperature or cloud emissivity, depending on the cloud thickness. The program plans to upgrade the cloud measurements to include cloud top, as well as base height, and cloud fraction. In addition, routine measurements of the atmospheric base state are

acquired with radiosondes, profilers, and surface meteorological sensors. A summary of the data acquired by the Manus ARCS during this current period is given in Section 1.2.1. We encourage members of the scientific community to access that data and use it in their research.

Table 1. ARCS Measurements and Instruments

Measurement	Instruments
Surface radiation	• Up- and down-looking pyranometers and pyrgeometers • Sun-shaded pyranometer and pyrgeometer • Normal incidence pyrheliometer • Up- and down-looking 9-11μm narrow field of view radiometers • UV-B hemispheric radiometer • Broad band (solar and infrared) net radiometer • Atmospheric Emitted Radiance Interferometer (Nauru site only)
Surface meteorology	• Temperature and relative humidity sensor • Barometer • Optical rain gauge • Propeller vane anemometer
Cloud properties	• Cloud lidar (523 nm) • Ceilometer (7.5 km maximum range) • 35 GHz radar • Whole sky imager
Aerosol optical depth	• Multi-filter rotating shadow band radiometer (total, direct, and diffuse irradiance in six 10 nm channels)
Column water	• Dual channel (23.8 and 31.4 GHz) microwave radiometer
Vertical structure of the atmosphere	• Rawinsonde • 915 MHz wind profiler with RASS[a]

a - Operated in cooperation with NOAA's Aeronomy Lab

SITING STRATEGY

An important property of the climate in the tropical Pacific is a strong east to west gradient in various climate parameters including sea surface temperature, water vapor column, and frequency of convection. High sea surface temperatures and frequent, deep convection characterize the western Pacific. Toward the eastern Pacific, there is a steady decline in sea surface temperature and a corresponding decrease in the frequency of convection. Because of this longitudinal structure and its variability it would be difficult to characterize the climate of the tropical Pacific with a single site. The plan for ARM in the TWP is to deploy an ARCS at three sites to sample the structure in this region, as shown in Fig. 2.

The deployment schedule and status of the sites are given in Table 2. The current implementation plan calls for the TWP locale to be fully operational by 2001. ARM and South Pacific Regional Environment Programme (SPREP) are working closely together in siting, public awareness, educational, and other aspects of implementing the TWP locale.

Table 2. TWP ARCS Sites Proposed Schedule and Status

	Site	Latitude	Longitude	Start Date	Status
1	Manus	2.060°S	147.425°E	1996	Operations began in October 1996
2	Nauru	0.521°S	166.916°E	1998	Operations began in November 1998
3	Kiritimati	1.87°N	157.33°W	2000	Planned

1.0 MANUS SITE (ARCS-1), PAPUA NEW GUINEA

The first TWP site is in Manus Province, Papua New Guinea (PNG). This site was chosen because of its location within the heart of the Pacific warm pool, the existence of a NOAA Integrated Sounding System (ISS), and the support of the PNG National Weather Service (NWS). The site is located at the NWS station at the Momote airport on Los Negros Island at 2.060^{o}S, 147.425^{o}E (Fig. 3).

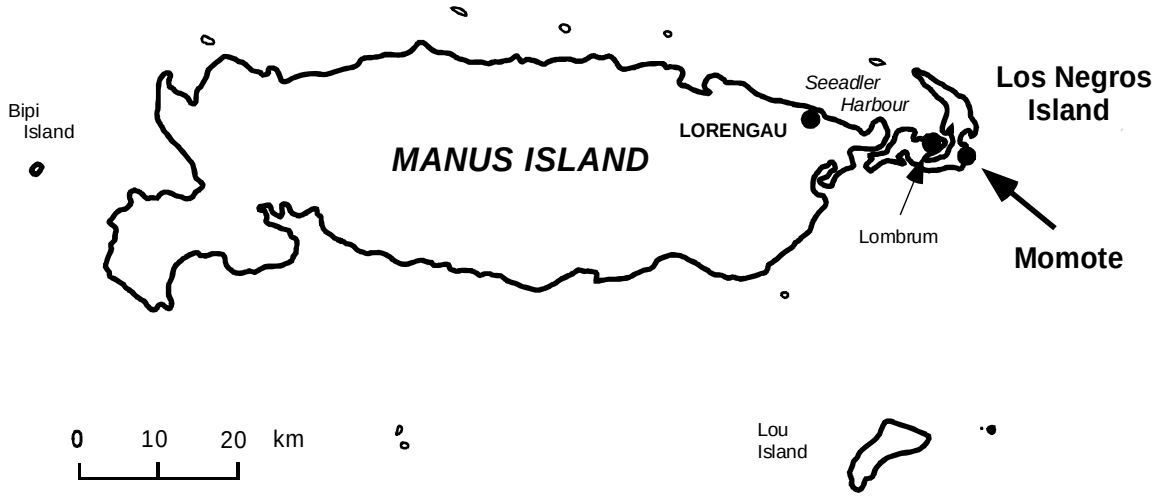


Fig. 3. Manus Province, Papua New Guinea. The ARCS is located at the National Weather Service station at the Momote airport on Los Negros Island.

The site is six meters above sea level. The highest point on Manus Island is 702 m, but most of the island has an elevation of less than 200 m. The highest point on Los Negros Island is 121 m but within 3 km of the site the elevation is less than 20 m. All equipment is located within the National Weather Service compound at Momote (Fig. 4). Appendix A shows the Manus site layout of instruments and facilities. The operation of the Momote site is a collaborative effort between ARM TWP and the PNG National Weather Service.

Fig. 4. ARCS installation at National Weather Service station at Momote airport, Manus Province, PNG.

1.1 Manus Operations

ARCS-1 was installed at Momote during August and September 1996. It was shipped from Long Beach, California on 22 May and all components were on site by 07 August. Installation began on 24 August and took 6 weeks and 435 man-days of work for completion. The site was formally commissioned on 12 September and routine operations began on 8 October. PNG NWS staff is in charge of the daily operations of the site. Assistance in performing these duties and in troubleshooting problems is provided by the TWP Operations Center in the US. Communication between the site and the Operations Center is conducted by phone, fax, and satellite. A REgional SErvice Team (RESET) visits the site periodically to perform maintenance and calibration. These routine visits are nominally scheduled at six -month intervals. Additional visits are made when required. Appendix A shows the Manus site layout of instruments and facilities.

Operation of the Manus site is managed out of the TWP Operations Center at Los Alamos National Laboratory in collaboration with the Papua New Guinea National Weather Service.

1.1.1 Manus Operations Status

The Manus site has been operating since 8 October 1996. Currently all planned instrumentation is installed and operating. Hydrogen is being generated on site and used as the lift gas for the once per day balloon borne sounding at 00Z (1000 Mountain Standard time). Health and status data are transmitted hourly from the site to the ARM Experiment Center via the GOES satellite system. All data are returned on tape every two weeks by courier service. Locally, normally three PNG NWS personnel operate the site.

RESET Visits:

A Regional Service Team (RESET) visit consists of two or more TWP technicians and is classified as either routine or non-routine visits. Routine visits are primarily aimed at instrument calibration, observer training, and semi-annual maintenance. They are scheduled at 6-month intervals. Non-routine visits are for special retrofits or emergency repairs and can be initiated at any time.

During January through June 1999 TWP conducted two RESET trips to the Manus site.

RESET-5M: (March 1999, 2 weeks, 3 people). This was a routine visit for instrument calibration, comparison testing, maintenance and changeout. Other important task were the mods to the Emergency Generator, SDL computer replacement, general Y2K compliance checks, H2 Generator/RBL reconnaissance, and Observer training.

RESET-6M: (June 1999, 2 weeks, 7 people). This was a non-routine visit for installation of the MMCR, RBL, and the repair of the H2 Generator. Other tasks were the installation of the air conditioned Y-Van, power system upgrades, and Observer training on the MMCR and Balloon Launching with the newly commissioned systems. Major troubleshooting of ADaM problems was also accomplished.

Significant Events

Below are significant operational events that occurred during the January – June 1999 period. The sequential labels (MAS-SE-N) indicate the Manus (MAS) Significant Event (SE) and number (N). A record of all events is available on the TWP website at: www.twppo.lanl.gov.

MAS-SE-19: Calibration of Manus Instruments:
During RESET-5M Bill Porch coordinated the calibration, comparison and changeout of instruments at Manus from 26Feb thru 07Mar99.

MAS-SE-20: New OIC asigned at Manus:
On 04Aug99 the PNG NWS management replaced long time ARCS-1 Officer in Charge(OIC) Geasa Stoesel with Observer Francis Anuma.

MAS-SE-21: ADaM stops reporting to GOES H&S
On 10May99 ADaM stopped reporting to the GOES H&S system. We do not believe any data was lost, but several people stateside and in PNG were involved in maintaining the ADaM remotely until it was repaired with the help of Kevin Widener during RESET-6M on 19Jun99.

MAS-SE-22: MMCR Installed:
On 12Jun99 the MMCR instrumentation and antenna was installed in the I-Van during RESET-5M.

MAS-SE-23: New Storage Van installed:
On 15Jun99, during RESET-5M, the new air conditioned Y-Van was set in place and powered up to provide controlled environment storage for instruments displaced by the installation of the MMCR. The Van was shipped by surface transport and served as the shipping container for the MMCR.

MAS-SE-24: H2 Generator repair and RBL installation:
On 16Jun99 the repair and installation of the new Remote Balloon Launcher(RBL) was completed. The Observers were trained in the operations of using the new equipment.

MAS-SE-25: MPL stops reporting data:
On 24Jun99 the MPL stopped reporting to ADaM. We had been having problems with the instrument for some time and it never recovered from an Observer “reboot”. It is scheduled to be replaced by a new MPL-HR on RESET-7M.

1.1.2 Manus Operations Projection

During the July – December 1999 period there will be two scheduled RESET visit to perform installations, upgrades and repairs as follows:

RESET-7M Visit(combination 2-Site visit)
This is a non-routine visit to do the following:

- **MPL-HR** changeout installation
- Install new **Digicora** software upgrade
- Coordinate **telephone** improvements w/Telcom
- Skyrad **IRT** lens replacement
- Grnrad **IRT** setting correction
- **MWR** computer changeout
- **MMCR** time resetting.

RESET-8M Visit(combination 2-Site visit)
This is a non-routine visit to do the following:

- Dismantle and remove **existing ADaM**
- Install **new ADaM** system(Y2K compliant)
- Replace power panel **circuit breakers**

- Install new **GOES antenna**
- **Install PC** for reporting instrument H&S directly to GOES
- **Modify MACS/COMS** to report Van H&S data only
- Zeno **logger Y2K** upgrade
- Increase **WSI data** collection frequency
- **H2 Generator** routine maintenance(BOM)
- Zeno Data **logger wiring** upgrade
- **Brusag Y2K** upgrade
- Replace the **MPL-HR** sunshade
- Replace **MMCR** DC-DC converter
- Replace **BBSS** Linebacker with PC
- Install site **poster**

1.2 Manus Data Quality

The TWP Site Science Office at Penn State University reviews all TWP data before being released for use. Data quality is assessed in two stages. First, the site transmits data via GOES satellite each day. This message includes hourly statistics (mean, maximum, minimum, and standard deviation) of most data streams. These data are automatically plotted each day and manually inspected for problems by the site science office. Full examination is reserved for the arrival of the complete tape data set.

Once the full data set is retrieved, the data are plotted using a set of Matlab tools developed at Penn State. These plots include simple daily plots of the raw data and diagnostic plots of instrument to instrument and instrument to model comparisons.

1.2.1 Manus Data Quality Status

Beginning 16 November 1998, the relative humidity has been exceeding 100 percent with unusual regularity. This problem indicates that the sensor calibration is drifting. At times the RH exceeds 103 percent which is the upper limit acceptable for saturation. A PIF has been submitted to propose changing this sensor. This change is expected to occur in June 1999.

The heater/blower assembly that prevents water from accumulating on the sensor's Teflon window was not working for part of this period. The heater was repaired on 28 February 1999. Prior to the heater replacement, the MWR data is subject to contamination due rain on the sensor window for several hours after the end of rain events and should be used with caution.

Beginning 5 May 1999, the MPL began to report a constant cloud base of 305 meters. This problem is evidently due to condensation on the window.

The MFRSR head was replaced on 27 February. This new head is expected to provide a more stable calibration which will allow aerosol optical depths to be retrieved more readily.

1.2.2 Manus Data Quality Projection

To address the problem of the drifting relative humidity sensor calibration, a plan is being developed to change out and test the sensor on a regular schedule.

The MPL will be upgraded to the hi-resolution version. Based on performance of the hi-resolution instrument at Nauru, this new instrument is expected to be more sensitive than the old instrument, particularly during the day.

2.0 NAURU SITE (ARCS-2), REPUBLIC OF NAURU

This second TWP site is located on Nauru Island in the central Pacific (Fig. 2). The Nauru site was chosen because of its location on the eastern edge of the warm pool under La Niña condition and its variable climate associated with ENSO events. Also its small size and isolation suggest that its climate should be strongly oceanic. The site is located in the Denigomodu District near the General Hospital on the west side of the island at 0.522 °S, 166.913 °E, 7m MSL (Fig. 5).

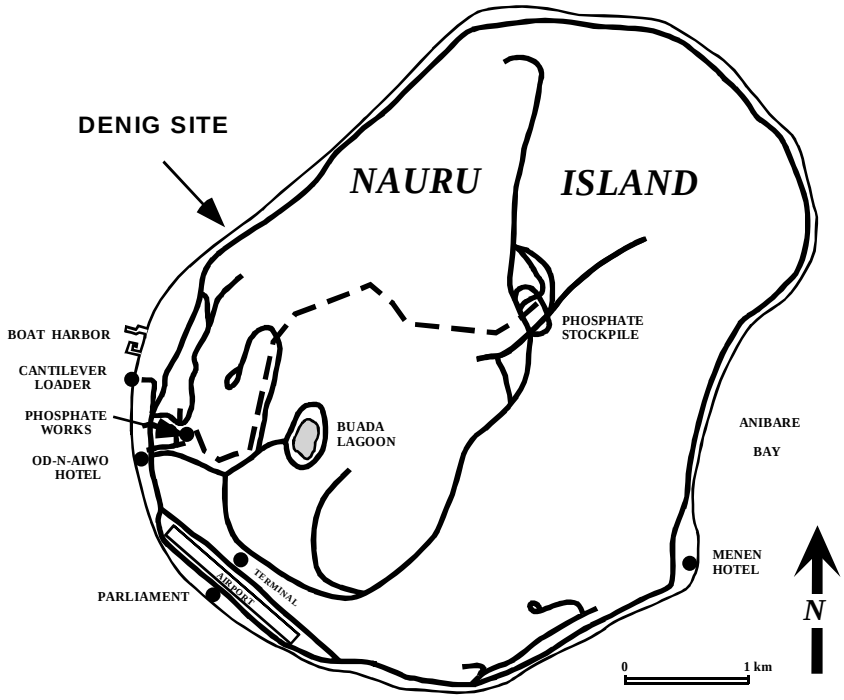


Fig. 5. Nauru Island. The ARM station is located in Denigomodu District on the western shore.

The ARCS-2 was installed at this location during October and November 1998. In addition to the standard set of ARCS instruments, the Nauru site has an Atmospheric Emitted Radiance Interferometer (AERI), a hydrogen generator to produce lift gas for the balloon soundings, and a remote balloon launcher. Figures 6 and 7 show panoramic views of the site.

Formal operations of the Nauru site began on 21 November 1998, after official opening ceremony on the island on 20 October. The operations are a joint effort of the ARM Tropical Western Pacific (TWP) Program Office and the Nauru Department of Island Development and Industry (IDI).

Fig. 6. Panoramic view of site looking northeast to southeast (left to right).

Fig. 7. Panoramic view of site looking southeast to northwest (left to right).

2.1 Nauru Operations

ARCS-2 was installed at Nauru during October and November of 1998. It was shipped from Long Beach, California in July and all components were on site by September. Installation began on 06 October and took 7 weeks to complete. The site was formally commissioned on 20 November and routine operations began on 23 November. Nauru IDI staff is in charge of the daily operations of the site. Assistance in performing these duties and in troubleshooting problems is provided by the TWP Operations Center in the US. Communication between the site and the Operations Center is conducted by phone, fax, and satellite. A REgional SErvice Team (RESET) visits the site periodically to perform maintenance and calibration. These routine visits are nominally scheduled at six -month intervals. Additional visits are made when required. Appendix A shows the Nauru site layout of instruments and facilities.

Operation of the Nauru site is managed out of the TWP Operations Center at Los Alamos National Laboratory in collaboration with the Nauru Department of Island Development and Industry.

2.1.1 Nauru Operations Status

The Nauru site has been operating since 23 November 1998. Currently all planned instrumentation are installed and operating. Hydrogen is being used as the lift gas for the twice per day balloon borne sounding at 00Z and 1200Z (1000 and 1300 Mountain Standard time, respectively). Health and status data are transmitted hourly from the site to the ARM Experiment Center via the GOES satellite system. All data are returned on tape monthly by courier service. Locally, four Nauru IDI personnel rotate shifts to operate the site.

RESET Visits:

A Regional Service Team (RESET) visit consists of two or more TWP technicians and is classified as either routine or non-routine visits. Routine visits are primarily aimed at instrument calibration, observer training, and semi-annual maintenance. They are scheduled at 6-month intervals. Non-routine visits are for special retrofits or emergency repairs and can be initiated at any time.

During January through June 1999, TWPPO conducted one RESET trip to the Nauru site.

RESET-5N: (March 1999, 1 week, 2 people). This was a non-routine visit for emergency power generator safety modifications, H2 Generator mods and maintenance, SDL upgrade, ADaM backup, and troubleshooting of the Inmarsat B satellite communication system.

Significant Events

Below are significant operational events that occurred during the January – June 1999 period. The sequential labels (INU-SE-N) indicate the Nauru (INU) Significant Event (SE) and number (N). A record of all events is available on the TWP website at: www.twppo.lanl.gov.

INU-SE-2: H2 Generator repair:
The H2 Generator had problems running for extended periods due faulty reed switches. On 17Jun99 an Australian BOM technician was able to repair the system in time for the Nauru 99 IOP. The Observer commenced 2 launches per day.

INU-SE-3: Nauru99 IOP:
The ARCS-2 site on Nauru was the core of the very successful Nauru99 IOP that included 2 ships, an airplane, topside met stations and lots of scientists and technicians. The IOP lasted from 12 June through 18 July 1999.

2.1.2 Nauru Operations Projection

During the July – December 1999 period there will be two scheduled RESET visits to perform installations, upgrades and repairs as follows:

RESET-7N Visit(combination 2-Site visit)
This is a routine visit to do the following:

- Instrument **Calibration**
- Instrument **changeout**
- **Brusag Y2K** upgrade (Spare too if possible)
- Install new **Digicora software** upgrade
- **AERI maintenance**, troubleshooting
- Diagnose **Cavity Radiometer** problems
- **SAM** system Laptop changeout
- **MWR** computer changeout
- **Bouda lagoon** reconnaissance

RESET-8N Visit(combination 2-Site visit)
This is a non-routine visit to do the following:

- Dismantle and remove **existing ADaM**
- Install **new ADaM** system(Y2K compliant)
- Zeno **logger Y2K** upgrade
- Increase **WSI data** collection frequency
- **H2 Generator** routine maintenance(BOM)
- Zeno Data **logger wiring** upgrade
- Replace the **MPL-HR** sunshade
- Replace **MMCR** DC-DC converter
- Replace **BBSS** Linebacker with PC

- **SMET Logger** Seacon connector upgrade
- Replace the **MPL-HR** sunshade
- Replace **BBSS** Linebacker with PC
- Move **GOES** H&S antenna from D-Van to Z-Van
- Test spare **UPS Module**
- **Anemometer** bearing changeout

2.2 Nauru Data Quality

2.2.1 Nauru Data Quality Status

There were no sondes launched from 23 December 1998 through 2 March 1999 (inclusive). During this period, the hydrogen generator was not working, and there was no helium on site. A shipment of helium arrived at the site in early March, and the hydrogen generator has been repaired.

Between December 1998 and January 1999, anemometer #1 (there are two anemometers on the MET tower) periodically reported wind speeds of sero or values significantly lower than anemometer #2.

On several occasions, large (10 percent) differences between the global PSPs and the NIP were observed. IN each case, the HIP reported low relative to the direct flux reported by the PSPs. These occurrences persisted for several days each time and are likely due to salt on one or more of the radiometers. The dates and times of these events are listed in Table 3.

Table 3: Differences in readings between PSPs and NIP

Start		End	
Date	Time	Date	Time
16 January 1999	04:00	19 January 1999	02:00
6 February 1999	22:00	8 February 1999	03:00
18 February 1999	22:00	20 February 1999	23:00

In response to this problem, we have asked the observers to clean the radiometers on a regular schedule, whether the domes appear to be dirty or not (the salt film can be difficult to see).

The MPL detector failed on 25 January 1999 and was revived on 20 April 1999. A special trip was made to expedite this repair.

2.2.2 Nauru Data Quality Projection

The biggest activities right now that affect data quality (for both sites) are efforts to improve communication from the United States to the sites – particularly for work on the data system, and for data transmission and the development of a plan to provide data (particularly surface met data) in near real time to the on-site observers and to WMO for

global model forecasts. Improving connectivity to the site and providing better access to the data will refine the ability of the site operations staff and the site science team to assess data quality in near real time.

3.0 SITE 3

We have been considering the possibility of locating the third TWP site on the Kiritimati Island (Christmas Island) in Kiribati. An initial site-scouting visit was made to the island in August 1998 in which preliminary negotiations with the government of Kiribati were started. Planning for the Kiritimati Island site was put on hold on 1 February 1999 while the TWP Science Advisory Committee considered alternate sites. This issue has not been resolved as of the writing of this report.

4.0 IOPs, CAMPAIGNS, AND OTHER COLLABORTIONS

IOP Nauru 99 is a campaign offshore of Nauru Island (site of ARCS 2) occurred in June/July 1999. The campaign included the Japanese Research Vessel MIRAI for six weeks of measurements and the NOAA ship RON H. BROWN. The Nauru Science and Implementation Plan can be found at www.etl.noaa.gov/nauru99 under Expeditions.

The ARCS stations supplied measurements of the surface radiation budget and radiatively important atmospheric properties at single points. Understanding how island measurements represent conditions over the nearby ocean is important for the interpretation of the measurements. The ARM program is making a concerted effort to address this question. This requires making similar measurements on the open ocean near the islands. Also, there are a variety of atmospheric processes, such as the vertical transport of water and energy by tropical convection that cannot be addressed within normal operating conditions in the TWP due to logistical and cost constraints.

Nauru99 was conceived to address several hypotheses:

- Island effects are minimal during periods of active convection such as the Madden-Julian Oscillation (MJO) effects and during the night.
- There may be some island affect during the day.
- Small islands do not affect isolated cirrus clouds.
- Island effects will be noticeable in cloud fraction and liquid water content, but the impact of small islands on overall downwelling radiation, relative to the open ocean, is small.

The Nauru99 operation began 18 June 1999, with the arrival of the Japanese ship MIRAI in the Nauru area. The NOAA ship RON BROWN arrived a few days later; these two research vessels occupied stations in two different triangle patterns designed to study different mesoscale processes. In the large triangle pattern, each ship took position near NOAA TAO buoys at 165W longitude, equator and 2S latitude, forming a triangle with sides of approximately 200 km with the ARCS site, The small triangle had

sides of 25 km and 50 km. At some point, 1 or 2 concentrated platform intercomparisons were made near the island. The operation ended when the RON BROWN departed on 18 July 1999.

Both ships had nearly redundant instrumentation to that on the island, including Lidars, S-band radar, radiosondes, and radiometers. Each ship operated a 5-cm Doppler weather radar, and dual-Doppler studies of clouds were conducted. Each ship was fully equipped to make direct measurements of all components of the air-sea energy flux, both by direct eddy-correlation and by bulk transfer methods. In particular, the RON BROWN collected aerosols, which were analyzed on board.

A Cessna research aircraft operated by Flinders University, Adelaide, Australia concentrated on measuring the boundary layer along the legs of the triangle and over the island. In addition to the standard ARCS instruments, the following were deployed on the island during the campaign:

- Portable Radiation Package (PRP) – BNL
- Hemispheric Sky Imager (HSI) – PSU
- Rotating Shading-Arm Radiometer (RSR) – PSU
- CIMEL Sun Photometer
- Two Meteorology and Energy Balance Stations (TEBS) – PSU

All of these were operated at the Nauru ARM site except for the TEBS which was deployed on topside in the interior of the island.

Rawinsonde was launched at the Nauru ARM site on a schedule that matched the schedule of the two ships.

5.0 OCEAN PROJECT

The goal of the ARM TWP Ocean Project is to provide a means by which ARM can obtain data that apply to the oceanic environment and supplement the measurements taken at the TWP island stations. The ARM Ocean Working Group (AWOG) was formulated to create a means of focusing the ARM ocean activities. The primary scientific issues suggested by this group are:

- Spatial variability of radiation and all fluxes in the oceanic heat budget
- Lower atmospheric mixed-layer physics
- Upper-ocean mixed-layer physics
- Island-induced errors
- Spatial and temporal variability in the sea-surface temperature (SST)
- Cycles of convection on all spatial scales

In keeping with the ARM Science Plan for the TWP, both intensive field campaigns and long-term measurements of properties and fluxes at the ocean-atmosphere interface will be considered. As these activities require access to floating platforms, both ship and buoy observation systems are under development.

More information on the Ocean Project can be found at www.armocean.bnl.gov.

TAO Buoy Radiometer Program

ARM is participating in the international Tropical Atmosphere and Ocean (TAO) buoy program in the Pacific Ocean. With ARM support, the NOAA Pacific Marine Environmental Laboratory (PMEL) has developed a special digital version of the Eppley PSP for use with their next generation ATLAS buoy package.

Four prototype TAO-PSP radiometers have been operating successfully since June 1997. The daily average insolation values, transmitted via the ARGOS satellite, are most encouraging and it appears the internally stored, 2-minute averages will produce a good test of short-wave irradiance measurements. The program then deployed radiometers and rain rate sensors on all seven buoys along the 165E longitude line from 8N to 8S and all were measuring short wave radiation and rainfall in January 1998.

JAMSTEC is in the process of deploying their TRITON buoys at sites west of 165E. These buoys, which will eventually replace the NOAA buoys, will also have high quality radiation sensors, the Woods Hole IMET sensors. The TRITON buoys will completely replace all NOAA buoys west of 165E* in the next few years and it is essential that ARM establish connections to this data set to provide a good inter- comparison and added coverage in the TWP.

Instrumentation Development

Several instruments, under development for Volunteer Ship Observing System (VSOS) activities worldwide, are being considered for ARM/TWP observing platforms. A Fast-Rotating Shadowband Radiometer has been developed at BNL and was operated successfully on the CSP and TOCS cruises. A multi-frequency version was developed and deployed on two cruises in 1998. A marine version of the AERI, called M-AERI, has been developed by the University of Wisconsin and is operated by the University of Miami on several ships. A simple infrared thermometer has been used to successfully measure SST to the required +/-0.01 C accuracy. Engineers at BNL are working with scientists at Univ. of Colorado to develop this into a low-cost, unmanned system for the VOS effort. A series of field inter-comparison studies are planned with the goal of achieving an optimum measurement system for the volunteer ship network worldwide.

6.0 EDUCATIONAL OUTREACH

Plan Overview

DOE mandates that its programs have some form of educational outreach program. From the first days of ARM, developing the education outreach program has been assigned to each CART site. A small but consistent funding base has been allocated for

the development of the education program, and the Site Scientist and/or the Site Program Manager usually administer it. The content of the site education program, while at the discretion of each site, must be relevant to the communities around each CART site.

The TWP presented us with unique problems for developing an education plan. The three TWP sites are spread out over a huge geographic area, and each site is in a different country with a unique language and culture. More importantly, the local schools generally lack advanced technology, such as Internet capabilities. Many do not have TV, video, or film resources and some are lacking the material, infrastructure and educational resources that are considered to be standard in the US. Our goal has been to identify the various educational needs in the communities close to each site, and to attempt to deliver enrichment opportunities to satisfy some of those needs.

The overall vision for the TWP education outreach plan is to enrich primary, secondary and college science programs in the TWP region with a focus on basic science, climate, climate change and effects relevant to the region. The TWP educational outreach plan must have a broad scope to address local, national and regional issues and needs, and be flexible to stay current and relevant over the potential 10-year operating period of the TWP locale. The program must include both technical training for on-site staff, and public education and outreach for local communities, as well as addressing the needs of the more formal education systems of communities.

Significant Events

In April 1999 we introduced the two newsletters from the Tropical Western Pacific Program Office: *TWP Update* and *Tropical Winds*.

TWP Update focuses on general programmatic issues, such as installation and operation of the ARCS sites in the Tropical Western Pacific region. The other newsletter, *Tropical Winds*, provides students and teachers with news about the U.S. Department of Energy's (DOE) ARM program and global climate issues, as well as classroom activities to demonstrate basic scientific concepts related to climate and weather. We will publish the newsletters three times a year.

In May 1999 we held the second set of Curriculum Implementation Workshops for teachers and educators in Port Moresby and Manus, Papua New Guinea. We were assisted by one of the curriculum authors, Dr. Than Aung, from the National Tidal Facility at Flinders University, Australia. Sixty-two teachers and principals from high schools and primary schools attended the 5-day workshop and earned certificates of completion. Teachers learned how to present about 50% of the activities in the curriculum modules. Workshop evaluations of content, format, utility and delivery showed good to excellent scores on most categories; over 80% of participants wanted 2 or 3 weeks instead of a 1-week workshop. Written comments were extremely valuable. We will also conduct 1 and 3-year follow up evaluations.

In June 1999 we participated in the first DOE Global Change Program/Summer Undergraduate Research Experience Workshop at the University of California—Davis. The TWP presentation covered program goals, objective and data.

Plan Goals

- **Needs Assessment**: Meet with local and regional educators to determine the ways we can support educational needs for communities and the region. Needs assessment must be an ongoing task.

- **Curriculum Development**: Develop a regional curriculum for enriching science curricula in the secondary schools in collaboration with SPREP and other organizations.

- **Curriculum Implementation**: Develop and implement workshops to assist education departments using the curriculum. We will focus first on the communities and education departments close to the TWP sites, but will also participate in regional implementation efforts**.**

- **SPaRCE (Schools of the Pacific Rainfall Climate Experiment)**: Support the SPaRCE program through assisting in the enrollment of schools in the program, support for development of automated school weather stations and advanced equipment, and also in participation in and joint sponsorship of in-service training.

- **Newsletters**: Develop quarterly newsletters for schools and for public information. These newsletters will have information on ARM and TWP progress, information on climate issues with a regional focus (e.g. El Niño) as well as a Q&A section for readers to submit issues and concerns.

- **Material Support**: Support the improvement of material and equipment as needed and as funds available in the schools close to the ARCS sites. This material support may include books, video resources, computer usage, and simple automated weather stations and equipment.

- **Teacher Training**: Support enrichment for teachers as needed and as funds are available including attendance at meetings, and other in-service training.

- **ARM Resources**: Support tours of the ARCS, access to TWP and ARM data, and help with data analysis. TWP scientists and technicians will visit schools and give presentations to faculty and classes on the ARM program; we will assist on occasion with local needs for computer support or equipment issues.

- **Public Relations**: Develop a public relations plan in conjunction with on-site colleagues in the relevant government departments. Activities may include town meetings, local events, site tours, radio or TV interviews. The TWP program goal is

to be responsible and communicative about ARM activities, and to assist with building local capacity for addressing climate and other environmental issues.

- **Technical Training**: Develop a technical training plan in conjunction with the on-site staff, the staff supervisors or employers, and the TWP program office. Build on existing technical skills, and offer opportunities for training that might not normally be available to the technical and management staff assisting with the day-to-day operations of the ARCS. Initially, observers will be trained to operate the equipment at the site. The initial equipment training will be followed by side-by-side working and training with TWP technicians, engineers and scientists; it could include formal training given by another provider depending on funding.

Plan Implementation Summary: January-December 1999

(Plan elements completed prior to January 1999 are listed in the previous Site Science Mission Plans for January-June 1999 and July-December 1998.)

Plan Element	Progress: January-June 1999	Planned: July-December 99
Needs Assessment	• Continue discussion with Manus and Nauru education departments.	• Initiate discussion with educators at the third TWP site after site selection.
Curriculum Development	• Complete	
Curriculum Implementation	• 2 curriculum workshops in Port Moresby and Manus, PNG in May 1999. • Complete curriculum implementation plan for 1999-2000; begin implementation.	• Draft and complete NTF (Flinders Univ.) contract for workshop. • Complete implementation plan w/ NTF and SPREP 10/30/99. • Publish curriculum on Web: curriculum activities by 9/30/99; full publication by 12/30/99. • Curriculum workshops planned for 12/99 and 7/00.
SPaRCE (Schools Of The Pacific Rainfall Climate Experiment	• Support SPaRCE program with small funding grant from 1994 to present.	• SPaRCE participation in curriculum implementation workshops planned for FY99.
Newsletters	• Drafted Issue #1 1/15/98. • Issue #1 distributed 4/1/99.	• Issue #2 drafted 9/15/99. • Issues to be shipped for distribution at each location 3 times/yr (15 Mar, 15 Jul, and 15 Nov).
Material Support	• Book shipment (donated books from the TWP team) to Manus 3/5/99.	
Teacher Training		• See implementation workshops.
ARM Resources	• Continued TWP site tours. • Trained Nauru Observers to conduct site tours.	• Education management meeting w/ SPREP 9/27/99.
Public Relations	• Conducted TV/radio interviews in Nauru during Nauru99 IOP. • Sent PR packages to PNG NWS Head Office 3/15/99. • Completed Nauru99 Fact Sheet; distributed in Nauru April 99. • Provided PR support to ARM during Nauru99 (June/July 1999). • Video filming for an ARM/TWP introduction video during RESET, site evaluation trips, and Nauru99.	• The ARM/TWP introduction video is being produced by Tradewind Communications, a New Zealand-base media company. The date of release is TBA.
Technical Training	• Trained Observers on Manus to operate Hydrogen Generator June 1999. • Further training of Nauru Observers on Hydrogen Generator operations. • Overall review and revision of Manus and Nauru staff training plans April 1999.	• Management training for Officer in Charge, Manus on hold pending PNG NWS restructure. • Plan WMO training for Nauru Observer #2. • Periodic hands-on technical refresher training for Manus and Nauru Observers. • Additional computer training for Manus Observers.

7.0 DISTRIBUTION OF DATA

During the January – June 1999 period, we released the following data sets:

Manus:

August	1998
September	1998
October	1998
November	1998
December	1998
May	1998
June	1998
July	1998

Nauru:

November	1998
December	1998
January	1999
February	1999

Specific information on data availability by instrument and day can be found at: www.dmf.arm.gov.

Available data can be obtained from the ARM Experiment Center by contacting

ARM Experiment Center Manager, Ms. Robin Perez
robin.perez@arm.gov

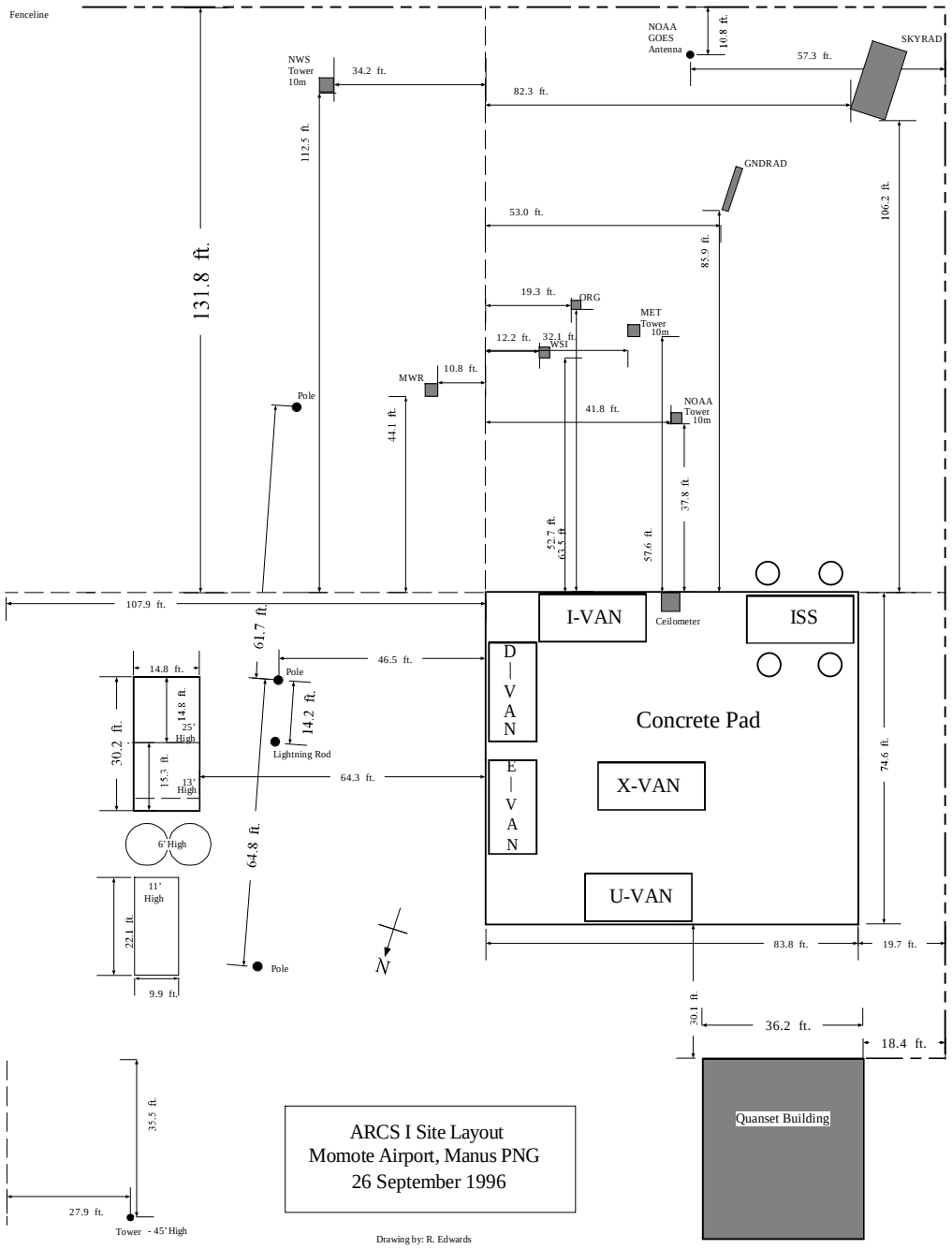
ACRONYMS

ACCESS	Automated Communication Control and Environmental Supervision System
ADaM	ARCS Data and Management System
ARCS	Atmospheric Radiation and Cloud Station
ARM	Atmospheric Radiation Measurement
ATLAS	Atmospheric Laboratory for Applications and Science
AVHRR	Advanced Very High Resolution Radiometer
AWOG	ARM Ocean Working Group
BBSS	Balloon Borne Sounding System
BNL	Brookhaven National Laboratory
CLASS	Cross-Chain LORAN Atmospheric Sounding System
CSP	Combined Sensor Program
DOE	U.S. Department of Energy
ECMWF	European Centre for Medium-Range Weather Forecasts
ENSO	El Nino Southern Oscillation
GNDRAD	Groundward Looking Radiometer Stand
GOES	Geostationary Operational Environmental Satellite
HRPT	High Resolution Picture Transmission
INU	Nauru
IOP	Intensive Operational Period
IRT	Infrared Radiometer
ISS	Integrated Sounding System
JAMSTEC	Japanese Marine Science and Technology Center
MAS	Manus
MFRSR	Multi-Filter Rotating Shadowband Radiometer
MPL	Micro-Pulse Lidar
MWR	Microwave Radiometer
N	Number
NCAR	National Center for Atmospheric Research
NIP	Normal Incidence Pyreheliometer
NOAA	National Oceanic and Atmospheric Administration
NSA/AAO	North Slope of Alaska and Adjacent Arctic Ocean
NTS	National Tidal Facility
NWS	National Weather Service
PIR	Precision Infrared Radiometer
PMEL	Pacific Marine Environmental Laboratory
PNG	Papua New Guinea
PSP	Precision Spectral Radiometer
RACE	Remote Accessibility Communication Equipment (ACCESS)
RASS	Radio-Acoustic Sounding System
RESET	REgional SErvice Team
SAM	Supervision and Management (ACCESS system)
SE	Significant Event
SGP	Southern Great Plains

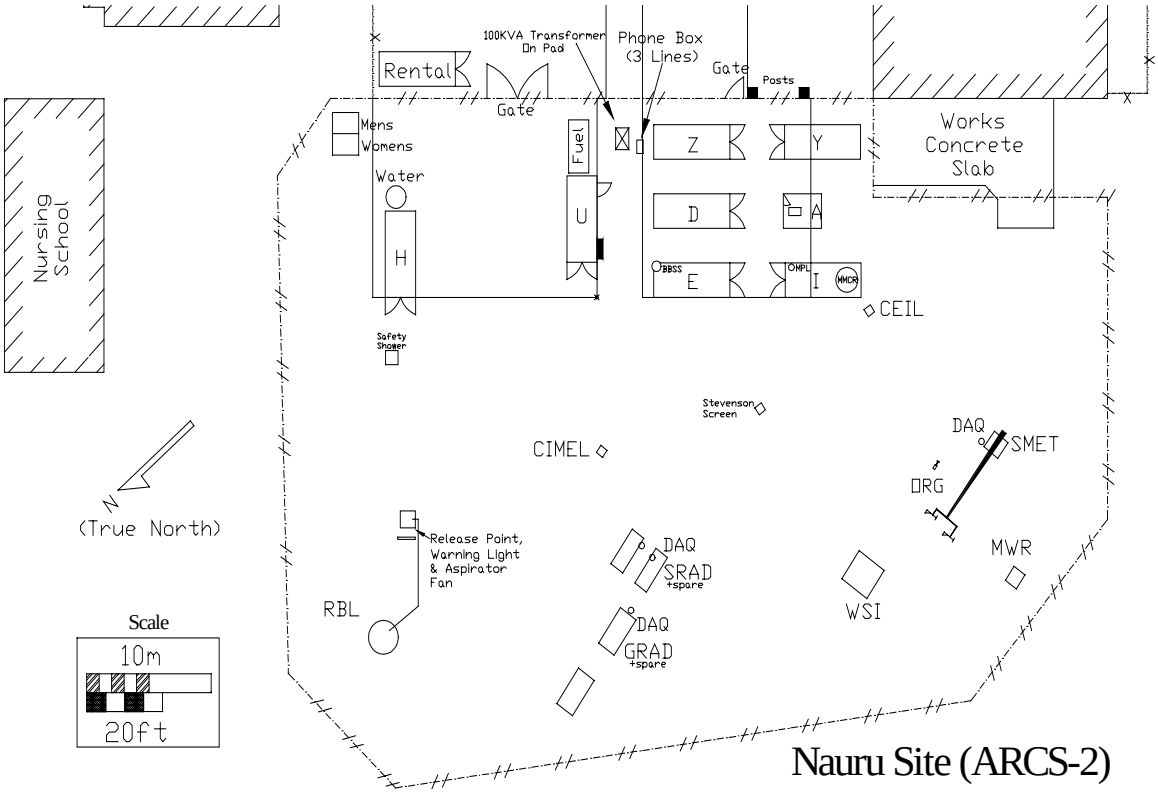
SKYRAD	Skyward Looking Radiometer Stand
SPaRCE	Schools of the Pacific Rainfall Climate Experiment
SPREP	South Pacific Regional Environment Program
SST	Sea-Surface Temperature
TAO	Tropical Atmosphere-Ocean
TOCS	Tropical Ocean Climate Study
TOGA	Tropical Ocean and Global Atmosphere
TOGA COARE	Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment
TRITON	Triangle Trans-Ocean Buoy Network
TWP	Tropical Western Pacific
VCEIL	Vaisala Ceilometer
VISSR	Visible and IR Spin Scan Radiometer
VOS	Volunteer Observing Ship
VSOS	Volunteer Ship Observing System
WMO	World Meteorological Organization

APPENDICES

A. Manus Site Layout



B. Nauru Site Layout



Nauru Site (ARCS-2)