FIRE

MARINE STRATOCUMULUS INTENSIVE FIELD OBSERVATIONS

June 29 - July 19, 1987

1987 OPERATIONS PLAN

MAY 1987

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1.0 INTRODUCTION

Project FIRE (First ISCCP Regional Experiment) is a U.S. cloud climatology research program to validate and improve ISCCP (International Satellite Cloud Climatology Project) data products and cloud/radiation parameterizations used in general circulation models (GCM's).

The goals of FIRE are (1) to seek the basic understanding of the interaction of physical processes in determining life cycles of cirrus and marine stratocumulus systems and the radiative properties of these clouds during their life cycles and (2) to investigate the interrelationships between the ISCCP data, GCM parameterizations, and higher space and time resolution cloud data.

The FIRE Implementation Plan (FSET, 1985) outlines a series of investigations and observations designed to meet the goals of basic understanding and parameterizations of cirrus and marine stratocumulus cloud fields and ISCCP data products. There are three components described in the Implementation Plan: a modeling component and two data gathering components involving Extended Time Observations (ETO) and Intensive Field Observations (IFO).

The Modeling component includes radiative transfer models, cirrus and marine stratocumulus physical process models, general circulation and climate models, and satellite retrieval algorithms. All FIRE modeling strategies seek (1) to compare the best current understanding of a phenomenon with observations of that phenomenon and (2) to extend that understanding by utilizing the models to extrapolate to other conditions.

The Extended Time Observations component will consist of coordinated satellite data, meteorological analyses, and data from a limited number of surface observing sites throughout the year over a four year period. These data will provide a means of extending the results derived in the more detailed Intensive Field Observation intercomparison studies to larger time and space scales. The ETO program will directly support the ISCCP and GCM validation efforts.

The ETO component is subdivided into two space scales: Extended Area (EA) and Limited Area (LA). The EA data set is meant to provide data over a large geographical area where occurrences of cirrus and stratocumulus cloud systems may be found in a variety of geographical locations, and to allow for multi-satellite, multiple-view observations of these systems. The LA data set is geographically specific to the location and surrounding area of surface observing sites being maintained throughout the FIRE experiment.

Although the results of the LA studies will be significant in and of themselves, it is their relationships to the other parts of FIRE marine stratocumulus studies that is most important. For example, preliminary cloud modeling results have shown that the linkage between fine-scale radiative and microphysical processes determines the overall character of a cloud in a given environment. However, the linkage between microphysical and radiative parameters in actual clouds is speculative. The LA studies will increase our understanding of this radiative microphysical coupling.

The Intensive Field Observations (IFO) data gathering component consists of separate field missions to study cirrus clouds over the mid-continental U.S. and marine stratocumulus clouds off the southwestern coast of California. The first cirrus mission was performed in October of 1986 in central Wisconsin; the Marine Stratocumulus Intensive Field Observations will be performed in July of 1987 in the vicinity of San Nicolas Island, California. Each three-week mission combines coordinated satellite, airborne, and surface observations with modeling studies to investigate the cloud properties and physical processes of the cloud systems. Both field missions will be repeated: the cirrus in the fall of 1989 and marine stratocumulus in July 1990.

There is a close relationship between the Intensive Field Observations and the Limited Area climatological studies. Results of the climatological studies will be used to evaluate the representativeness of the specific intensively observed cases. Results from the IFO's will be used to interpret the climatological studies.

The Marine Stratocumulus Intensive Field Observation program is planned to support research tasks requiring high time and space resolution information to marine stratus and stratocumulus cloud systems. In addition to supporting the marine stratocumulus studies, these data will be instrumental in the development of parameterizations of cloud-scale processes, based climate-scale variables, and a better understanding of ISCCP data products. The intensive field observations will be gathered from a variety of platforms on a relatively local, but regionally representative, geographical scale. Data will be collected from multiple satellites, aircraft, balloon, and surface-based instrumentation.

Two field experiments are planned with the first in July 1987 and the second in July 1990. Each will be three to six weeks in duration. A target of sixteen case study samples should be attainable in this two stage experimental setting. The two observational periods will provide an opportunity for researchers to develop strategies and instrumentation based on the experience and results of the first experiment. The planned two-phase intensive field program is especially important to reaching the goals of furthering our understanding of marine stratocumulus cloud systems to the point where reliable GCM parameterizations can be developed. For each field experiment there will be a period of preparation to allow time for the planning and development of suitable data acquisition and processing techniques. These planning activities will make use of both previous and concurrent experiments with related objectives. For example, DYCOMS (Dynamics and Chemistry of Marine Stratocumulus), was conducted in August 1985 off the California coast using the NCAR Electra in conjunction with a pre-FIRE field experiment involving the NOAA P3. The use of satellite observations to characterize the Cloud Topped Boundary Layer (CTBL) can begin immediately, using archived data. A full spectrum of modeling studies will contine throughout the experiment. There will be many opportunities for comparisons of field observations with model results.

This Operations Plan fully documents the detailed experiment and operation plans of the Marine Stratocumulus IFO data gathering component.

2.0 SCIENCE OBJECTIVES

2.1 General

During the Marine Stratocumulus IFO data will be gathered to support high spatial and temporal resolution studies of marine stratocumulus cloud fields. These observations will provide the greatest accuracy for validation of radiative transfer models, ISCCP cloud property retrievals, and GCM cloud models, but over limited areas and time intervals. Diagnosis of cloud processes requires not only careful measurement of the environment but also observations during the complete life history of cloud structure. The two new aspects of this field study for FIRE are: a. inclusion of simultaneous "cloud truth" observations to validate satellite measurements of the cloud environment, and b. observations of radiation from atmosphere, surface, and clouds to be related to satellite radiance measurements. The intensive measurements will be coordinated with satellite observations so that diagnostic results can be extended to scales of greater than 100 km and days.

In addition, the intensive phase will provide the opportunity for a three-platform intercomparison study. Ground, aircraft, and satellite measurements will be combined to infer the effects of processes that are extremely difficult to measure directly. For example, aircraft radiation measurements taken above the clouds will be combined with satellite measurements to deduce free-atmospheric radiative heating/cooling rates; likewise, ground and aircraft data will be used to deduce whole boundary layer heating rates. Furthermore, multiple aircraft flight levels will allow separation of free-atmospheric and boundary layer heating/cooling rates into discrete wavelengths associated with particular atmospheric constituents (H_2O, CO_2, etc.).

Radiative modeling is required in this analysis to test the accuracy of extending the "point" measurements to larger scales. Cloud process models are needed to attempt simulations of the observed time history and to understand the significance of the larger scale variations. GCM studies should concentrate on forecast studies to determine both the sensitivity of such forecasts to measured variables and the crucial quantities or statistics that must be measured to constrain parameterizations. Model studies should also be used to plan subsequent observational sequences.

2.2 Specific

The specific goals and research strategy of FIRE with respect to marine stratocumulus clouds are detailed in the FIRE Implementation Plan (FSET, 1985). The research strategy involves the application of strongly coupled observational and theoretical (modeling) approaches to consider cloud properties and relevant physical processes over a range of spatial and temporal scales. This strategy holds the most promise for achieving the FIRE goals with respect to marine stratocumulus. The Marine Stratocumulus IFO is the common element through which the required coupling is made.

The specific observational objectives of the Marine Stratocumulus IFO are as follows:

1. Determine the large scale structure of clouds and surrounding meteorological environment.

2. Characterize the fine scale microphysical, radiative, dynamic, and structure of marine stratocumulus clouds, with emphasis on multiple angular and spectral observations and characterization of the marine stratocumulus life cycle.

The specific objectives related to the understanding of the physical processes of clouds are as follows:

3. Determine the factors that affect the fractional cloudiness and cloud morphology.

4. Identify the role of cloud-top entrainment instability in determining cloud type.

5. Investigate the factors that determine the magnitude of the entrainment rate.

6. Determine how the diurnal radiation cycle is transmitted into a diurnal behavior of the cloud layer.

7. Determine how the maritime aerosols relate to droplet distributions in the stratocumulus clouds.

8. Identify "characteristic" large scale meteorological environmental features associated with stratocumulus.

lhe specific objectives related to modeling goals of FIRE are as follows:

9. Provide a data set to relate the (observed) microphysical structure of marine stratocumulus clouds to radiative properties as a function of convective structure meteorolgical environment conditions.

10. Provide a data set to relate the (analyzed) cloud structure and radiative properties to the radiation field as a function of spatial scale.

11. Provide a data set to seek the optimal means to describe the marine stratocumulus cloud field for diagnosis of large scale properties of radiative convergence/divergence and satellite observations.

12. Provide a data set to define the description of cloud properties and classification of marine stratocumulus clouds on various temporal and spatial scales. Specific cloud properties are: cloud topology (cloud size, horizontal and vertical aspect ratios, orientation angle of cloud street features, and cloud top texture) and cloud internal variability (liquid water content and hydrometer size distribution).

13. Provide a data set of multiple angular and spectral radiation observations for validation and improvement of radiation transfer models.

14. Provide a data set for statistical studies of cloud space and time spectra.

15. Provide a data set for validation and improvement of satellite cloud retrieval algorithms. Specific retrieval parameters are cloud cover and cloud height.

16. Provide a data set for validation and improvement of GCM parameterizations. Specific properties are: (a) large scale meteorological fields (winds, temperature, and water vapor) and satellite derived cloud properties (cloud fraction, cloud top height, albedo, and long wave emitted flux) at spatial resolution of 25 km and temporal resolution of 1 hour, and (b) satellite derived cloud properties and Marine Stratocumulus IFO observed cloud water content, cloud droplet size distribution, and cloud base altitude at spatial resolution of 1 km for a 500 km X 500 km region.

A summary of the observations necessary to address the specific scientific objectives is given in Table 2.2.

TABLE 2.2: SUMMARY OF INTENSIVE OBSERVATIONS

1. Aircraft:
   a. Direct Observations
      i. Entrainment rate (through inversion budgets)
      ii. Thermodynamic profiles of mean and turbulent variables, particularly for adjacent cloudy and cloud-free environments.
      iii. Radiative flux profiles
      iv. Cloud drop size distribution
      v. Photography, particularly showing details of cloud top morphology
   b. Validation Platform for Remotely Sensed Parameters
      i. Lidar, cloud top morphology
      ii. Radiometry, satellite calibration
      iii. Microphysical probes, cloud liquid water structure
      iv. Turbulent flux probes, turbulence parameters

2. Surface-Based Observations:
   a. Radar, Microwave Radiometer, and Doppler Sodar
      i. Cloud structure
      ii. Variability of liquid water within cloud system
      iii. Cloud and subcloud layer kinematics (doppler), velocity statistics that contribute to the turbulence kinetic energy budget, and measurement of the entrainment rate.
   b. Tethered Balloon
      i. Turbulence measurements
      ii. Radiometric measurements
      iii. Microphysical measurements

TABLE 2.2: SUMMARY OF INTENSIVE OBSERVATIONS (continued)

c. Surface and Tower

i. Turbulence measurements

ii. Radiometric measurements

iii. Microphysical measurements

d. Rawinsonde and Cloud Ceilometer

i. Vertical structure of temperature, dewpoint, and horizontal winds throughout boundary layer and free troposphere

ii. Cloud base height

e. Constant-level Balloons

i. Low level trajectories

ii. Pressure, height and temperature.

3.0 PLATFORMS, INSTRUMENTS, AND MEASUREMENTS

3.1 Satellite

Satellite data are required on a daily basis for the period beginning one week prior to the Intensive Field Experiment, during the experiment, and one week following the field program.

The data will be collected for the IFO region (see Figure 3.1) defined by 30N to 40N and 117.5W to 137.5W as follows:

1. NOAA AVHRR HRPT Data: 1 km resolution, 5 spectral bands, 2 satellites, day and night.

2. NOAA AVHRR GAC Data: 5 spectral bands, 2 satellites, day and night. This data is the reduced resolution version of the HRPT data.

3. NOAA TOVS Radiance Data: 20 spectral bands, 2 satellites, day and night.

4. GOES VISSR Data: 1 km resolution visible channel and 8 km resolution infrared data, every 30 minutes through the 3-week experiment period from the GOES satellite, or GOES West if there are two satelletes. These data will ensure an average separation of AVHRR/ TOVS data from GOES data of 7.5 minutes.

5. GOES VAS Sounder Data: During the FIRE IFO period, the GOES VAS data will be obtained from the GOES satellite. VAS data should be simultaneous with the TOVS data whenever possible. In addition, on at least 7 of the 21 experiment days, a 3-hour period coincident with aircraft flights should be used to obtain dedicated VAS sounder data with 30 minute time resolution and 7 km spatial resolution.

6. LANDSAT Thematic Mapper Data: For the IFO data period, several LANDSAT Thematic Mapper scenes will be collected. Each scene covers a 180 km square region. At 35N (midpoint of IFO region) adjacent LANDSAT orbits are separated by 125 km, giving 55 km overlap between LANDSAT scenes taken from adjacent orbit paths. Orbit repeat cycle is 16 days so that the satellite ground track passes over the same point every 16 days. For a given target point, LANDSAT will sample 3 adjacent orbit paths as follows: (path 1 on days 1 and 17, path 2 adjacent to the east on days 10 and 26, and path 3 adjacent to the east of path 2 on days 3 and 19. For a 3-week experiment, 5 LANDSAT orbits will fall within an east-west distance of 250 km. For the FIRE IFO, 2 along-orbit scenes will be collected for each of these orbits giving 10 LANDSAT scenes with a

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INTENSIVE FIELD OPERATIONS AND EXTENDED TIME STUDIES

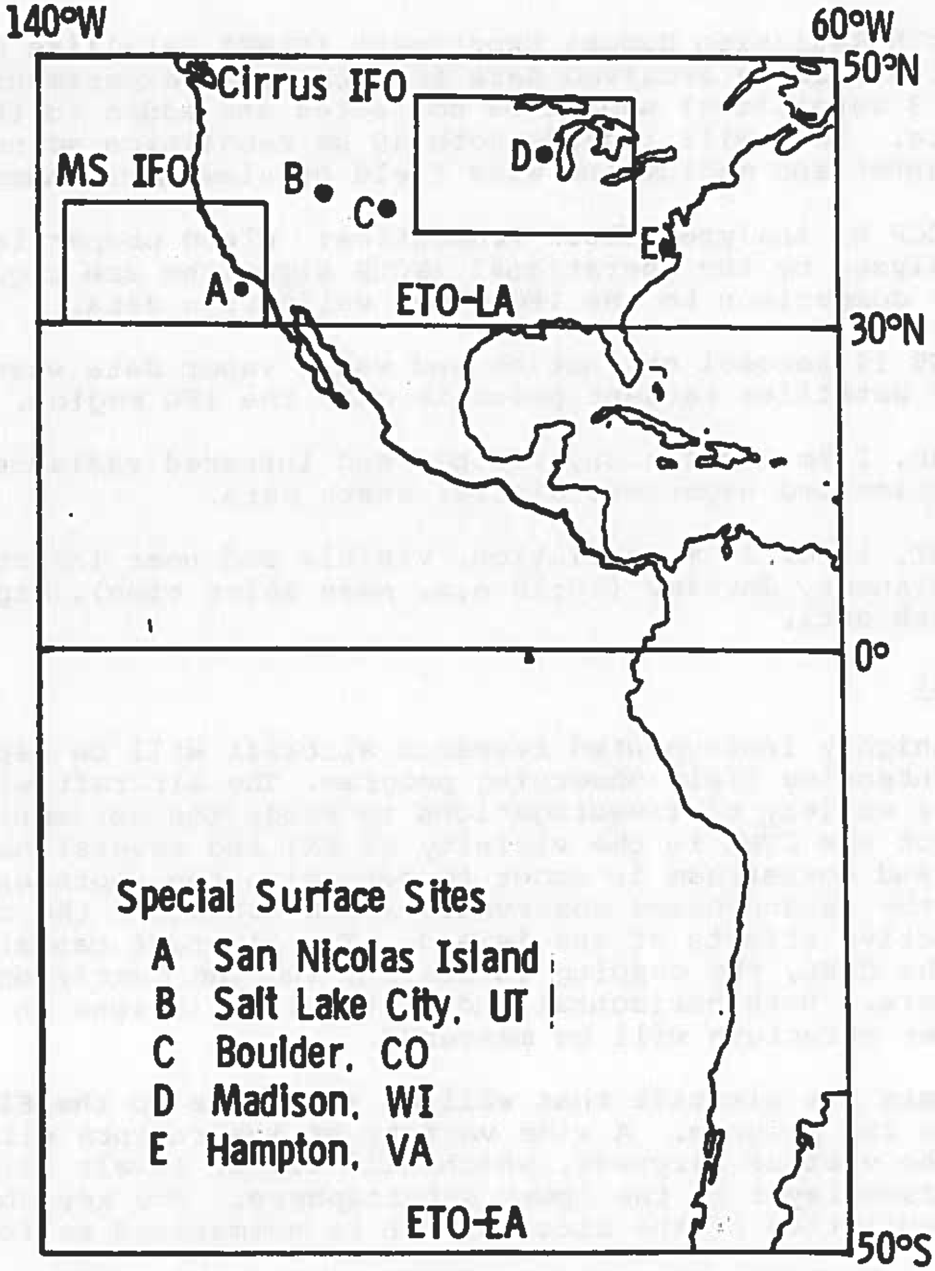


Figure 3.1 - FIRE ETO and IFO Regions and Special Surface Sites

coverage of 180 km by 350 km 5 times during the IFO experiment. The LANDSAT orbit GMT time of the data will be the same within plus or minus 1 minute for all 5 orbits sampled.

This time can be predicted well in advance (approx. 10:45 a.m. local time) for any region so that simultaneous GOES, aircraft, and surface based data can be taken at these times.

7. Earth Radiation Budget Experiment (ERBE) Satellite Data: All available archived data from the ERBE experiment (up to 3 satellites) should be collected and added to the IFO data. This will include both 30 km resolution scanner scanner and medium and wide field of view nonscanner data.

8. ISCCP B3 Analyzed Cloud Properties: Cloud properties as analyzed by the operational ISCCP algorithm are required for comparison to the IFO cloud validation data.

9. SAGE II aerosol extinction and water vapor data whenever the satellite tangent point is over the IFO region.

10. DMSP, 1 km resolution, visible and infrared radiances, daytime and nighttime, digital swath data.

11. SPOT, 10 or 20 m resolution, visible and near infrared radiances, daytime (10:18 a.m. mean solar time), digital swath data.

3.2 Aircraft

A number of highly instrumented research aircraft will be deployed during the intensive field observing program. The aircraft will be used for a variety of investigations to study the horizontal variability of the CTBL in the vicinity of SNI and several hundred km upstream and downstream in order to determine the representativeness of the island-based observations and establish the magnitude of advective effects at the island. The aircraft can and will probe the CTBL, the capping inversion, and the overlying free atmosphere. Both horizontal and vertical variations in boundary layer structure will be measured.

Table 3.2 lists the aircraft that will be available to the FIRE Stratocumulus IFO program. A wide variety of instruments will be carried on the various aircraft, which will fly at levels ranging from the surface layer to the lower stratosphere. The key observational capabilities of the aircraft can be summarized as follows:

1. fast response (~10 Hz bandwidth) measurements of air velocity components and scalar variables to be

TABLE 3.2 - AIRCRAFT PARTICIPATING IN THE MARINE STRATOCUMULUS IFO

Aircraft	Home Institution	Measurements	Flight Level	Funding
ER-2	NASA/AMES	lidar, radiation	lower stratosphere	NASA
Electra	NCAR	turbulence, radiation, cloud microphysics	PBL	NCAR
C-131	U. Washington	radiation, cloud microphysics	PBL	NSF
C-130	British Meteorological Office	turbulence, radiation, cloud microphysics	PBL	BMO
Piper Navajo	NOSC/San Diego	aerosols	PBL	NAVY
Beech Baron	NOAA/ARLFRD	balloon reconnaisance	mid-level	NASA

used for turbulence flux estimates and other turbulence statistics;

2. mean in situ measurements of wind and scalar variables;

3. remote sensing with radiometers and lidar;

4. accurate horizontal and vertical aircraft positioning, and measurements of air chemistry (for entrainment rates).

The nominal horizontal resolution/sampling interval is ~100 m or less for most airborne systems, with turbulence systems measuring to about 5 m. The cloud lidar will generate a high resolution description of cloud base and top heights, areal cloud fraction, particle phase and orientation, and cloud optical depths at the sampled wavelengths. Other radiometric instrumentation will serve to define the upwelling and downwelling broadband fluxes and spectral radiances. The aircraft observations will also permit direct analysis of the fine-scale structure of the temperature, humidity, and motion fields.

The aircraft will be based at three locations. The ER-2 will be located at NASA Ames Research Center, Moffett Field, California. The C-131, C-130, and Electra will be located at NAS North Island, San Diego, California. The Piper Navaho will be located at Montgomery Field, San Diego, California.

NASA ER-2 Instrumentation

A downward pointing lidar and a multispectral cloud radiometer will fly on the NASA ER-2 in the lower stratosphere, for the purpose of mapping the structure of the cloud-top surface. This will provide high-resolution data on the entrainment process at the cloud top, and will also give quantitative information about the small scale structures of in-cloud turbulent elements. It will be particularly useful in cases where the cloud is in the process of breaking apart. The ER-2 will also be instrumented with a multispectral cloud radiometer, to measure cloud optical and radiative properties, and a thematic mapper simulator that mimics the AVHRR satellite instrument. ER-2 flights will be coordinated with coincident flights by the University of Washington C-131A cloud/aerosol research aircraft that will provide the necessary in situ measurements to allow the cloud microphysics and radiative properties to be related. The ER-2 will be used as a "mini" satellite to provide full coverage of a 200-by-200 km area in a 3-hour period by the onboard scanning radiometers to a 50 m resolution.

The following instrumentation is available for operation from the ER-2 platform (see Appendix A.2 for more details):

1. Cloud Lidar System (CLS) - a downward pointing Nd

and doubled Nd (1.064 and 0.532 μm) dual polarization lidar with ~7.5 m vertical resolution and 50 m horizontal sampling interval.

2. Multispectral Cloud Radiometer (MCR) - a scanning (45° cross-track) multispectral (0.754, 0.760, 0.763, 1.644, 1.713, 2.164, 10.070 μm) radiometer with resolution of about ~100 m at the nadir, sample synchronized with CLS and simultaneous in all channels.

3. Daedelus Scanning Cloud Radiometer - a scanning (84° cross-track) multispectral (6 visible, 0.83, 0.98, 3.7, 11, 12.5 μm) radiometer with resolution of about ~50 m at the nadir, channelization allows use as a NOAA-PO AVHRR/HRPT simulator in addition to its use as a LANDSAT/5 thematic mapper simulator.

4. Two channel IR broadband hemispherical flux radiometer flipping up and down.

5. Narrow spectral bandpass, narrow field of view down-looking 2 channel IR radiometer.

6. Hemispherical solar flux radiometers upward and downward looking.

7. Narrow spectral bandpass hemispherical solar flux radiometer.

8. Temperature and Pressure Probes.

9. INS Wind System.

10. Down-looking Vinton 90 mm camera.

NCAR Electra Instrumentation

The NCAR Electra aircraft will be used as an in situ sampling platform. It will specialize in microphysical measurements and air motion sensing within the marine stratocumulus cloud layer. The aircraft is equipped with a nose-boom-mounted gust probe system for turbulence measurements, as well as a wide variety of other sensors, including cloud microphysics and radiation instruments. It will complement both the ground-based and satellite observations. It will be used in FIRE to make cross-wind and along-wind measurements in the vicinity of SNI in coordination with the ground, satellite, and other aircraft observations and will be used to sample the undisturbed boundary layer away from the island. In addition, complementary atmospheric chemistry measurements will be made to provide additional insight on the entrainment process and coupling between cloud and subcloud layers.

The following instrumentation is available on the NCAR Elecrtra: (see Appendix A.2 for more details).

1. Winds: Gust probe, inertial navigational system

2. Temperature: Rosemount, NCAR, reverse flow, fast response, radiation

3. Water Vapor: Lyman-Alpha Hygrometer, dewpoint hygrometer

4. Liquid water droplet distribution: Knollenberg, Johnson-Williams liquid water, and King CSIRO Probe.

5. Shortwave and Longwave Irradiances: Eppley Pyranometers and pyrgeometers

6. Ozone: Pearson-Stedman

7. Cloud Structure: Lidar

8. Atmospheric Chemistry: Nitric acid, cloud water.

<u>University of Washington C-131 Instrumentation</u>

The University of Washington (UW) C-131 cloud and aerosol research aircraft will provide cloud microphysics observations on the cloud particle size distribution, thermodynamic phase, and liquid water and ice water contents. A multichannel scanning radiometer designed to derive the spectral single scattering albedo of clouds will also fly (see Appendix A.2 for more details). The following instrument systems will be available for FIRE:

1. Meteorological quantities: Horizontal winds, temperature, dew point.

2. Cloud physics: 5 PMS probes, hydrometeor phaze, King and JW liquid water probes.

3. Radiometric: NASA Cloud Absorption Radiometer, up and downward pyranometers, UV radiometer.

4. Aerosol physics: Aerosol size, macro and optical properties outside of cloud and interstitially between droplets.

<u>British Meteorological Office C-130 Instrumentation</u>

The British Meteorological Office (BMO) C-130 aircraft will be used as an in situ sampling platform to measure thermodynamics (including fast response Lyman-Alpha hygrometer), radiation (both visible and infrared), and cloud microphysics. It is also equipped with a nose-boom-mounted gust probe sensors for turburlence measurements.

The following instrumentation will be available and generated from the C-130 platform (see Appendix A.2 for more details):

1. Winds: Gust probe, inertial navigation system

2. Temperature: Rosemount, CO_2 in cloud radiation thermometer*

3. Water Vapor: Hygrometer, microwave refractometer

4. Liquid Water: Johnson-Williams

5. Total Water content: Lyman-Alpha Hygrometer

6. Shortwave and Longwave: Eppley pyranometers and pyrgeometer, Barnes PRT-5, multi-channel radiometer*

7. Particle size distribution: FSSP, 2D-cloud; 2D-Precip; holographic camera

8. Beta scattering aerosols: Nephelometer

<u>NOSC Piper Navaho Instrumentation</u>

The NOSC Piper Navahoe will be used as an insitu sampling platform to measure cloud microphysics and ambient meteorology in a profiling mode.

The following instrumentation will be available and operated from the Piper Navahoe platform (see Appendix A.2 for more details):

1. Particle size distribution: Knolleberg probes

2. Temperature: Rosemount probe

3. Dew point: EG and G hygrometer

4. Sea surface temperature: Barnes PRT-5

5. Winds: Loran C navigation system

<u>NOAA/Constant-level balloon tracking</u>

3.3 Surface

The Marine Stratocumulus IFO will be conducted over the eastern Pacific Ocean off the southwest coast of California. A number of surface-based observations will be performed along the California coastline (see Figure 3.3.1).

First, the rawinsonde stations operated by NOAA/NWS at Montgomery Field, Vandenberg AFB, and Oakland will make standard rawinsonde releases. These measurements will be augmented with rawinsonde releases from Pt. Mugu and SNI. Second, Pt. Mugu operates a network of surface meteorological stations at Pt. Mugu, Santa Barbara Island, San Miguel Island, and SNI to measure temperature, humidity, and winds. Third, the Pennsylvania State University and Naval Postgraduate School will monitor the release and downwind track of constant level balloons. The balloons will provide crucial information on the movement of marine boundary layer air as it moves downwind over time, thus allowing the various aircraft to measure the evolution of marine clouds over 24-48 hours. The balloons will be released from a ship that will be located several hundred km upwind of SNI. The fourth and largest component will be a large complement of measurements from SNI.

SNI, operated by the U.S. Navy Pt. Mugu Pacific Missile Test Center, is a small base (airport, harbor, housing, food services, etc.) that is maintained primarily for radar tracking (see Figure 3.3.2 and Appendix E. The island is relatively small and minimally disrupts the marine boundary layer flow; climatological data show that the northwest tip of the island receives marine flow more that 60% of the time; marine stratocumulus clouds occur approximately 38% of the time during the month of July. As part of the Pacific Missile Test Center, the island has very good support facilities for scientists and their experiments. The restricted airspace around the island will eliminate any conflict with commerical air traffic. Collaboration with the Naval Postgraduate School and Naval Research Laboratory personnel will be optimized as a result of their access and previous utilization of the SNI facilities. The NW tip of the island has a fully instrumented micrometeorological tower (at the high tide line) that has been used for marine surface layer research.

High temporal resolution observations of the mean, turbulence, radiative and microphysical characteristics of marine stratocumulus will be obtained from San Nicolas Island. These observations will be made using surface, tower, rawinsonde, balloon, sodar, ceilometer, radar and microwave radiometer measurements. A detailed description of the instrumentation to be based on SNI during the stratocumulus IFO are described in Appendix A.3. A general description is included here.

<u>Tower</u>

A 19m tower located on the NW tip of the island will be instrumented and operated by the Pennsylvania State University. The tower will provide continuous measurements of baseline meteorological data - sea surface temperature, humidity and winds. Additionally, the tower will provide turbulence measurements that will be used to obtain the surface fluxes of sensible and latent

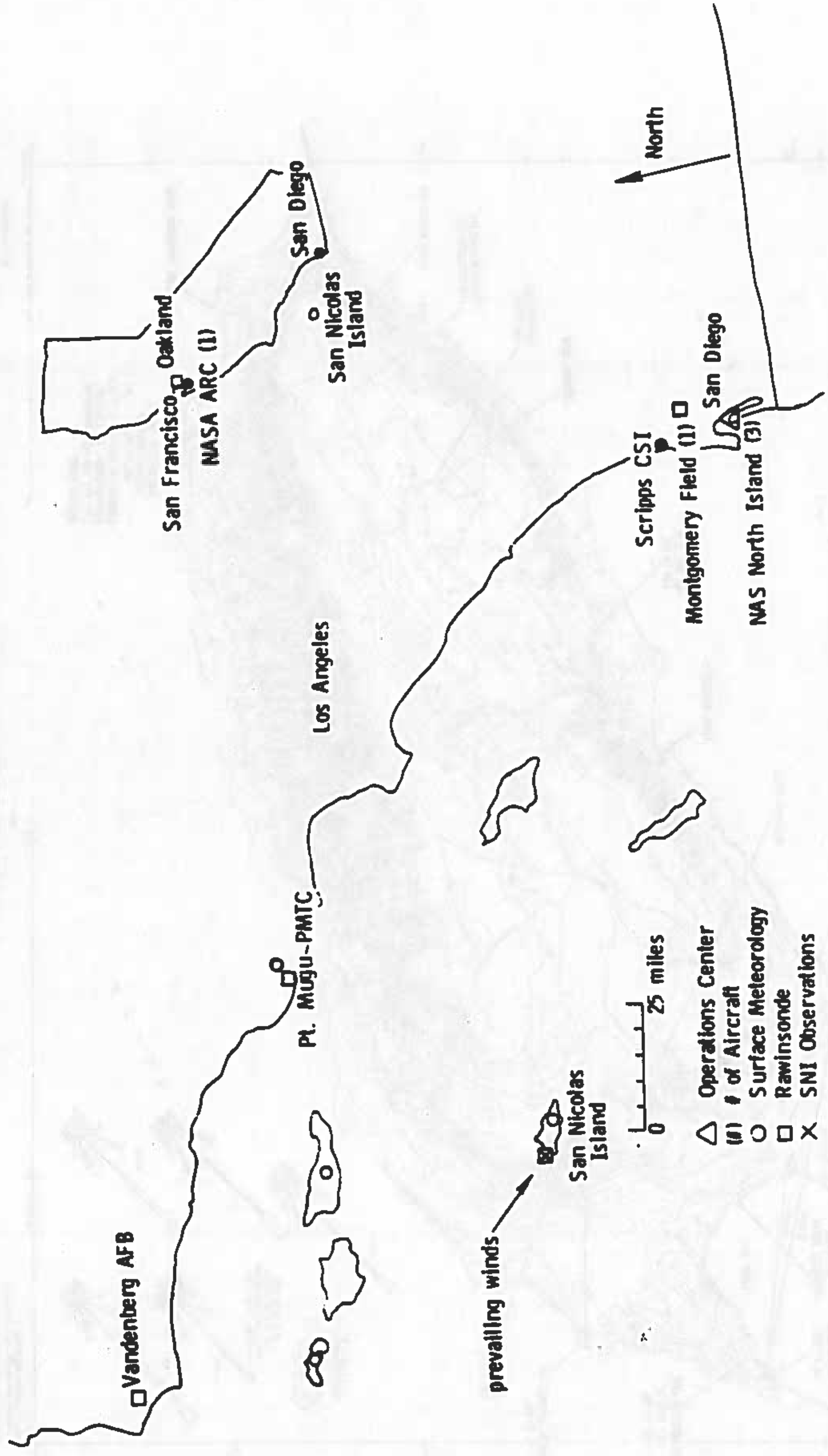


Figure 3.3.1: Surface Based Instrumentation

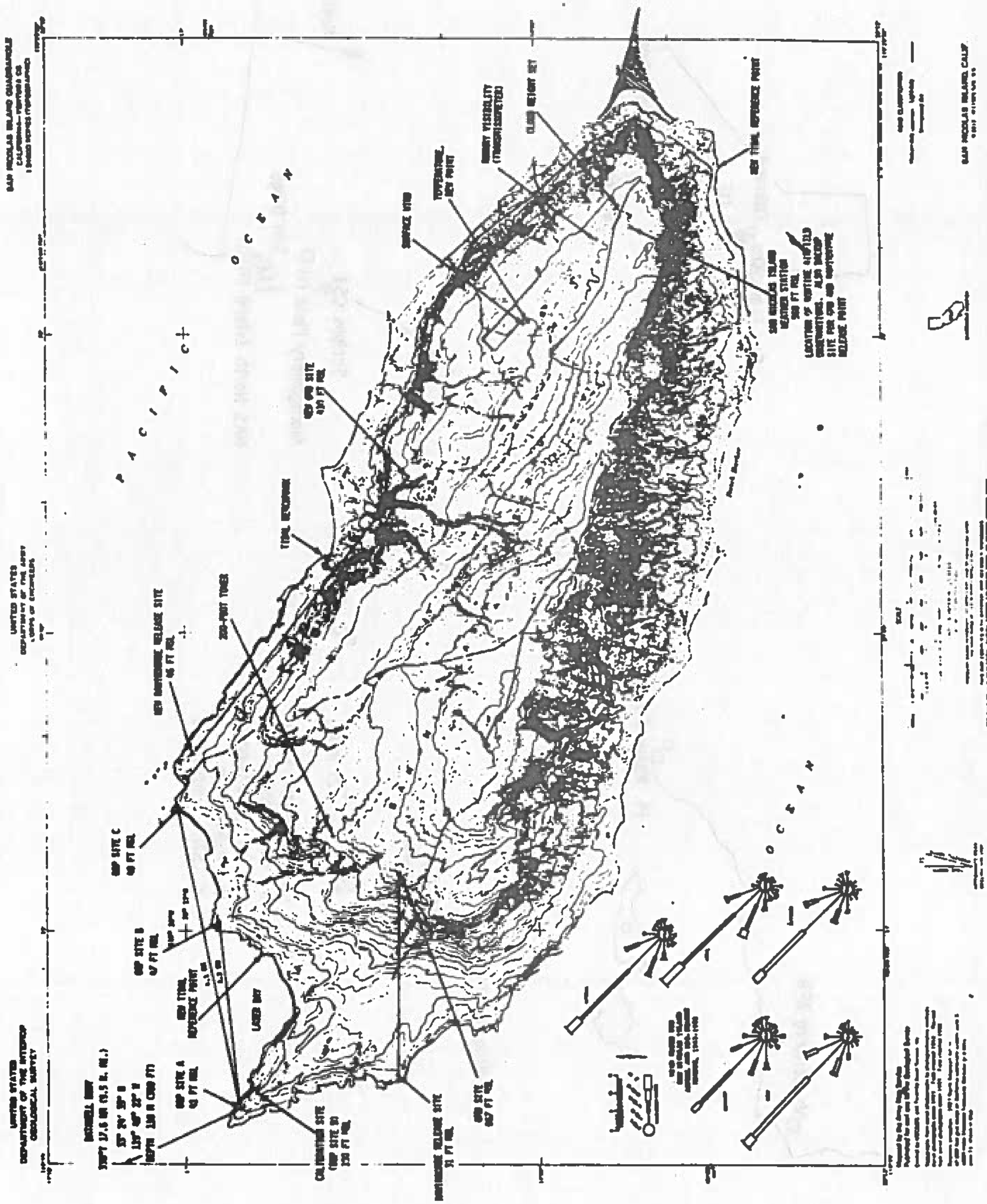


Figure 3.3.2: San Nicolas Island

heat. An optical particle counter will be used to obtain aerosol size spectra. The tower measurements are intended as a lower boundary condition for MABL model, a constant source of baseline calibration data for aircraft and balloon meteorological sensors, and baseline aerosol data for selecting the cloud microphysics.

Surface Radiation

Several measurements of downward shortwave and longwave radiation fluxes will be made using standard pyranometers and pyrgeometers and other instruments from Pennsylvania State University and Colorado State University. The ETO system will be already located near the tower site. These instruments may be supplemented with additional, but similar, sensors that will be tied into the tower data acquisition system. This will allow for redundancy and faster sample rates. Spectral radiances will be obtained and IR sky temperature will be obtained with a Barnes PRT-5. These data will be used in conjunction with aircraft and satellite data in verification studies of radiative transfer models.

Rawinsonde

Temperature, humidity, and wind profiles will be obtained from San Nicolas using the NCAR/CLASS rawinsonde system operated by Colorado State University. The frequency of launches will depend on weather conditions and will vary from 2 to 8 per day. Soundings from existing rawinsonde stations (Montgomery Field, Oakland, Pt. Mugu, and Vandenberg AFB) can be used to define the winds and thermodynamic structure in the area surrounding SNI. Soundings may also be obtained from the Point Sur ship when it is in the vicinity of SNI.

Sodar Measurements

The Pennsylvania State University doppler sodar will be used to provide continuous measurements of a variety of MABL dynamical properties. The doppler shift of the return signal provides air motion information and the intensity of the return is a function of the imbedded microturbulence.

Since the microturbulence is present throughout the MABL, this information is obtained in both the subcloud and cloud layers. Mixing of recently entrained air at the top of th MABL causes a greatly enhanced signal at Zi. Thus, the sodar data is particularly reliable in the entraining region. Profiles of mean wind and wind variances are typically obtained with 50 m resolution after averaging for 15 minutes. Under good conditions, intensity and vertical velocity interaction from individual sound pulses can be used (this gives a temporal resolution of about 30 m). This provides high temporal resolution measurements of Zi and inversion layer turbulence properties plus MABL vertical velocities that can be used in entrainment and conditional sampling studies.

Combined with the tethered balloon and aircraft turbulence measurements, these data will be used to investigate the relation of small scale turbulence and MABL structure to the entrainment process.

Doppler Radar

The Pennsylvania State University 404 Mhz doppler wind radar system will be used during the IFO period to define the temporal variation of cloud structure and the associated variations in the turbulence scale vertical velocity. The radar will be used to define cloud-top structure in the vicinity of the inversion for the study of entrainment processes. The measurements made with the radar will be used in conjunction with other remote and direct measurements being made at the island. The radar will provide a description of cloud structure that can be compared with that obtained from satellite measurements and aircraft observations in the vicinity of the island. Radar measurements will be during periods designated as extensive data collection periods or when scientists on the island determine that conditions are suitable.

Microwave Radiometer

The NOAA Wave Propogation Laboratory two-channel microwave radiometer will provide a detailed time series of the integrated liquid water and water vapor content of the atmospheric column. The total water measurement will support and complement the sodar, balloon and radar measurements. The liquid water measurements will be most useful when there are no clouds overlying the low-level clouds. Rawinsondes, aircraft or satellite will be used to establish conditions above the boundary layer.

Ceilometer

The NWS will operate a Varsilla Ceilometer system on SNI to measure the cloud base heights on a continuous basis. This information is crucially needed to properly interpret the downwelling longwave radiation measurements, especially in the presence of low clouds.

Tethered Balloons

Two tethered balloons will be available for use during the IFO. One is a balloon that will be deployed from San Nicolas Island during the summer of 1987 as a part of EOMET, a NRL/NOSC program. This balloon has a payload capacity of 140 kg. The balloon instrument package is equipped with a temperature and pressure sensor, a wet bulb psychrometer, a saturation hygrometer and a forward scattering probe that measures liquid water. Since the balloon has a greater capacity than needed for this instrumentation, FIRE investigators may be able to work jointly with Navy researchers to provide measurements that would complement the measurements planned for EOMET. The balloon has sufficient capacity to allow the period June 7-11. The deployment point will be approximately 100-200 miles west of Santa Cruz, California. The actual time and location of the launches will be determined by meteorological conditions. An attempt will be made to launch balloons that will not drift into the restricted air spaces as they move southward. The balloons will be tracked by an aircraft operated by NOAA/ARLFRD. The balloon positions will be reported to North Island. There will be contact from the ship to shore through a single side-band radio. In addition, there will be direct ship-to-aircraft, aircraft-to-shore, and aircraft-to-aircraft radio links.

4.0 EXPERIMENT DESIGN

4.1 Site

The surface installations may be considered as eight distinct entities, which are:

1. Operations Center - consisting of a centralized communications facility and housing the Mission Planning Team. This center will be at NAS North Island, San Diego, California.

2. Forecast Center - consisting of the forecast team and required support facilities including real time access and interactive processing and display capabilities for GOES satellite data and NWS data and analysis products. This center will also be at NAS North Island California.

3. Surface Observing Site - consisting of a complex of in situ and remote instruments operating from surface, tower, balloon, and sonde platforms to measure the aerosol properties, dynamics, downwelling radiation, range-resolved clouds and aerosols, and meteorology of the marine environment. This site will be San Nicolas Island.

4. Conventional Rawinsonde network - consisting of three NOAA/NWS stations at Oakland, Montgomery Field, and Vandenberg AFB. Extra launches on high priority days will be made from Vandenberg AFB. Two launches per day are made during weekdays from SNI and PMTC.

5. Aircraft Base 1 - housing the NASA ER-2, the flight and ground crew, instrument scientists and technicians, and facilities for maintenance and operation of this aircraft. This base will be at Ames Research Center, Moffett Field, California.

6. Aircraft Base 2 - housing the NCAR Electra, University of Washington C-131, British Meteorological Office C-130, the flight and ground crews, instrument scientists and technicians, and facilities for maintenance and operations

measurements of cloud droplet spectra using an optical scattering droplet spectrometer. A turbulence probe and radiation sensors would further the usefulness of the EOMET balloon package for cloud microphysical measurements during FIRE.

The second, significantly larger tethered balloon has been developed by the Wallops Flight Facility of the NASA/Goddard Space Flight Center. It is portable, and has flown at various sites including Virginia and Alaska. It is 31.6 m long, has a volume of 1275 m^3, and under zero-wind conditions can lift a payload of approximately 400 kg to an altitude of 1 km. It is capable of operating in flight-altitude winds exceeding 25 $m\ s^{-1}$.

This balloon will carry instrument packages that have been designed and built by the British Meterological Office. A total of 5-10 packages will be attached at various intervals along the balloon's tether to provide simultaneous measurements at several levels. Each package can measure temperature, pressure, humidity and the 3 wind components. These packages can be used to obtain both the mean and turbulence structure. Each package has its own telemetry system. There is a possibility that some or all of the instrument packages will be equipped to measure radiative fluxes and liquid and total water content. Constant level measurements will be used to obtain turbulence quantities. Detailed vertical structure will be obtained using the balloon in a profiling mode.

The balloon will also carry a large gondola of instruments designed and built by Colorado State University. The instruments, which will fly about 200 feet below the balloon, will measure the radiation, microphysics, and meteorology properties of the marine clouds. Detailed vertical structure will be obtained using the balloon in a profiling mode.

As with the Navy balloon, the Wallops balloon will have sufficient payload capability to include instruments from the NRL/NOSC project. The capability for both balloons to incorporate instruments from all three groups will allow for maximum flexibility in case of balloon equipment problems, etc.

Ship Point Sur

The Naval Postgraduate School will operate the Ship Point Sur in the vicinity (upwind) of SNI during the IFO. Observations include radiation, aerosols, microphysics, sea state parameters, and meteorology. A rawinsonde system will also be included. A detailed description of the instrumentation is given in Appendix A.

Constant-Level Balloons

Approximately 15 constant-level balloons (tetroons) will be launched from a chartered ship the Shana Rae (an Alaskan tuna boat). These balloons will be used to track boundary layer motions along the California coast. They will be launched sometime during of these aircraft. This base will be at NAS North Island, San Diego, California.

7. Aircraft Base 3 - housing the NOSC Piper Navaho aircraft, the flight and ground crews, instrument scientists and technicians, and facilities for maintenance and operations of this aircraft. This base will be located at Montgomery Field, San Diego, CA.

8. Aircraft Base 4 - housing the NOAA Beech Baron aircraft for tracking of the constant level balloons. The base has not been identified as the Beech Baron will land at targets of opportunity fields along the California coast as it follows the balloons southward.

9. Ship Point Sur - The ship will be located upstream from of San Nicolas Island.

4.2 Simultaneous Satellite/Aircraft/Surface Observations

One of the key elements of the FIRE plan is to obtain a set of aircraft surface observations which are time and space coincident with satellite overpasses. The most critical coincidences are between the aircraft, SNI, and either LANDSAT or NOAA AVHRR-HRPT observations. The SPOT, LANDSAT and HRPT data provide the highest spatial resolutions (10 meter, 28.5 meter and 1.1 km respectively) allowing the most direct comparisons of aircraft surface and satellite radiance data.

The SPOT, LANDSAT and GOES satellites will have overpass times above SNI that are invariants from day to day (within less than 1 minute). The NOAA polar orbiter (TOVS, AVHRR, ERBE), the ERBS satellite (ERBE, SAGE-II), and the DMSP satellite will have SNI overpass times that vary as much as an orbital period (approx. 100 minutes). A summary of the time coincidence for each satellite is given below.

Preliminary estimates of times of potential coincident satellite observations within the field site and surrounding region, (30N to 40N and 117.5W to 137.5W, see Figure 3.1) will be included in the operations plan. This will allow targeting of specific "most opportune" times for aircraft and surface operations.

4.2.1 GOES Satellite Data

The GOES satellites start an Earth scan at the North Pole, and scan the Earth's disk from north to south in approximately 18 minutes. GOES East scans start on the hour and the half hour, GOES West scans start at 15 minutes past the hour and 45 minutes past the hour. Currently one GOES satellite is operational, with scans starting on the hour and the half hour. The time of GOES observations for any surface station is simply a function of the latitude of the surface station and is given by

$$T = T_{start} + 9*(1-\sin\theta)$$

where θ is the latitude (positive north, negative south, T is in minutes, and T_{start} is at the time at which the GOES scan starts.

4.2.2 LANDSAT Satellite Data

Currently LANDSAT 5 is the primary LANDSAT satellite. Data is operationally acquired over the entire continental U.S. The LANDSAT orbit is adjusted as necessary to maintain the sampling time for each region constant to within 1 minute. LANDSAT data is collected in "scenes" which are 180 km by 170 km in size. The satellite views the scene area in approximately 170 km / (7 km/sec) = 24 seconds. Since LANDSAT only acquires data immediately beneath the satellite (viewing zenith angles within 7 degrees of nadir), complete Earth coverage requires many days of sampling. The orbit has been designed so that each LANDSAT scene is viewed once each 16 days. Therefore for a given surface observation site, LANDSAT data will be taken over that site once every 16 days at the same GMT time each day. Appendix D gives a sample of the overpass times for SNI, California.

4.2.3 NOAA Polar Orbiter Satellite Data

NOAA overpass times for a given surface site will vary by up to 100 minutes from day to day. Predicted satellite orbital elements are used to predict the viewing conditions (time and viewing angle) for each day of the year for selected ET-LA surface sites. Because the NOAA satellite orbits are not continually adjusted like the LANDSAT satellites, the orbits drift in time. It is estimated that predicted satellite overpass time are accurate to plus or minus 5 minutes. Overpass times have been calculated for each day of the year for the SNI, California area from April 1986 through December 1986. Updates to these overpass times will be issued at every 6 months beginning in December, 1986. Experience with the accuracy of the orbital predictions will dictate if more frequent updates are required. Appendix D gives a sample of the overpass times and viewing angles at SNI, California.

4.2.4 Earth Radiation Budget Satellite (ERBS)

The primary surface/satellite coincidence target for this satellite is the SAGE II solar occulatation measurement. This measurement is taken at sunrise/sunset and coincidence times will vary from surface site to surface site. Observation days will be scattered through the year for any given site. Appendix D gives the times and locations of the tangent point occultations for the SNI, California region.

4.2.5 DMSP Satellite Data

To be supplied by J. Bunting, AFGL.

4.2.6 SPOT Satellite Data

SPOT data scenes are 60 km square (at nadir) with oblique viewing up to 26° from nadir. The sun-synchronous orbit overpasses the SNI area at 10:18 a.m. mean solar time and repeats every 26 days. The oblique viewing capability allows for about a dozen viewing opportunities over the 3-week mission. Either panchromatic (single channel; 0.5 - 0.7 micron; 10 m resolution) or multispectral (3 channels; 0.5 - 0.6, 0.6 - 0.7, 0.8 - 0.9 microns; 20 m resolution) digital data is available.

4.3 Flight Constraints

The next section (4.4 - Experiment Plans) has the detailed flight plans for each of the experiment objectives. The flight plans will depend upon specific meteorological conditions and the operational limitations of the aircraft. This section will describe some of these aircraft limitations.

The advanced technology instrumentation flown on the aircraft can require from 30 to 60 minutes after take-off to reach a stable operating condition. During this 'warm-up' period the aircraft will be involved with take-off maneuvers and ferrying to a given experimental area. This warm-up phase will allow instrument testing and, in some cases, large-scale data sets to be assembled.

Within the depth of the CTBL frequently in the range 500 - 1000 m, with cloudbase at 200 - 300 m, operating more than one aircraft in the boundary layer in coordinated patterns while maintaining the recovery height safety separation would be virtually impossible for any length of time. This has strongly influenced the planning of the low level aircraft mission. Where detailed vertical resolution in a limited area is required, this is achieved with a single aircraft flying multiple legs, the other aircraft remaining well separated horizontally. Only in other conditions or with other objectives does vertical stacking of the aircraft at low levels become a feasible proposition.

Therefore, in order to have the flexibility to efficiently conduct the Marine Stratocumulus IFO, the mission will require approval from the FAA and military authorities to operate each of the aircraft in the prescribed volume of airspace of the IFO region. All flight operations will be in accordance with existing rules and regulations governing aircraft operations in U.S. airspace. The appropriate aviation officials in San Francisco, Los Angeles, Pt. Mugu, and San Diego will be briefed 12 to 24 hours in advance of any experiment flight, and they will be provided with a detail flight plan including geographic coordinates, altitudes, and mission time-lines.

The FIRE flight coordinator will be the principal contact between the aircraft crews and the flight control agencies.

4.4 Experiment Plans

The instruments and instrument platforms available during FIRE will be used in a number of configurations to satisfy the scientific objectives described previously. The studies required to meet these objectives can be classified into three main groups:

1. a description of the structure of clouds and the boundary layer.

2. a description of the evolution (spatial and temporal) of clouds and the boundary layer.

3. intercomparisons of measurements from various systems.

A summary of the studies to be completed during the stratocumulus IFO are shown in Table 4.4. Aircraft, land-based, and satellite measurements will be used for these studies; each of these platforms have inherent strengths, weaknesses and limitations. The weaknesses will be minimized by integrating the observations from those various platforms and systems to provide a complete description of stratocumulus clouds ranging from the large-scale structure inferred from satellite to the detailed microphysical and turbulence structure obtained from aircraft or island-based measurements.

The principal strength of the island measurements is that they can describe the temporal evolution of the boundary layer. The multi-level sampling capability of the tethered balloon instrumentation also provides unequaled vertical resolutions and compensates for the inability of the aircraft to fly vertically stacked in shallow cloud topped boundary layers. Thus, the island measurements could be used to study cloud dissipation and formation. In addition, the island measurements planned for FIRE are particularly well suited for the study of the structure of the inversion layer, entrainment processes, and vertically coherent boundary layer circulations. Since these measurements are from a single point, however, they cannot be used to resolve horizontal variations on scales significantly larger than the scale of the turbulence. This shortcoming will be minimized by using aircraft measurements to define conditions upstream from the island and to extend the domain of the island-based measurements to scales resolved by the satellite.

In addition to providing descriptions that complement the island-based measurements, the aircraft will provide independent estimates of quantities obtained independently from the island measurements. For example, the entrainment rate estimated from aircraft measurements could be compared with those inferred from sodar and radar measurements. These intercomparisons will help with the interpretation of the island observations when supporting aircraft measurements are unavailable.

A negative aspect of San Nicolas Island as a site is that during some conditions the boundary layer structure in the vicinity of the island may be influenced by coastal effects. In addition, there are large sea surface temperature gradients in the vicinity of the island. In some situations this may be a positive factor. Diurnal variations, for example, may be greater at the island

TABLE 4.4: SUMMARY OF SPECIFIC IFO STUDIES USING ISLAND (I), AIRCRAFT (A) AND SATELLITE (S) MEASUREMENTS.

I. Definition of cloud and boundary layer structure

A. Mean vertical structure (I,A)

B. Turbulence (I,A)

C. Entrainment processes (I,A)

D. Cloud-top structure (I,A,S)

E. Radiative fields (I,A,S)

F. Cloud microphysics (I,A)

G. Mesoscale structure (A,S)

II. Evolution of cloud and boundary layer

A. Diurnal variation (I,A,S)

B. Generation and dissipation (I,A,S)

C. Cloud-top entrainment instability (I,A,S)

D. Downstream evolution (A,S)

III. Intercomparisons and simultaneous observations

A. Aircraft-Aircraft (A)

B. Aircraft-Island (A,I)

C. Aircraft-Satellite (A,S)

D. Island-Satellite (I,S)

E. Island-Aircraft-Satellite (I,A,S)

than over the open ocean. This may provide a larger amplitude signal for the study of generation and dissipation processes than exist at locations farther off the coast.

The strength of the aircraft is that they can be used to measure horizontal variability in the cloud and boundary layer structure. The use of two boundary layer aircraft will allow for unambiguous estimates of time and spatial derivatives. Intermediate and upper-level aircraft will provide areal mappings of cloud structure that can be compared with satellite observations. Aircraft measurements can be made over the open ocean, away from the complications at San Nicolas due to coastal effects and large sea-surface temperature gradients.

The boundary layer aircraft (BMO C-130 and NCAR Electra) may be less suitable for studying inversion layer structure and internal circulations than the island-based measurements because of limitations of sampling. The coordinated island-aircraft missions should, however, provide complementary information and will institute a unique data set for the detailed turbulence structure in the CBTL.

A number of configurations involving different aircraft, satellite and island-based systems will be used during FIRE. The selection of these configurations will depend on the weather conditions and the availability of the various systems. The types of missions scheduled on a given day will vary from single-aircraft missions to intensive missions (IM's) involving all available aircraft, island and satellite systems. The IM's will be made when cloud conditions at the island are well defined and coastal effects are determined to be a minimum. Extensive coordinated missions involving only aircraft and satellites will be made in regions away from the island. The locations of these IM's will be determined by satellite positions and weather conditions. For some conditions two or more single or multiple aircraft missions can be flown simultaneously at different locations. For some conditions at San Nicolas measurements will be made regardless of the availability of supporting aircraft. The various missions planned will be assigned a priority and a rough estimate of the desired number of each type of mission will be made prior to the experiment.

Since the upper-level, intermediate-level and lower-level aircraft each have a fairly well-defined role in the experiment, they will generally fly similar flight patterns or sequences of flight patterns on a given mission. The missions, however, may involve different combinations of aircraft and different degrees of coordination with the ground-based and satellite observations. The flight plans given in section 4.4.1 are individual elements of flight plans which will be combined and flown on either single-aircraft or multiple aircraft missions. Missions involving various combinations of aircraft, land-based and satellite systems are described in Section 4.4.2.

4.4.1 Basic Flight Plans - Individual Elements

1. Area Mapping (Figure 4.1)

The two patterns shown are nominal. Figure 4.1a shows the pattern used for bi-directional reflectance studies, and Figure 4.1b shows the pattern used when overlapping swath coverage is needed. (All distances and, in Figure 4.1b, the numbers of legs are considered to be adjustable.)

A third mapping pattern more suitable for the C-130 is shown in Figure 4.1c. This takes into account the aircraft's lower speed and ceiling and the fact that its multichannel radiometer does not scan rapidly between different viewing angles compared with the ER-2 and its radiometers. The length of the runs should be between 50-200Km and their separation, s, 10KM (for a/c flying 20,000' above cloud) R1, 2, 3, 5, 7 with radiometer viewing at nadir + 60° R4, 6 viewing at nadir.

Purposes: The area mapping flights are designed to give cloud characteristics over an extended area. These flights are designed to provide a bridge between the detailed boundary layer measurements and satellite observations. They will generally be flown in conjunction with either satellite, low-level aircraft, or island-based measurements.

Description: The upper- and intermediate- level aircraft will fly over the area of interest in a grid pattern. This flight path could be altered to keep the aircraft in loose coordination with other aircraft, and when 2 aircraft are used, they generally will fly the pattern 90° out of phase.

Remarks: Since the low-level clouds may be organized in regular patterns some legs should be perpendicular to flown others to minimize sampling biases. In addition, the overall orientation of the pattern may be to satellite orbit tracks and/or the solar plane.
Aircraft: Used primarily by ER-2, with one mission planned for the C-130. Could also be used for low-level aircraft for surface temperature mapping.

Time: The ER-2 would be able to map out a 200 x 200 km area in approximately 2 hours using the pattern in Figure 4.1a.

2. Profiles (Figure 4.2)

Purpose: Designed to give a high resolution profile of thermodynamics, wind, radiative fluxes, microphysics, etc. These profiles establish significant levels and will be used to give mean conditions above and in the boundary layer.

Description:

a. Transit profiles

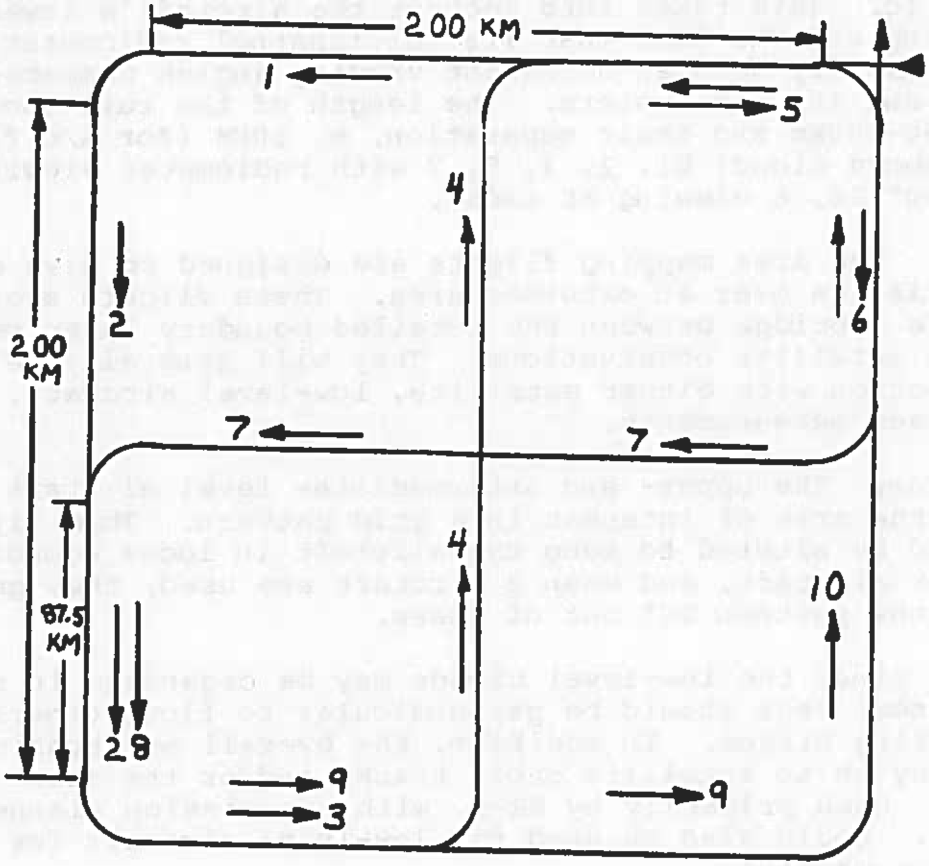


Figure 4.1a: Bi-directional Reflectance studies

Figure 4.1: Area Mapping

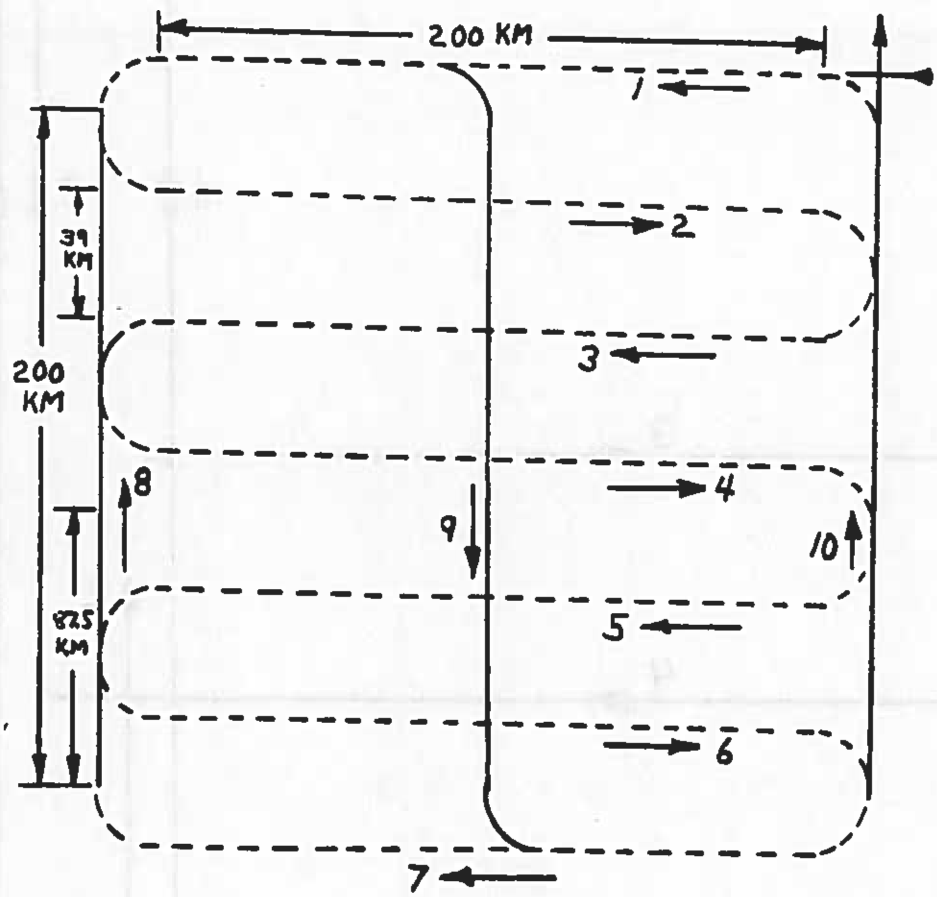


Figure 4.1b: Overlapping Swath Coverage

Figure 4.1: Area Mapping

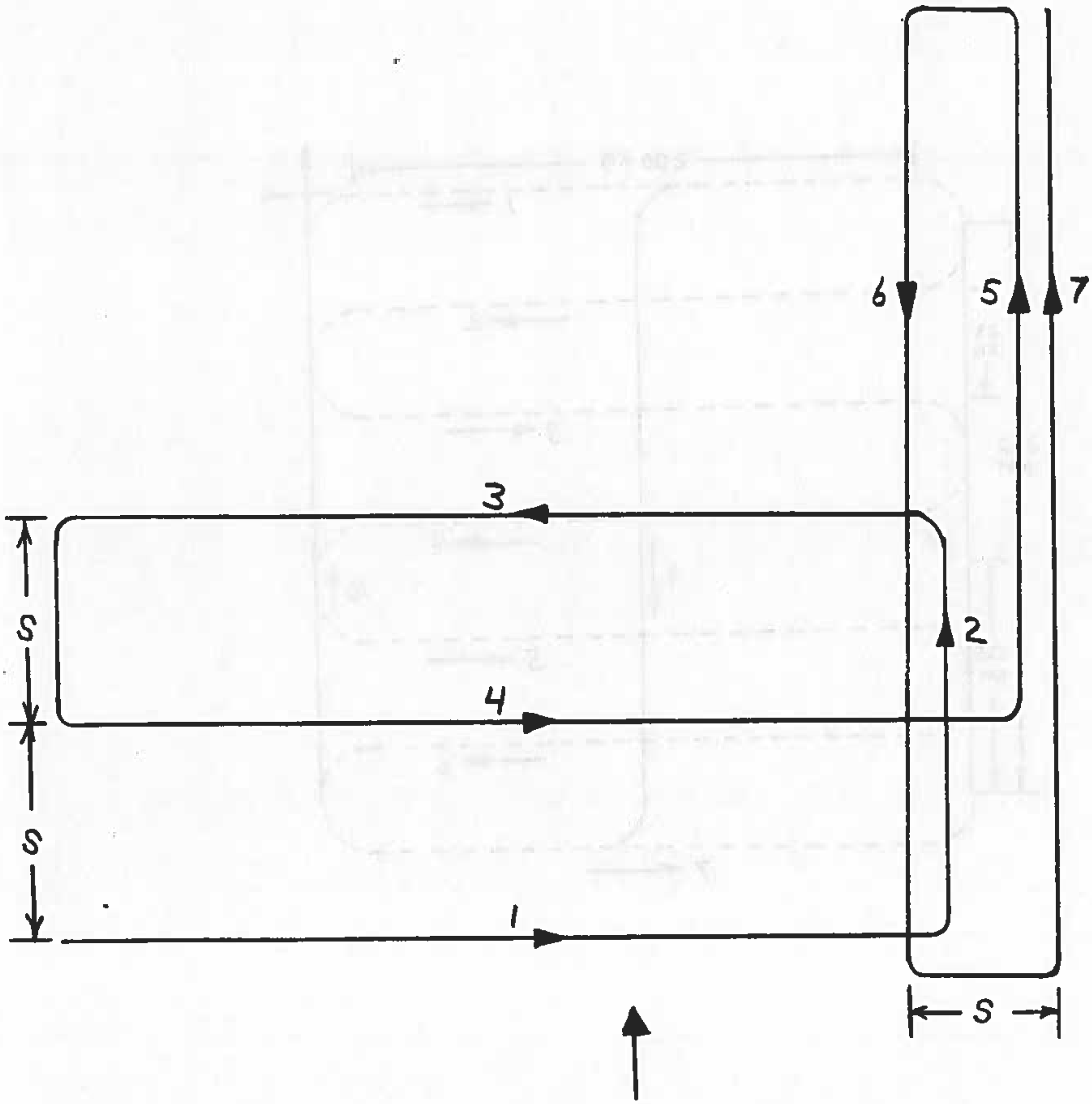


Figure 4.1c: Overlapping Swath Coverage

Figure 4.1: Area Mapping

Descend from transit altitude at a constant rate of descent (1000 ft/min) in the region of interest. Reduce rate of descent just above cloud top (500 ft/min) and continue to lowest allowed altitude. Can be reversed on ascent to transit level at end of mission.

b. Mini-profile

Profile the boundary layer by descending from a level above the - cloud layer to the lowest possible altitude and then return to cloud top or any other level. This pattern could be initiated from any level and the profile could be limited on the lower end to a level just below cloud base.

c. Stepped profiles

Stepped profiles are used for making radiation measurements in the free atmosphere with radiometers mounted externally on the aircraft. A level leg of at least 3 minutes, with 4 minutes desirable, allows the radiometer to come into thermal equilibrium.

Remarks: If winds and radiation are not essential, mini-profiles can be made during turns at the end points of level runs. It is useful to have an ascent and descent profile in the same region since data collected from these profiles can be used to estimate the effects of instrument lag on measurements made in the vicinity of the inversion.

Aircraft: Any aircraft but the ER-2.

Time: If the ferry altitude is 10,000 ft, the transit profile requires approximately 10 minutes. The mini-profiles require only a few minutes and can under some conditions be made during turns to save time. A stepped profile from the top of the boundary layer to 10,000 ft/ would require approximately 30 minutes.

3. Turbulence and cloud structure (Figure 4.3)

Purpose: Straight and level sections at a constant height give horizontal averages, variances, and covariances of all variables.

Legs at different levels give vertical distribution of these quantities.

Description: The pattern is designed to be flown by a single aircraft. Straight or L-shaped patterns are flown for a distance that gives stable statistics. Distance on each straight path depends on the observed scale of the cloud structure, but will normally be ~ 60 km. Nominally a total of six flight legs will be flown above, in and below the cloud.

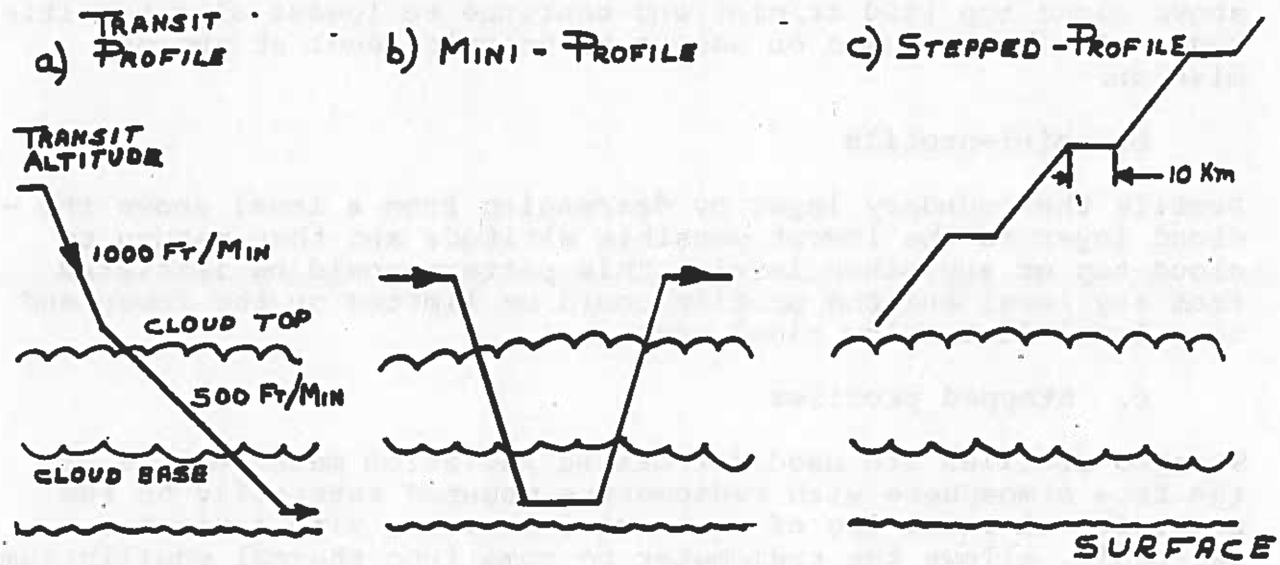


Figure 4.2: Profile Patterns

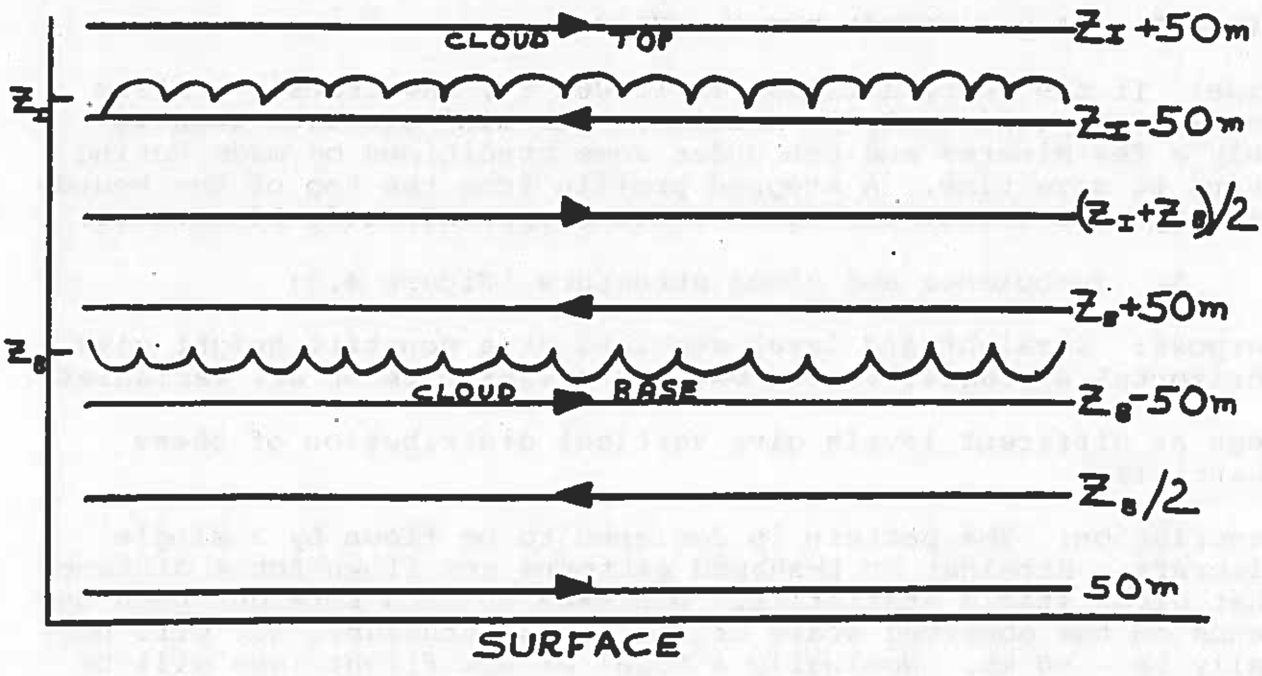


Figure 4.3: Vertical Structure Sampling Levels

Remarks: If L-patterns are flown, the paths should be flown perpendicular and parallel to the mean boundary layer winds. If a straight path pattern is flown, it should be flown perpendicular to the mean boundary layer wind. The levels near the cloud boundaries should be flown so that the leg is flown entirely within or outside of the cloud if possible. This may not be possible just below the inversion due to the horizontal variations in the inversion height. Although data collected at this region may not give reliable means, conditional sampling techniques can be used to study entrainment processes with this data.

Aircraft: Low-level aircraft.

Duration: Each leg will require approximately 10 to 30 mintues. An entire turbulence profile will take approximately 3 hours.

4. Larger scale broken cloud structure (Figure 4.4)

Purpose: To investigate the structure (both horizontal and verticle) of cloud fields which are broken or show dominant scales larger than those which can be investigated using pattern type 3 (> 10-15 km)

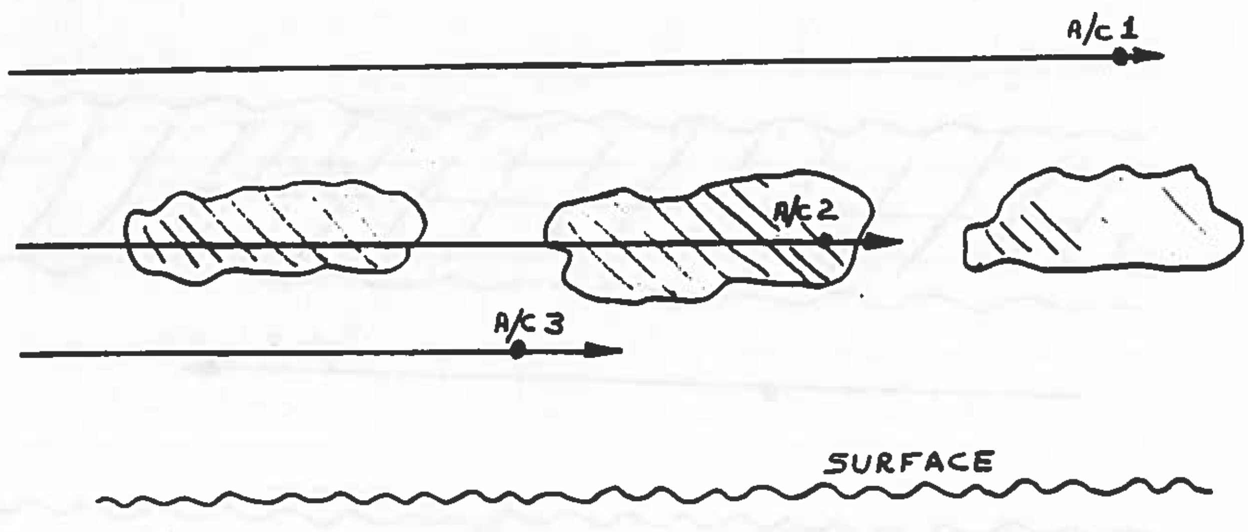


Figure 4.4: Larger Scale Broken Cloud Structure Sampling Levels

Description: Straight or L-shaped patterns are flown for a distance that gives stable statistics (up to ~ 150 km). Because of the extra time taken by a single horizontal pattern, vertical information is obtained by stacking two or more aircraft in loose formation with horizontal separation. Levels may be changed at the end of a pattern.

Remarks: The orientation of the pattern should repeat any directional organization seen in the cloud patterns.

Aircraft: Low-level aircraft.

Duration: Each leg will take approximately 30 minutes.

5. Simultaneous radiation and cloud-physics (Figure 4.5)

Purpose: To measure the properties of the radiation field above, below, and within cloud simultaneously with the cloud microphysics.

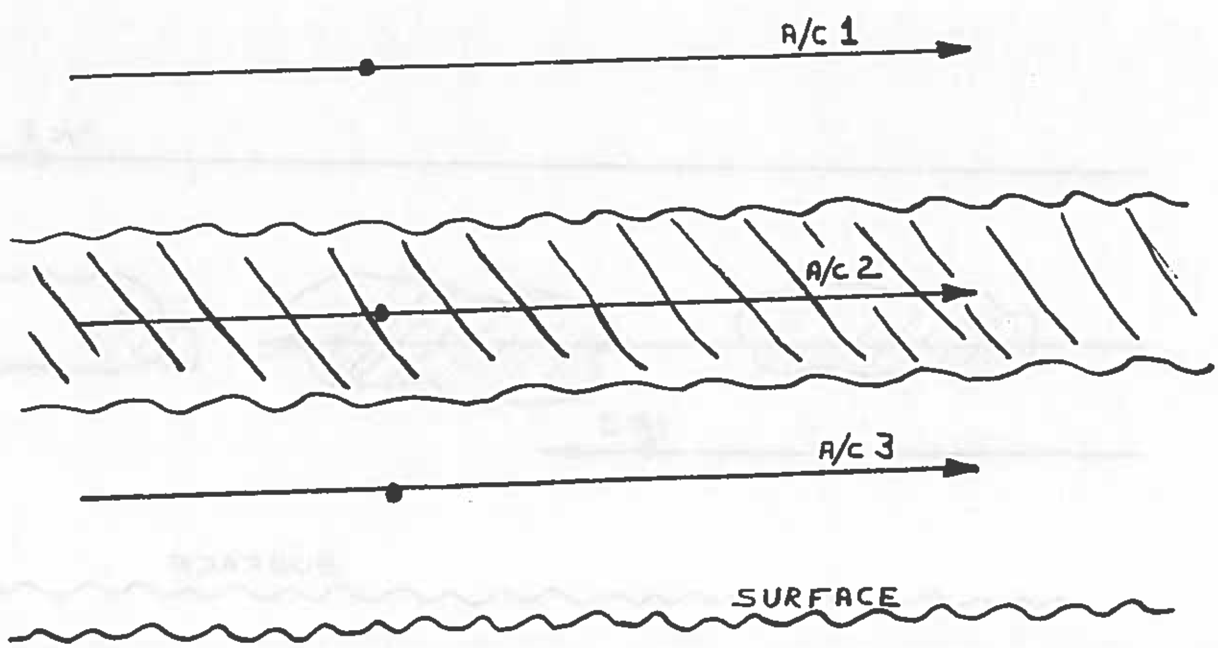


Figure 4.5: Simultaneous Radiation and Cloud Physics Sampling Levels

Description: Straight legs flown at three different levels, above, below, and within a well defined uniform sheet of cloud, the length of the legs being sufficient to give stable statistics (nominally 60 km).

Remarks: Aircraft in a vertical stack flying between same ground positions. Execution of this plan will entail careful planning to adhere to air safety regulations. Highest and lowest aircraft to exchange levels for repeat run if possible.

Duration: Two runs of 60 km plus turns gives approximately 30 minutes for whole pattern.

6. Structure Flights (upstream from island)

The NOSC Piper Navahoe will fly approximately 4 flights upstream from San Nicolas Island. These flights will be made during the period when the Point Sur is on station. Upwind and cross-wind legs will be used to define horizontal structure. Spirals flown at various locations will be used to obtain the vertical structure. The possible dates for these flights (subject to the availability of air space) are July 8, 10, 11, 12, 14, 16, 17, 18 or 19.

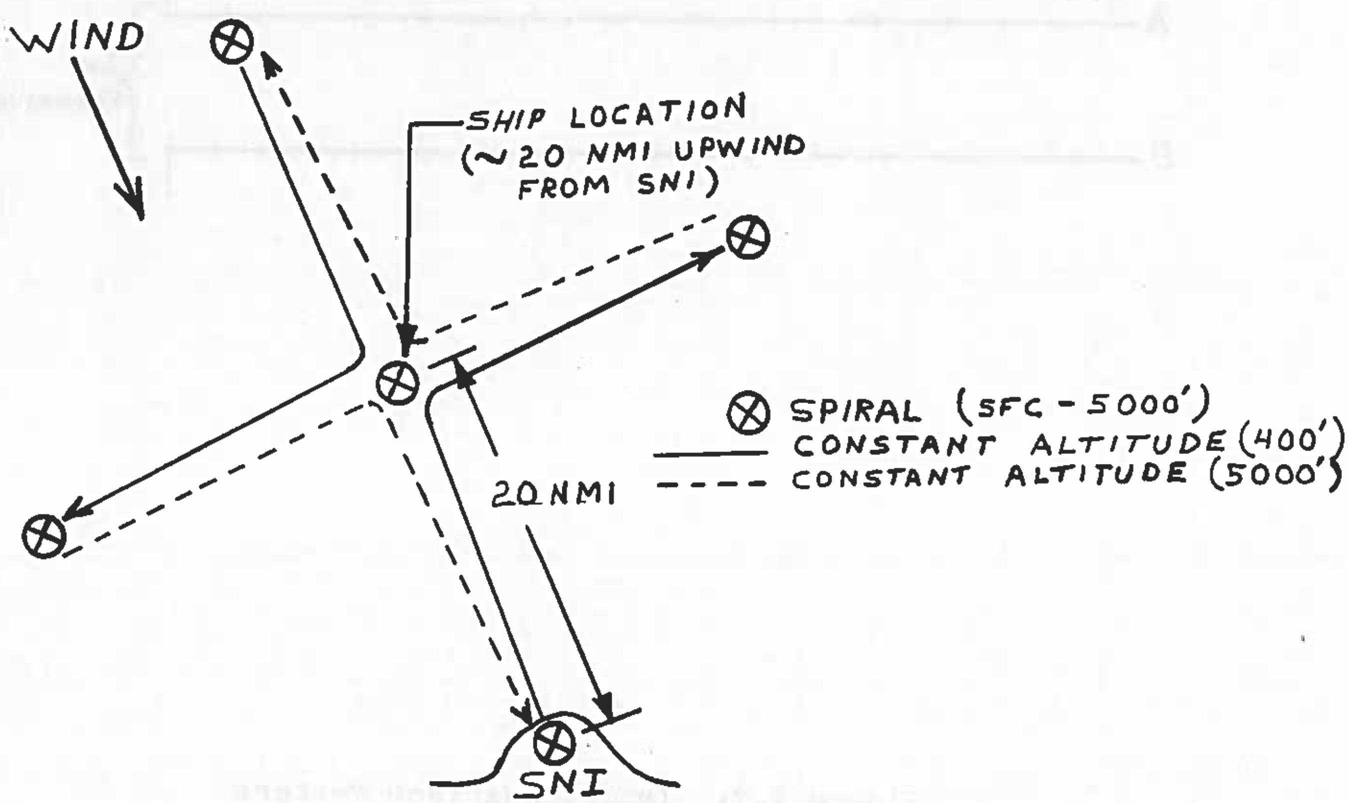


Figure 4.6: Low-level Structure Flight Pattern

7. Intercomparisons (Figure 4.7)

Purpose: To compare mean and fluctuating values of all quantities measured from two or more aircraft.

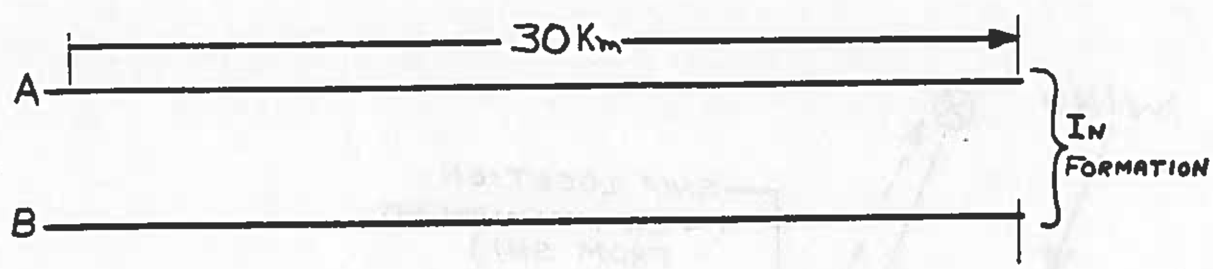


Figure 4.7: Intercomparison Pattern

Description: Fly in formation at constant height with minumum horizontal separation for a distance of at least 30 km. This should take place preferably within the boundary layer. To ensure significant fluctuation levels similar to those where rest of the measurements will be made.

Remarks: Can be flown on transit to and from experiment site.

Time: At 100 m/s the time required would be 5 min.

4.4.2 Intensive Measurements

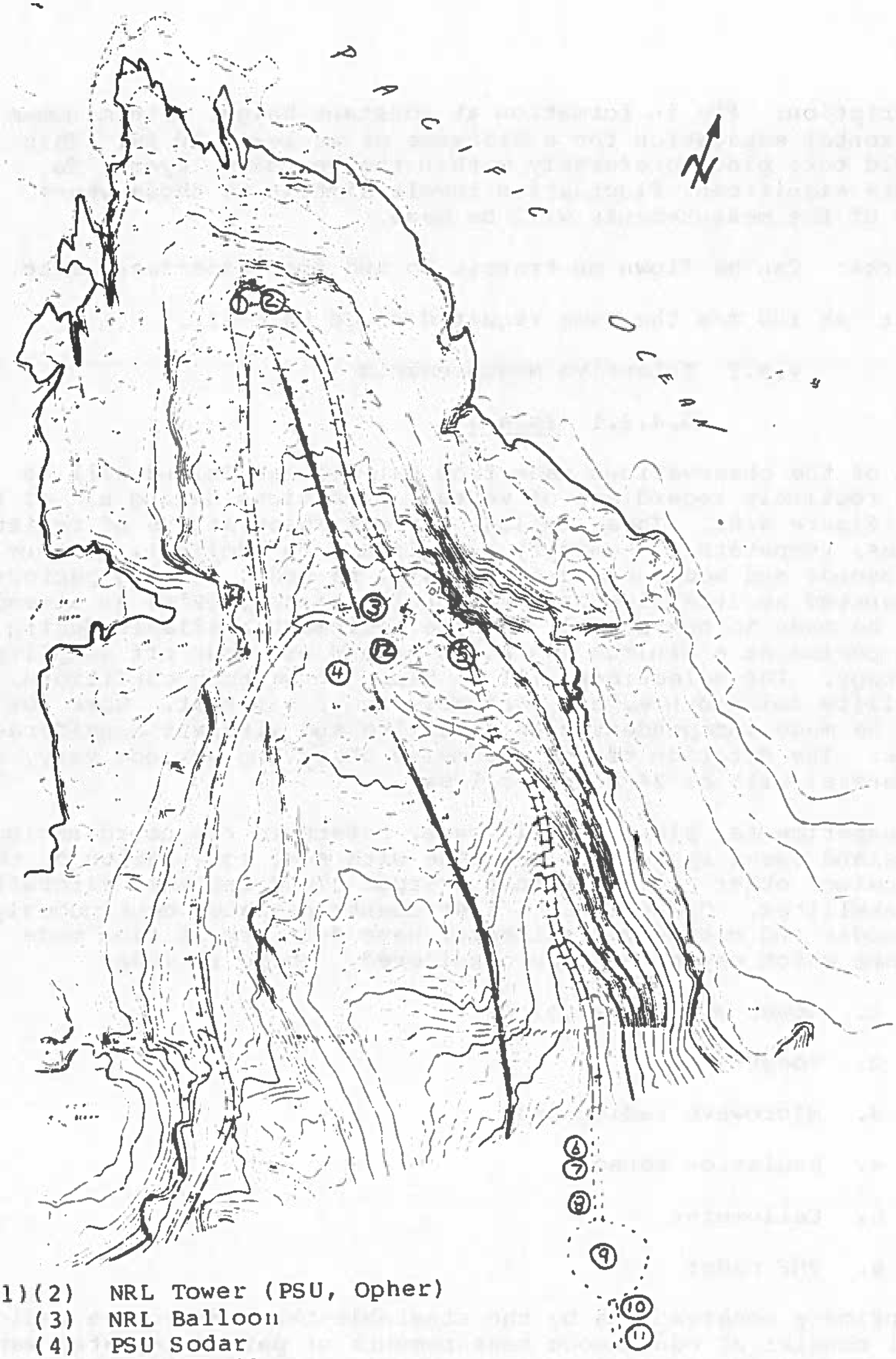
4.4.2.1 Island

Many of the observations made from San Nicolas Island will be made routinely regardless of weather conditions during all of the IFO (Figure 4.8). These include surface observations of radiative fluxes, temperature, humidity and winds. In addition, routine radiosonde and sodar measurements will be made. During periods designated as intensive observational periods (IOP's) an attempt will be made to operate all surface equipment available during that period at a minimum two hours on and one hour off sampling strategy. IOP selections will be based on weather conditions, satellite coincidence, and availability of aircraft. Some IOP's will be made independently of satellite and aircraft considerations. The duration of the intensive observing periods vary, but in general will be 24 hours or less.

The experimental plan, in this case, refers to the coordination of island based systems to coincide with some combination of the following: other island sensors, target cloud regimes, aircraft or satellites. One subset of instruments operates continuously The sodar and microwave radiometer have data acquisition mode options which may have to be considered. These include:

1. Tower micrometeorology
2. Sodar
3. Microwave radiometer
4. Radiation sensors
5. Ceilometer
6. VHF radar

The primary observations by the steerable-beam, microwave radiometer shall consist of continuous measurements of path-integrated water vapor and cloud liquid in the zenith direction (zenith mode). The microwave radiometer will be operated in the zenith mode continuously execpt for the selected periods outlined in the next paragraph.



(1)(2) NRL Tower (PSU, Opher)
(3) NRL Balloon
(4) PSU Sodar
(5) NOAA Trailer
(6)(7) Helium Trailers
(8) Langley Trailer
(9) WFC Balloon
(10) CSU Bus
(11) CSU Rawinsonde
(12) PSU Radar

Figure 4.8: Instrumentation Layout at North End of San Nicolas Island

During periods of cloud cover, the radiometer will perform periodic 360 deg azimuth scans in order to measure the spatial variability of the liquid water (scan mode). Azimuth scans shall be made at approximately 15 deg elevation angle. Observations in the scan mode shall be coordinated with simultaneous cloud liquid measurements by the NRL tethered balloon, and when possible, with aircraft measurements in the vicinity of the island. One scan per hour (15 min required) shall be performed; the radiometer will be operated in the zenith mode during the remainder of the hour.

The following subset of instruments is typically operated episodically. This may be due to the large data volume produced, limited battery lifetime, the necessity for continuous onsite operation by ground crews, or cost constraints:

1. Tethered balloons

2. Rawinsonde

In general, it is desirable to operate all sensors concurrently during periods of interest. Since some systems may not be available for the entire FIRE IFO, it is important to consider rescheduling the remote sensors and tethered balloons for maximum overlap.

aircraft flight plan). Barring problems with RFI, colliding balloons or reflections from balloons, it is anticipated that all systems will be located in the immediate vicinity of the NW tip of SNI.

Where there are two sources of power and telephone lines separated by about 200 m, ("site A" and "NRL site N"), details of the location of individual equipment trailers and/or sensors within this area must be coordinated with PMTC. In the case of the tethered balloons, we must also consider vertical sampling strategies.

The microphysics balloon (NRL) is essentially only one level of instrumentation and, therefore, will be predominately used in a profiling (yo-yo) mode. The turbulence balloon (BMO) has nominally 5 levels of instruments deployable at selectable locations along the tether. Two strategies are presently envisioned:

1. Entrainment. In this case most packages are distribtued with a small separation (-20 m) and located across the inversion region in order to resolve gradients in the upper 100 m of the cloud (the primary region of IR radiative flux divergence).

2. MABL dynamics. In this case the packages are nominally distributed evenly throughout the MABL in order to examine flux profiles and turbulence budgets.

In either scenario some vertical profiling by varying the balloon may be desired, but in general, this will be a more static system than the microphysics balloon.

The coordination of island operations is outlined in Table 4.4.2.1. The four modes of operation are listed in the left column. The top row lists activity during aircraft operations near the island, with the second row lists activity during intensive island operations with no aircraft nearby. The remaining two modes are the standard island operations and the NPGS Ship Point Sur coordinated operations.

4.4.2.2 Aircraft

In order to address the specific IFO studies in Table 4.4.2.2, several types of aircraft missions will be undertaken. These are designed to cover all these study areas with sufficient redundancy that there is a high probability that the MS IFO objectives will be attained. It is important to bear in mind that weather and serviceability in the field are unpredictable so the list is designed to be flexible. Since the most complex missions involve the five long range aircraft, the discussion centers on the multi-aircraft missions.

The basic configuration for multi-aircraft missions will be to use low-level aircraft to obtain turbulence, cloud microphysics and radiation measurements in theboundary layer, an intermediate level aircraft to measure the radiative fluxes and the thermodynamic structure about the boundary layer, and a high-level aircraft (ER-2) to map cloud top structure and to provide a link to satellite measurements. The area covered by the mapping flights will be in the vicinity of the low level aircraft measurements.

The airspace within 200 nm of the southwest coastline of California is controlled by Pt. Mugu PMTC , which conducts several hundred airspace-required missions each week. FIRE aircraft will not have unrestricted access to the airspace in the vicinity of and upwind of SNI. According to the personnel at PMTC, the chances of FIRE aircraft receiving clearances to operate in PMTC airspace <u>during the week</u> is marginal; but <u>during the weekends</u> the chances are probably excellent. Consequently, FIRE will plan to perform island/aircraft missions on weekends. During the week, if PMTC clearance is not obtained, FIRE aircraft will operate westward past the PMTC restricted zone. These operations will by necessity be aircraft only and involve long-base-leg flights over the ocean.

TABLE 4.4.2.1: ISLAND OPERATIONS SCHEDULE

MODE OF OPERATION	WALLOPS BALLOON	NRL BALLOON	RAWINSONDE	ERL MICROWAVE	SOLAR UHF PROFILER, CEILOMETER, TOWER
Intensive - with aircraft	Constant Level ± 1 hour	2 Profiles per day	0 GMT 15 GMT 6 " 18 " 9 " 21 " 12 " 24 "	Zenith Scan	Continuous
Intensive - without aircraft	Step profile (1 hr) constant level Step profile (20 min)	2-4 profiles per day	0 GMT 15 GMT 6 " 18 " 9 " 21 " 12 " 24 "	Zenith scan	"
Standard Operations	Constant Level	2 profiles per day	0 GMT 12 GMT	Zenith	"
Point Sur Coordination (July 7-16)	Step profile	2-4 profiles per day	0 GMT 18 GMT 6 " 12 "	Zenith	"

TABLE 4.4.2.2: FIRE COORDINATED AIRCRAFT MISSIONS

No.	Numbered Flights	Mission Description
1	1	Aircraft-Satellite Intercomparison Mission. ER-2 coordinated racetrack pattern at 60,000' C-130 coordinated racetrack pattern at 20,000'-25,000' C-131 coordinated racetrack pattern in cloud Electra coordinated racetrack pattern below cloud
2	3	Aircraft-Island-Satellite Intercomparison Missions Upstream of SNI. ER-2 in coordinated overflight pattern at 60,000' Electra, C-130, C-131 in structure patterns in boundary layer
3	2	Open-Ocean Broken Cloud Missions (within LANDSAT Scene if possible and during AVHRR satellite overpass). ER-2 in coordinated overflight pattern Electra, C-130, C-131 in mapping and large structure patterns
4	2	Open-Ocean Boundary Layer Evolution Mission. Emphasis on solid/broken transition in downwind direction, mapping patterns possibly stretched to give low-level structure coverage. ER-2 in coordinated overflight pattern Electra, C-130, C-131 in boundary layer structure patterns
5	2	Diurnal Evolution Missions. Primarily turbulence A/C, back-to-back single A/C missions to cover ~ 0300-1200 LST and ~ 1700-0200 LST dawn and evening transitions. ER-2 in coordinated overflight pattern Electra, C-130 in single leg or L-patterns

..ISSION M1

Central objectives: Radiation intercomparisons - a/c, satellite

Primary platforms: Aircraft, satellites

Preferred conditions: TBD

Location: Co-ordinated with satellite overpass at sub-satellite point

Patterns flown: Mapping (4.1) or coordinated overflight racetrack pattern: ER-2 (60,000'); C-130 ~ 20,000' - 25,000')

Radiation (4.5) Low level aircraft: C-131 (in cloud); Electra (below cloud)

MISSION M2

Central objectives: Boundary layer evolution, detailed structure of turbulence, radiation, microphysics upstream of SNI.

Primary platforms: Aircraft, satellites, island.

Preferred conditions: Cloud conditions homogeneous on small scales (< 50km).

Location: Upstream of SNI.

Patterns flown: Structure patterns (4.3): Electra, C-130, C-131 (in boundary layer)

Radiation (4.5) as above
Mapping patterns (4.1) or coordinated overflight patterns: ER-2 (60,000')

Remarks: The use of more than one aircraft allows time and space derivatives to be unambiguously and accurately defined. A typical pattern that could be flown with two or more aircraft consists of a series of structure profiles flown along a boundary layer trajectory as shown in Figure 4.9. In some cases it might be desirable to fly only crosswind legs. Approximately six levels would be flown at each location and mini-profiles would be flown at each location. For two aircraft, the initial sequence would be a/c1 at position 1 and a/c2 at position 2 (see Figure 4.7). The next pattern would be flown with a/c1 at position 2 and a/c2 at position 3, etc. The time and space derivatives are defined as shown in Figure 4.10. The pattern can be easily extended to include extra legs of the L-shaped patterns so that the distance between each location could be decreased. Radiation measurements (4.5) could be inserted as an add-on.

The cloud overflight aircraft would overfly the area covered by the low-level aircraft. Highest priority would be given to times and locations when LANDSAT and SPOT data could be collected. Because

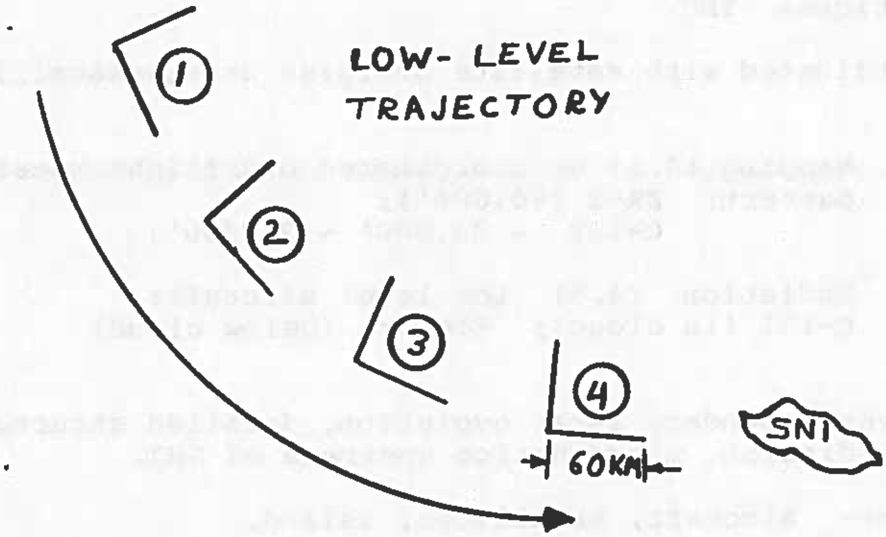


Figure 4.9 : Trajectory

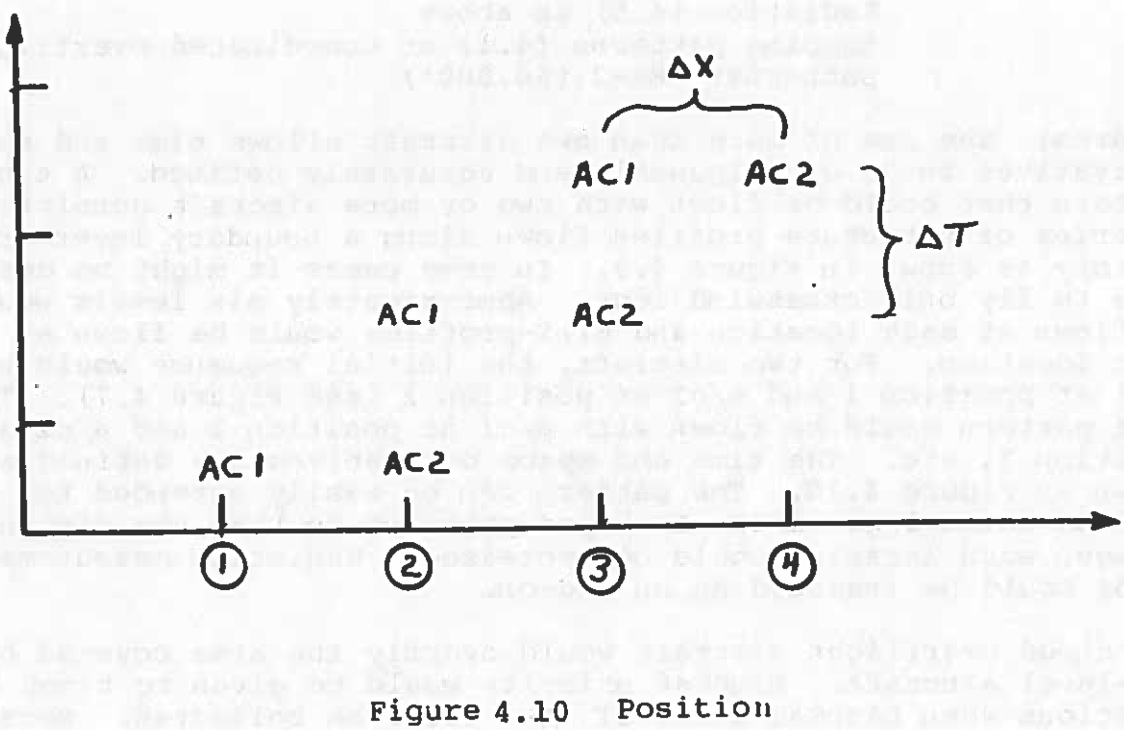


Figure 4.10 Position

of the complexity of these missions, it will be necessary to define the locations of these multiple aircraft missions prior to take-off, although some mechanism for modifying the locations while in the air should be determined.

MISSION M3

Central objectives: Structure of broken cloud fields

Primary platforms: Aircraft, satellites

Preferred conditions: Clouds broken on scales > 10-15km

Location: Open ocean

Patterns flown: Mapping patterns (4.1) or coordinated overflight patterns: ER-2, C-130 (20,000' - 25,000')

Large structure patterns (4.4): Electra, C-130, C-131

Remarks: Scale and configuration of structure patterns tailored to match scale of cloud patterns.

MISSION M4

Central objective: Open ocean boundary layer evolution and detailed structure, with emphasis on solid/broken transition in downwind direction. A number of downstream missions will be made in coordination with the constant-level balloon deployments during the period July 6 - 10. The NCAR Electra will fly a boundary layer mission as close to the launch point for the balloons as possible. An attempt will be made to fly in the same air mass during the following two to three days so that the downstream evolution can be studied.

Primary platforms: Aircraft, satellites

Preferred conditions: Cloud homogeneous on small scales with well-defined downstream changes.

Location: Open ocean

Patterns flown: Mapping patterns (4.1) stretched to include downwind structure coverage or coordinated overflight patterns: ER-2

Structure patterns in boundary layer (4.3): Electra, C-130, C-131

Radiation (4.5): as a possible add-on.

MISSION M5

Central objectives: Diurnal evolution of a cloud layer.

Primary platforms: Aircraft, satellites

Preferred conditions: Solid cloud layer

Location: Open ocean

Patterns flown: Back-to-back single aircraft structure missions (4.3), L-patterns or single legs: Electra, C-130 (C-130 co-ordinated during daylight hours)

Mapping (4.1) or coordinated overflight patterns: ER-2

Remarks: Aircraft to fly air positions to give a Lagrangian drifting pattern. Flights are sequential to cover dawn and evening transitions e.g., 0300-1200, 1700-0200.

During some conditions it may be desirable to fly single-aircraft missions. Almost any of the flight patterns described previously could be flown as a single-aircraft mission. These missions will be flown, however, only when a multi-aircraft mission of higher or the same priority is not planned using that aircraft of if conditions of sufficient interest to justify a single-aircraft mission. For single-aircraft turbulence measurements 2 or 3 turbulence profile flights could be flown along a trajectory defined by the boundary layer winds. Another possible candidate single-aircraft missions would be cloud structure and radiation measurements using the C-131.

Anticipated Allocation of Missions

(based on 10 turbulence aircraft missions)

Mission	Number
M1	1
M2	3
M3	2
M4	2
M5	2

4.4.2.3 Coordinated Island, Aircraft, and Satellite Measurements

The multi-aircraft mission described previously could be used to define the conditions upstream from the island during IOP's and to compare aircraft with island-based measurements. A high priority would be assigned to this type of mission when the island is experiencing undisturbed northwest flow and during periods of coincident satellite observations. When a multi-aircraft mission is located over the open ocean, a single aircraft could be used to define conditions in the vicinity of the island. Similarly, cloud mapping flights could be made in the vicinity of the island without the low-level aircraft.

4.5 Experiment Plan Schedule

A baseline experiment plan schedule is given in Table 4.5. This schedule incorporates the experiment plans designed by the FIRE Science Experiment Team and reflects the maximum flight hours allocated to the mission, the aircraft flight crew constraints, and a maximum of 21 days stay in California. The schedule is, of course, subject to change depending on weather conditions, aircraft and instrument status, and FAA and military airspace restrictions.

4.6 Communications

The FIRE Project Office will establish (as permitted by the FCC) a communications network to provide clear voice channels between the Operations Center and the various components of the expedition. This network will permit real-time coordination during the field operations. The following information lists the radio and phone links.

Radio links:

1. NCAR Electra - NASA ER-2 - UW C131 - BMO C130 - NOSC Piper Navaho

2. Operations Center - NCAR Electra - NASA ER-2 - BMO C130 - NCAR Electra - NOSC Piper Navaho

3. Airbase 1 (Moffett Field) - ER-2

4. Aircraft - SNI (tethered balloon sites)

1., 2., and 3. are absolutely essential

4. may be useful but is not essential

Phone links:

1. Operations Center - Aircraft Base 1 (Moffett Field)

2. Operations Center - Aircraft Base 2 (NAS North Island)

TABLE 4.5: MARINE STRATOCUMULUS IFO BASELINE EXPERIMENT PLAN SCHEDULE

Flight No.	Relative Date	Experiment	Flight Duration (hours) ER-2	Electra	C-131	C-130*	Piper Navaho
	(day 0 = start of mission)						
T-1	-6	Instrumentation Test Flight (at aircraft home base)	4	3.5	3.5	3.5	---
T-2	-4	Instrumentation Test Flight (at aircraft home base)	4	3.5	3.5	3.5	---
1	-2	Transit to California	N/A	3.5	3.5	10	---
2	0	TBD	4	7	3.5	8	---
3	2	TBD	4	-	7	8	4
4	4	TBD	5	7	3.5	8	---
5	6	TBD	5	-	7	8	4
6	8	TBD	5	7	3.5	8	---
7	10	TBD	5	7	7	8	4
8	12	TBD	5	-	3.5	8	---
9	14	TBD	5	7	7	8	4
10	16	TBD	5	7	3.5	8	---
11	18	TBD	5	7	7	8	---
12	20	TBD	5	-	3.5	8	---
13	21	Transit from California	----	3.5	3.5	10	---
		TOTALS	68.0	63.0	70.0	115.0	16.0

*C-130 will arrive PM 6/24/87, depart PM 7/22/87

3. Operations Center - Aircraft Base 3 (Montgomery Field)

4. Operations Center - San Nicolas Island (via Pt. Mugu)

5. Operations Center - Rawinsonde Sites (NWS, Pt. Mugu, and San Nicolas Island)

6. Operations Center - Institutions responsible for operations of various satellites, such as GOES and AVHRR.

A voice phone link with guaranteed access will be in place in each of the above cases.

An electronic bulletin board will be set up at the operations center. This will require an additional telephone line suitable for direct data transmission (Rawinsonde sites, and SNI) since data will be collected at the rawinsonde sites which is not routine (on-demand rawinsonde launches) and thus may not be included in the regular NSW data stream. Both digital and alphanumeric information can be transmitted/received by sites equipped with the appropriate computers.

Lastly, a datafax capability will be installed at the operations center and SNI for transmission of hardcopy information over the telephone lines.

Table 4.6 gives the locations, type equipment, frequencies, transmitted power, and functions for the communications network. Figure 4.6 gives a schematic description of the communications network. Protocol and schedules will be established as required to meet expedition operational needs. In general, on flight days all radios will be tested and manned throughout the flight period. A person or persons will be designated as the responsible party for communication on each radio. On non-flight days the Operations Center's radios will be manned on request.

4.7 Meteorological Support - Forecasting

A strong forecasting capability is essential to mission selection and planning and mission operations. Forecasts of expected conditions will be made to 12, 24, 36, and 48 hours. Near real time assessment of developing situations will be required during actual flight operations. In addition, outlooks to 72 hours and beyond will also be required. Forecast zones will include the primary target region of SNI and the surrounding 400 km, and corridors to primary target region from Moffett Field and San Diego, California. Forecasts will include assessment of significant weather, especially with respect to aircraft operations. Parameters of special concern are cloud conditions and lower tropospheric winds. It is emphasized that cloud conditions include not only lower tropospheric levels but all levels. This will be critically important in mission selection and planning due to the negative impact of intervening cloud layers on the downward looking lidar and radiometric observations with respect to the flying aircraft and due

TABLE 4.6: COMMUNICATIONS NETWORK

Location	Equipment	Frequency	Transmitted Power	Function
Operations Center, NAS North Island San Diego, California	1. Motorola "MAXAR" radio & antenna	164.225	25 watts	Voice link to aircraft
	2. Telephones (15)	-	-	Voice link to airbases surface sites, NWS, and FAA
	3. Electronic bulletin board	-	-	Data transmission to SNI
	4. Datafax	-	-	Hardcopy transmission between SNI
Surface Site, San Nicolas, California (via Pt. Mugu)	1. Telephone	-	-	Voice link to Operations Center and airbases
	2. UHF radio	164.225	10 watts	Voice link to aircraft, Operations Center, and possibly other SNI surface site
	3. Electronic bulletin board	-	-	Data transmission to operations center
	4. Datafax	-	-	Hardcopy transmission to operations center
Airbase 1 Ames Research Center, Moffett Field, California	1. Telephone	-	-	Voice link to Operations Center and air bases
	2. UHF radio	325.0 399.975 MHz	25 watts	Voice link to ER-2
Airbase 2 NAS North Island San Diego, California	1. Telephone	-	-	Voice link to Operations Center and airbases

TABLE 4.6: COMMUNICATIONS NETWORK

Location	Equipment	Frequency	Transmitted Power	Function
Airbase 3 Montgomery Field San Diego, California	1. Telephone	-	-	Voice link to Operations Center and airbases
NASA ER-2	1. Aircraft VHF radio	118 - 135.95 Mhz	10 watts	Voice link to Operations Center, tower, and other aircraft
	2. Aircraft UHF	325.0 399.975 Mhz	10 watts	Voice link to Moffett Field, California
NASA Electra	1. Aircraft VHF radio	118 - 135.95 Mhz 164.225	10 watts	Voice link to Operations Center, tower, other aircraft, and San Nicolas Island
University of Washington C-131	1. Aircraft VHF radio	118 - 135.95 Mhz 164.225	10 watts	Voice link to Operations Center, tower, other aircraft, and San Nicolas Island
BMO C-130	1. Aircraft VHF radio	118 - 135.95 Mhz 164.225	10 watts	Voice link to Operations Center, tower, other aircraft, and San Nicolas Island
NOSC Piper Navajo	1. Aircraft VHF radio	118 - 135.95 Mhz 164.225	10 watts	Voice link to Operations Center, tower, other aircraft, and San Nicolas Island

TABLE 4.6: COMMUNICATIONS NETWORK (continued)

Location	Equipment	Frequency	Transmitted Power	Function
Ship Point Sur	1. Ship VHF radio	TBD	TBD	Voice link to operations center
Shana Roe	1. Ship VHF radio	TBD	TBD	Voice link to operations center and aircraft

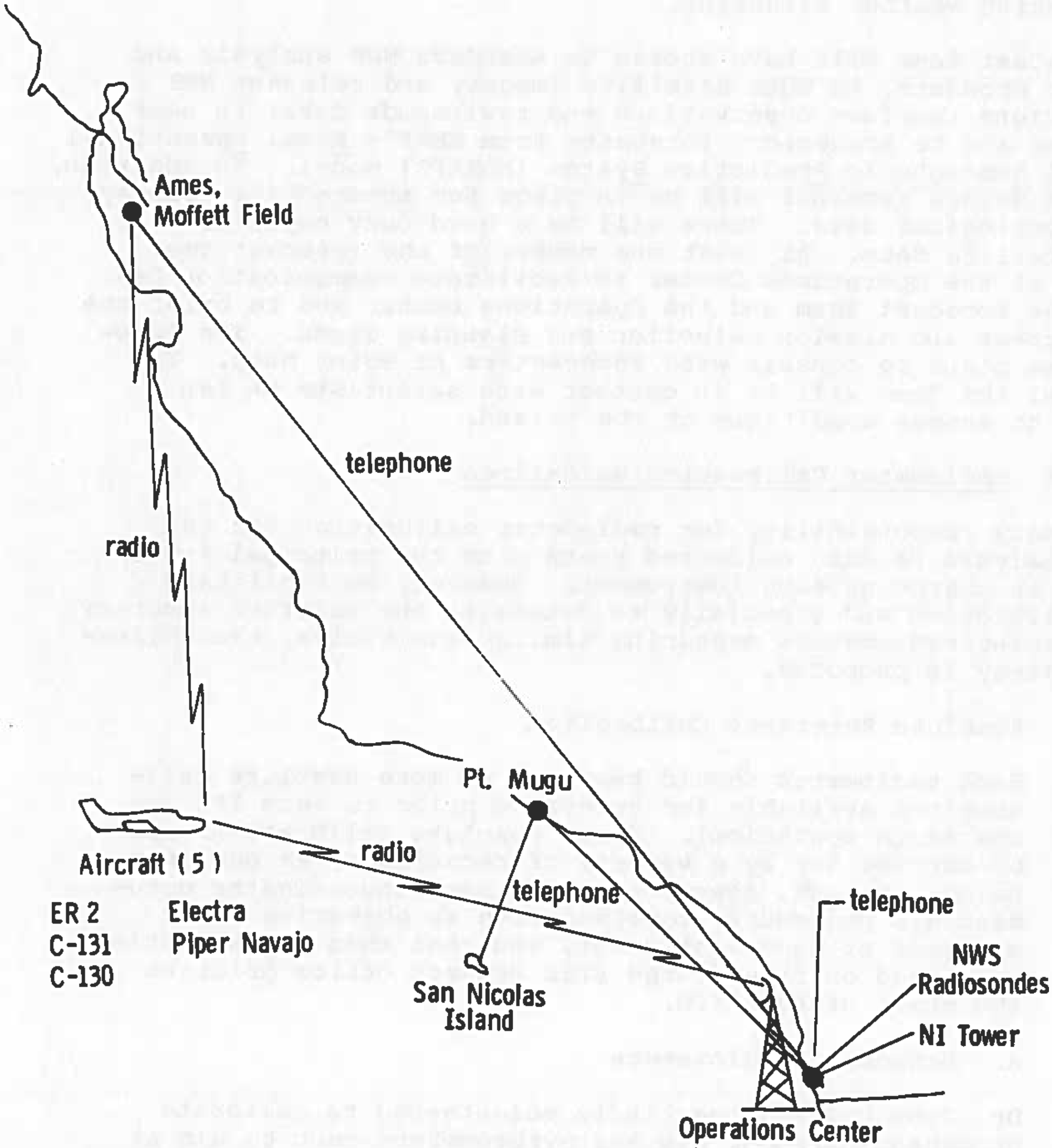


Figure 4.11: Communications Network

to practical constraints on aircraft flight operations. The Mission Selection Team will attempt to maximize optimal utilization of resources to accomplish the science objectives subject to the existing weather situation.

The forecast team will have access to standard NWS analysis and forecast products, to GOES satellite imagery and relevant NWS observations (surface observations and rawinsonde data) in near real time and to trajectory forecasts from NERF's Naval Operational Regional Atmospheric Prediction System (NORAPS) model. In addition, a remote McIdas terminal will be in place for interactive display of meteorological data. There will be a hard copy capability of GOES satellite data. At least one member of the Forecast Team will be at the Operations Center to facilitate communication between the Forecast Team and the Operations Center and to brief the flight crews and Mission Selection and Planning Teams. The Forecast Team plans to consult with forecasters at Point Mugu. In addition, the Team will be in contact with scientists on San Nicolas to assess conditions at the island.

4.8 Radiometer Calibration Guidelines

The primary responsibility for radiometer calibration and the error analysis of data collected rests with the principal investigator in charge of each instrument. However, to facilitate such calibration and especially to determine the relative accuracy of different radiometers measuring similar quantities, the following strategy is proposed.

1. Absolute Reference Calibration

   Each radiometer should have one or more absolute calibrations available for reference prior to each IFO (or the ET/LA operation). These absolute calibrations may be carried out by a variety of techniques, as outlined below. We ask, therefore, that each investigator document his procedure, together with an objective error analysis of each instrument, and that this documentation be placed on file at the FIRE Project Office prior to the start of each IFO.

   a. Broadband radiometers

   Dr. John Deluisi has kindly volunteered to calibrate broadband pyranometers and pyrgeometers sent to him at his calibration facility in Boulder. He will check the absolute calibration as well as the cosine response to direct solar irradiance. In the absence of a similar absolute calibration done elsewhere, individual investigators are therefore encouraged to avail themselves of this opportunity prior to the start of the ET/LA operation and about 5 months before each IFO.

b. Spectral radiometers

Calibration of these radiometers is far more instrument-dependent than is calibration of the broadband sensors.

The two techniques commonly used are (a) use of standard sources, and (b) use of standard detectors. It appears from surveying most of those involved that each investigator is relatively comfortable with his own procedure of applying one or other of these techniques to his instruments and no external calibration is suggested here.

2. Relative Calibration/Intercomparison

Each radiometer should undergo a relative calibration with respect to the other radiometers at the start (and, possibly, the finish) of each IFO, at a common location at the surface.

This intercomparison should serve to identify any drifts since the prior absolute calibration, as well as potential effects due to a different spectral distribution of the radiation under field conditions.

For the broadband surface radiometers, this relative calibration is relatively straightforward.

For the surface and aircraft spectral radiometers, the intercomparison may prove more difficult, and here it is proposed to make use of a secondary reference detector (Professor Cox's scanning radiometer), and secondary reference sources (Dr. Spinhirne's light box and cold chamber). We are hoping to have all aircraft and surface radiometers collocated at the start of each IFO for this intercomparison. This may not be possible for the marine stratocumulus IFO if the ER-2 is not based locally, and additional strategies may be developed as experience is gained on this problem.

3. Relative Intercomparison of Aircraft Instruments

Since some of the instruments are sensitive to ambient temperature and pressure, and since the surface intercomparisons may not be practical for some instruments, it is proposed to dedicate a portion of the flight time to instrument intercomparison. To be worthwhile, this would have to take place at the same altitude over a uniform underlying surface (e.g., Pacific Ocean), and with no cloud above the aircraft. Only one such intercomparison involving the ER-2 may be possible per IFO, due to its flight characteristics. The other aircraft should attempt more frequent intercomparisons, at least until the data becomes repetitive, regular, frequent intercomparisons whenever possible throughout the duration of the experiment.

5.0 SCHEDULES

5.1 1987 Marine Stratocumulus

See Figure 5.1.

5.2 Mission Flight Schedule

See Figure 5.2

5.3 1990 Marine Stratocumulus

See Figure 5.3

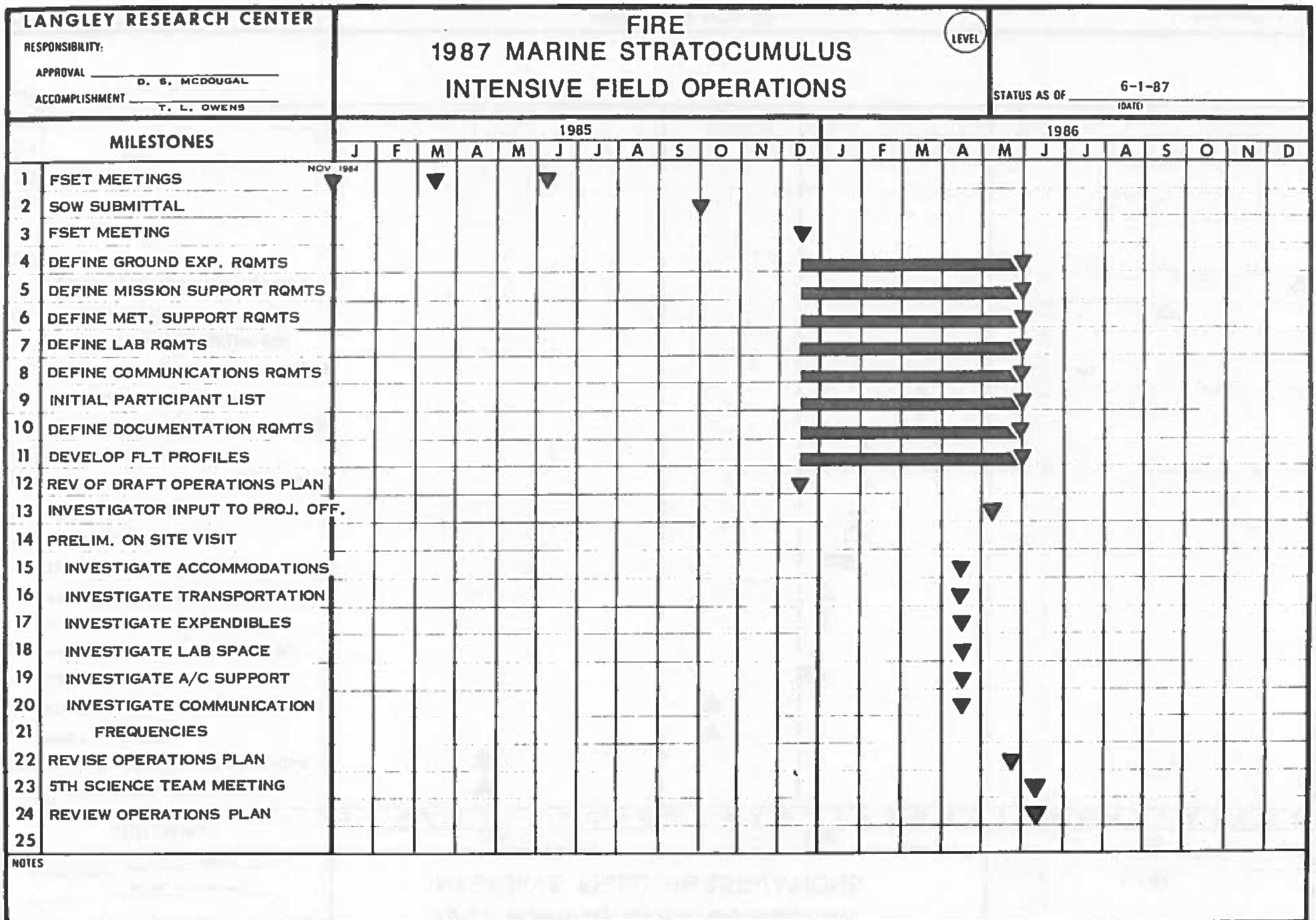

LANGLEY RESEARCH CENTER
RESPONSIBILITY:
APPROVAL D. S. MCDOUGAL
ACCOMPLISHMENT T. L. OWENS
FIRE
1987 MARINE STRATOCUMULUS
INTENSIVE FIELD OPERATIONS
LEVEL
STATUS AS OF 6-1-87 (DATE)
MILESTONES
1985
1986
J F M A M J J A S O N D J F M A M J J A S O N D
NOV 1984
1 FSET MEETINGS
2 SOW SUBMITTAL
3 FSET MEETING
4 DEFINE GROUND EXP. RQMTS
5 DEFINE MISSION SUPPORT RQMTS
6 DEFINE MET. SUPPORT RQMTS
7 DEFINE LAB RQMTS
8 DEFINE COMMUNICATIONS RQMTS
9 INITIAL PARTICIPANT LIST
10 DEFINE DOCUMENTATION RQMTS
11 DEVELOP FLT PROFILES
12 REV OF DRAFT OPERATIONS PLAN
13 INVESTIGATOR INPUT TO PROJ. OFF.
14 PRELIM. ON SITE VISIT
15 INVESTIGATE ACCOMMODATIONS
16 INVESTIGATE TRANSPORTATION
17 INVESTIGATE EXPENDIBLES
18 INVESTIGATE LAB SPACE
19 INVESTIGATE A/C SUPPORT
20 INVESTIGATE COMMUNICATION
21 FREQUENCIES
22 REVISE OPERATIONS PLAN
23 5TH SCIENCE TEAM MEETING
24 REVIEW OPERATIONS PLAN
25
NOTES
NASA Langley (July 1979)
PMSD-SA&CO N-225

FIGURE 5.1

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ACCOMPLISHMENT T. L. OWENS

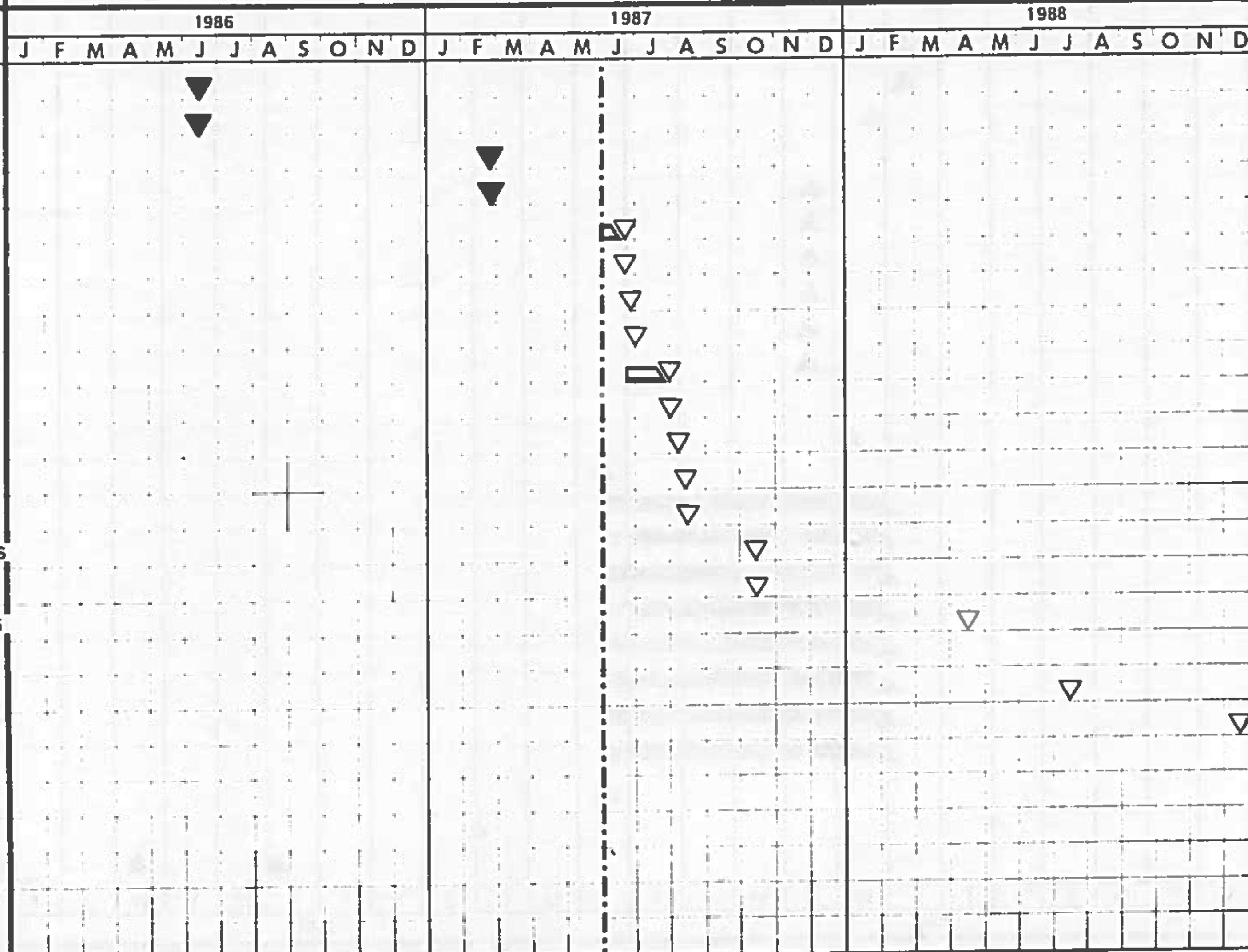
FIRE
1987 MARINE STRATOCUMULUS
INTENSIVE FIELD OBSERVATIONS

LEVEL

STATUS AS OF 6-1-87

MILESTONES

1	DEFINE AIRCRAFT LAYOUT
2	DEFINE INTEGRATION SCHEDULE
3	FSET MEETING
4	FINAL REVIEW OF OP. PLAN
5	AIRCRAFT LOADING
6	PAYLOAD OPER/SAFETY INSP.
7	EXP. CHECKOUT FLIGHTS
8	FINAL READINESS REVIEW
9	1987 MS IFO
10	POST MISSION DEBRIEF
11	MISSION CLOSE OUT
12	AIRCRAFT RETURN TO HOME BASE
13	UNLOAD AIRCRAFT
14	SUB. OF PREL. CATALOG TO PCDS
15	DATA ANALYSIS WORKSHOP
16	SUB. OF REDUCED DATA TO PCDS
17	REVIEW OF RESULTS/1990 MS
18	IFO PLANNING WORKSHOP
19	SUBMIT DATA ARCHIVE TO PCDS
20	
21	
22	
23	
24	
25	



NOTES

NASA Langley (May 1979)

FIGURE 5.1 CONTINUED

PMSD-SA&CO N-121

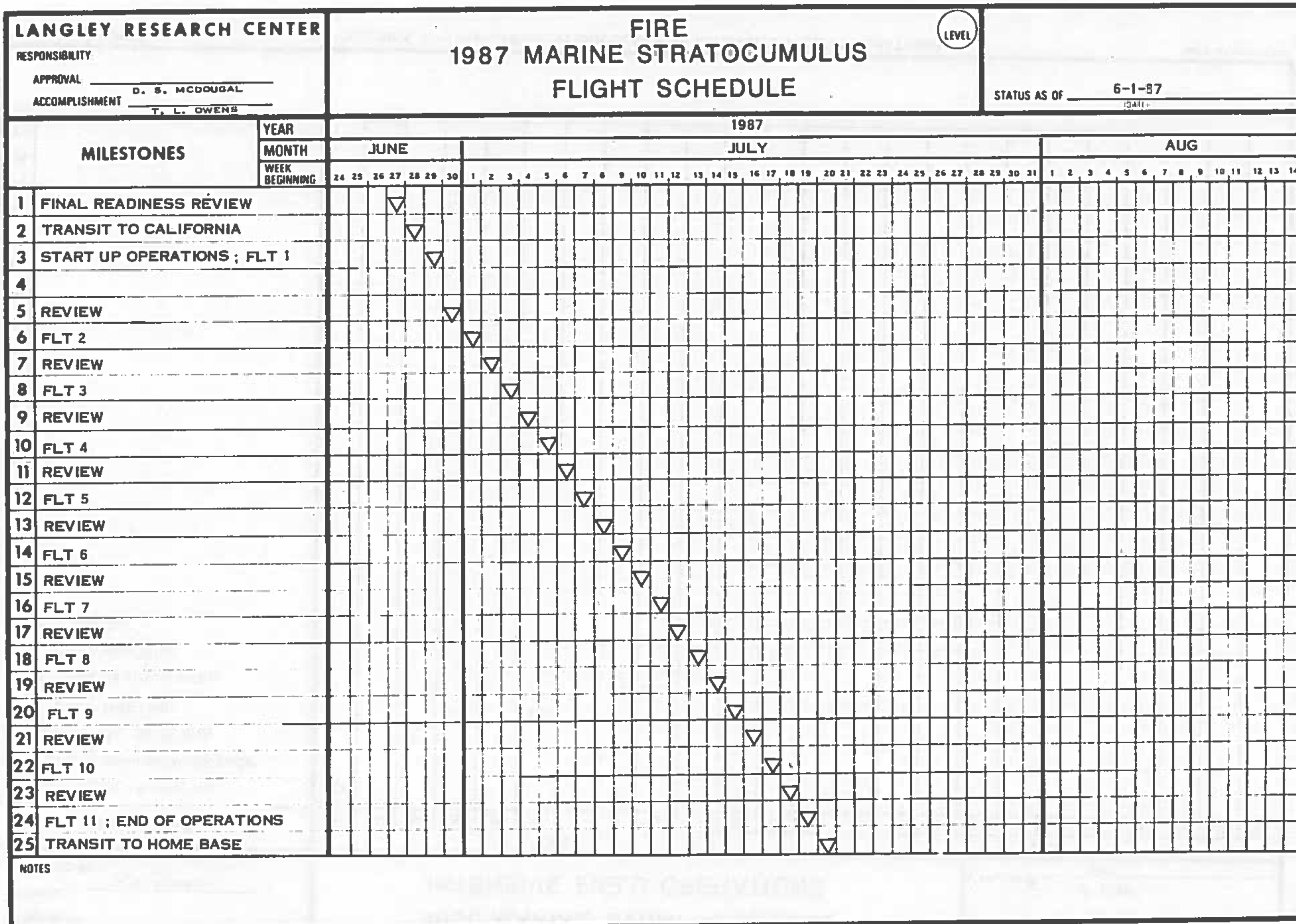


FIGURE 5.2 - FLIGHT SCHEDULE

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ACCOMPLISHMENT T. L. OWENS

FIRE
1990 MARINE STRATOCUMULUS
INTENSIVE FIELD OPERATIONS

(LEVEL)

STATUS AS OF 6-1-87 (DATE)

MILESTONES	1989 J	F	M	A	M	J	J	A	S	O	N	D	1990 J	F	M	A	M	J	J	A	S	O	N	D
1 1987 RESULTS/1990 MS	▽																							
2 IFO PLANNING WORKSHOP																								
3 SUBMITTAL OF PLANS			▽																					
4 FSET MEETING						▽																		
5 1990 OPERATIONS PLAN								▽																
6 FSET MEETING												▽												
7 1990 MS IFO																			▽					
8																								
9																								
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NOTES

NASA Langley (July 1979)

PMSD-SA&CO N-225

FIGURE 5.3 - 1989 MARINE STRAIOCUMULUS INTENSIVE FIELD OPERATIONS

6.0 DATA MANAGEMENT

Data management is an ongoing activity, beginning immediately in the pre-experiment phase and continuing through the end of FIRE. Most of the data management tasks will be performed by the FIRE Investigators acting individually or as members of the Marine Stratocumulus Working Group (see section 6.2). The FIRE working groups will be the foci for identifying and coordinating items relating to the acquisition and use of data as a communal resource, working closely with other groups dealing with scheduling of platforms, identification of calibration and intercomparison needs, colocation requirements, and selection of case studies and integrated analyses.

Data management activities in FIRE will insure the exchange of data among FIRE investigators that is required to produce the integrated analyses of multi-platform, multi-scale and multi-spectral data sets; these integrated analyses are central to the accomplishment of the FIRE science objectives. In addition the data management activities will insure the availability of FIRE data and analysis products to the entire science community. These activities will be carried out by four organizational components within FIRE; (1) the individual FIRE investigators, (2) the FIRE Working Groups, (3) the FIRE Central Archive, and (4) the FIRE Project Office. The strategy embodied in this organization is to disperse most of the data reduction and processing functions to the FIRE investigators engaged in collecting and analyzing the data, but to hold the resultant data sets and analysis products centrally for ready access by all FIRE investigators. The FIRE Central Archive and the FIRE Project Office will provide a centralized source of information and copies of data which are centrally archived, whereas the FIRE Working Groups, composed of the investigators, will coordinate the decentralized data reduction and analysis activities. In addition, the FIRE Central Archive will transfer from time to time, certified FIRE data to PCDS for permanent archive and for open access by the scientific community.

6.1 Data Products

The following is a description of the data products for each instrument in the FIRE Marine Stratocumulus IFO data set. Data products are described for raw data (investigator archived), reduced data (for the FIRE Central Archive) and value-added data (FIRE Central Archive).

6.1.1 Raw Data Products

All investigators will be saving raw data corresponding to the reduced data described in section 6.1.2. In some cases raw data may be saved at a higher rate than the corresponding reduced data sets. In other cases, the data collected are of such large volume and of such limited general interest that they will be archived as raw data only. Only those data that do not have corresponding reduced products will be described here.

Cloud Imaging Cameras

Measurements: 35mm film slides of camera field of view and/or Videotape of camera field of view.

Doppler UHF Radar

Measurements: Equivalent to reduced data except: Velocity spectra (Range: $\pm$ 18ms^{-1}, Data rate: 30 sec)

Doppler Sodar

Measurements: Equivalent to reduced data set except for: Velocity spectra (Range $\pm$ 18ms^{-1}, Data rate: 120 sec)

Instrument Microphysical Tower

Measurements: Equivalent to reduced data set

Rawinsonde

Measurements: Equivalent to reduced data set.

Microwave Radiometer

Measurements: Raw Data (Investigator Archived)

Investigator: J. B. Snider

Instrument	Measurement	Range	Accuracy	Data Output Rate	Remarks
Microwave Radiometer	20.6 GHZ Brightness	0-300 K	1.0 K	5 to 60 sec	5 sec-scan 60 sec-zenith
"	20.6 GHZ Absorption	0-2.5 neper		" "	"
"	31.65 GHZ Brightness	0-300 K	1.0 K	" "	"
"	31.65 GHZ Absorption	0-2.5 neper		" "	"
"	90.0 GHZ Brightness	0-300 K		" "	"
"	90.0 GHZ Absorption	0-2.5 neper		" "	"
"	Surface Temp			300 sec	
"	Dew Point			"	
"	Pressure			"	

Cloud Ceilometer

Measurements: Equivalent to reduced data set.

Tethered Balloon (Wallops)

Measurements: Equivalent to reduced data set.

Tethered Balloon (NRL)

Measurements: Equivalent to reduced data set except for:

Instrument	Measurement	Range	Accuracy	Data Output Rate	Remarks
Gil Bivane	Azimuth	0-7.5V		5 HZ	
	Elevation	0-7.5V		"	
Inclinometers	Pallet Yaw and Pitch	± 10V		"	
Compass	Pallet Azimuth				

Ship Point Sur

Measurements: Equivalent to reduced data except for 5 minute averages.

Constant Level Balloons

Measurements: Equivalent to reduced data.

6.1.1.2 Satellite Data

Raw satellite data will not be archived by the FIRE. Reduced (calibrated and geographically located) data and value-added data are described in sections 6.1.2.2 and 6.1.3.2.

6.1.1.3 Aircraft Data

Raw data products from the various systems to be archived by individual investigators are digital recordings on various media at a variety of rates. Some of this will be used during the field phase for "quick look" fine tuning of flight patterns and strategies. Some parameters describing aircraft altitude may be available as new data products.

6.1.2 Reduced Data Products

6.1.2.1 Surface

Deleted

6.1.2.2 Satellite Data

Satellite data which is particular to the Marine Stratocumulus IFO are the AVHRR-HRPT, GOES-VISSR (1 km visible channel resolution), LANDSAT/5 Thermatic Mapper, SAGE II solar occultation, and SPOT data. Additional satellite data from the AVHRR-GAC, TOVS, GOES-VAS Sounder, ERBE, and DMSP will also be collected. Data characteristics for these first three satellites are discussed below.

AVHRR-HRPT

All 5 spectral channels have a 1.1 km spatial resolution at nadir. The afternoon NOAA polar orbiter satellite is NOAA-9, which will observe the FIRE Marine Stratocumulus IFO regions at approximately 2:30 p.m. local time at the satellite's ground track (track around the earth of the sub-satellite point). Since the satellite views up to 15 degrees longitude on either side of the ground track, any given satellite coincidence for SNI will vary within plus or minus 1 hour of the nominal 2:30 p.m. crossing time. The morning NOAA polar orbiter (NOAA-10) will observe the FIRE region at approximately 9:30 a.m. local time.

Measurements:	0.58 - 0.68 micron lambertian reflectance
	0.725 - 1.10 micron lambertian reflectance
	3.55 - 3.93 micron brightness temperature
	10.3 - 11.3 micron brightness temperature
	11.5 - 12.5 micron brightness temperature

GOES VISSR

The visible channel data has 0.9 km spatial resolution; the infrared channel has 7.2 km spatial resolution (at nadir view). Half-hourly data from GOES-West, daily, will be obtained.

Measurements: 0.55 - 0.75 micron radiance (squared instrument counts.

LANDSAT/5 Thematic Mapper

The LANDSAT satellite orbits in a 9:45 a.m. sun-synchronous orbit. Data is collected for 185 km by 170 km scenes. Spatial resolution in the 6 shortwave and near-infrared window channels is 28.5 meters. Spatial resolution in the 11 micron window channel is 114 meters. A given LANDSAT scene is viewed once every 16 days. The data is taken every 16 days over the continental U.S., but is only processed (radiometric calibration and geometric location) upon request. For especially interesting marine stratocumulus conditions over the SNI, several LANDSAT TM scenes may be ordered. These scenes would be ordered only after preliminary examination of surface radar and cloud image data to verify marine stratocumulus conditions.

Measurements: 0.45 - 0.52 micron reflected radiance (digital counts which can be linearly converted to radiance using supplied calibration coefficients.)
0.52 - 0.60 micron reflected radiance
0.63 - 0.69 micron reflected radiance
0.76 - 0.90 micron reflected radiance
1.55 - 1.75 micron reflected radiance
2.08 - 2.35 micron reflected radiance
10.4 - 12.5 micron brightness temperature (K)

6.1.2.3 Aircraft Data

Reduced aircraft data will be formulated according to the FIRE standard format and submitted with documentation to the FIRE archive. It is anticipated that this will result in several 9-track tapes per aircraft mission. Specific data products can be inferred from the aircraft instrumentation descriptions (Appendix A.2).

ER-2

1. IR Brightness at two wavelengths; Data rate $1s^{-1}$.
2. Upward and downward broadband IR Irradiances; Data rate $1s^{-1}$.
3. Upward and downward narrowband solar irradiances; Data rate $1s^{-1}$.
4. Lidar cloud structure; Cloud-top height; optical depth estimates; Data rate $1s^{-1}$.
5. Thematic mapper simulator - narrow-band cross-track radiances; Data rate $1s^{-1}$.

6.1.3 Value-Added Products

The higher-order analyses planned as part of FIRE will require the integration of a diverse set of measurements from a variety of platforms. To facilitate these analyses various value-added data products will be produced and included in the FIRE archive.

6.1.3.1 Surface

The balloon, sodar, UHF wind profiler, and radiosonde data will be used to describe vertical profiles of the mean and turbulent state of the boundary layer. Radiative and convective flux profiles will be determined for the boundary layer under variety of meteorological conditions. These profiles will be included as value-added products in the FIRE archive and will be essential for the successful integration of the island measurements with those obtained from aircraft and satellite observations.

Time collated measurements from the surface, tower, microwave radiometer, ceilometer, wind profiler, and sodar will provide long time series descriptiion of the mean sate of the boundary layer. These descriptions will include turbulent and radiative fluxes at the surface, mean winds and turbulence levels at several levels, inversion height, cloud-base height and total liquid water content. These measurements will not only provide valuable information that can be integrated with the profile measurements, but can be used to describe the temporal evolution of the boundary layer.

6.1.3.2 Satellite Data

GOES-VISSR/AVHRR/LANDSAT/SPOT Intercalibration

Comparison of shortwave reflected radiances for the GOES-VISSR 0.55 - 0.75 micron channel, the AVHRR 0.58 - 0.68 micron channel, the LANDSAT 0.63 - 0.69 micron channel, and the SPOT 0.6 - 0.7 micron channel will require intercalibration of the four radiometers. This intercalibration is especially critical for determination of the directional reflectance of stratocumulus clouds for testing radiative models. Intercalibration will be achieved by obtaining time and viewing angle coincident data as the AVHRR, LANDSAT TM, and SPOT instruments underfly the GOES sensor.

6.1.3.3 Aircraft Data

Many of the reduced data products from the aircraft systems will be combined, refined, formulated to the FIRE specifications, and submitted to the FIRE archive. These analyses will include vertical profiles of the mean state, profiles of the turbulent fluxes (from the fast-response instruments), vertical profiles of cloud-droplet spectra, entrainment rate estimates, mapping of cloud-top structure and radiative properties, mapping of sea-surface temperature fields, and intercalibration tests. Analyses of case studies will be indluded in the archive as will analyses that attempt to integrate aircraft, island and satellite data.

6.2 Data Management Responsibilities

6.2.1 Principal Investigators

All data reduction and analysis functions in FIRE reside with the scientists carrying out their research as part of FIRE. To encourage the interaction of these researchers needed to integrate the various observations and models into a more comprehensive understanding of clouds, FIRE investigators will have free access to all data sets collected during FIRE, either by individual principal investigators or collected from satellites. Coordination of data analysis and modeling activities requires all FIRE principal investigators to perform certain other tasks as part of the FIRE data management. These functions are:

1. To provide to the FIRE Central Archive information concerning data holdings, including all data collected as part of FIRE and other data deemed relevant to FIRE research.

2. To save all data collected during FIRE in un-reduced form for five years so that reduction of data can be repeated if necessary.

3. To provide to the FIRE Central Archive copies of all reduced FIRE observations in the FIRE Standard Data Format, accompanied by complete instrument, reduction algorithm and data format documentation.

4. To provide, within nine months after acquisition, to the FIRE Central Archive copies of any data analysis products deemed relevant to the accomplishment of FIRE objectives, accompanied by appropriate documentation.

5. To provide for archival of all submitted data sets by producing back-up copies of all data and taking other necessary precautions to insure the preservation of the FIRE data throughout the duration of FIRE.

6. To provide to other FIRE investigators or the FIRE Central Archive, upon request, copies of other data sets acquired for FIRE research, that are relevant to other FIRE studies.

7. To provide to other FIRE investigators reasonable access to unreduced observations to facilitate particularly crucial multi-data analyses.

6.2.2 Working Groups

There are two FIRE Working Groups - a Cirrus Working Group and a Marine Stratocumulus Working Group. These working groups will be composed of FIRE principal investigators pursuing research relevant to that working group. The data management responsibilities of the individual principal investigators, as dispersed elements of the FIRE data processing system, could become onerous if not coordinated properly. Therefore, the FIRE Working Groups must govern these individual activities to insure progress toward the FIRE science objectives. The data management functions of the two FIRE Working Groups are:

1. To determine the content and format of all principal investigator data sets to be submitted to the FIRE Central Archive (only FIRE researchers will have access to data in the FIRE Central Archive of PCDS).

2. To set standards for data quality control, documentation of all data sets, and certification criteria for data products that will be released to the permanent FIRE data archive, the PCDS, and as such will be open to the at-large scientific community.

3. To select case study data sets for special intensive processing (including reformatting) by all relevant principal investigators and to identify other additional processing of data to accomplish FIRE objectives.

4. To coordinate data management decisions, through a standing Sub-Working Group on Data Management, to insure uniform FIRE data characteristics.

5. To certify, within 18 months after acquisition, those data products from the FIRE Central Archive that will be released to the permanent FIRE data archive, the PCDS.

6.2.3 FIRE Central Archive

The Pilot Climate Data Systems (PCDS) at Goddard Space Flight Center will serve as the FIRE Central Archive. The PCDS is an interactive, easy-to-use, on-line, generalized scientific information system. It provides uniform data catalogs, inventories, and access methods, as well as manipulation and display tools for a large assortment of Earth, ocean, and atmospheric data for the climate-related research community. Programs conducted by NASA-sponsored investigators, such as climate, weather, severe storm research, cloud and land-surface climatology, can be supported by the system.

Researchers can employ the PCDS to scan, manipulate, compare, display, and study climate parameters from diverse data sets. Data producers can use the system for validating, inventorying, and archiving data. Summary information about data can be used by managers for planning data processing and analysis activities. In addition, researchers can obtain quick access to selected portions of larger data sets.

For further information on PCDS, contact Dr. Robert Johnson, FIRE Data Manager, Mrs. Mary Reph, PCDS Manager, or Ms. Lola Olsen, PCDS, User Support Office.

The FIRE Central Archive provides a centralized data holding and data cataloging service in order to facilitate easy access to all FIRE data by all FIRE investigators. Since most of the satellite data are not collected directly by FIRE principal investigators, the Central Archive will also be responsible for holding of the satellite data sets required for FIRE research from the relevant satellite operating agencies. The specific data management functions of the Central Archive are:

1. To hold all reduced observations and data analysis products submitted by individual principal investigators or groups of principal investigators upon the request of the FIRE Working Groups.

2. To hold all satellite data sets required for FIRE as specified by the FIRE Working Groups.

3. To provide, upon request, copies of any data sets to FIRE investigators (at minimal cost to investigators).

4. To produce a catalog of the complete FIRE data holdings of the archive and the individual principal investigators indicating the current analysis status of these data. The catalog entries should provide information about the location of the data holding, the instrument(s) performing the observations, the resolution and areal coverage of the data, the date, time and location of the observations, and the format of the data.

5. To update the catalog (item 4) every year and to make it available to FIRE investigators in both hard copy and electronically (on-line dial-up) form.

6. To restrict access to the data products in the FIRE Central Archive to only researchers associated with the FIRE project. The at-large scientific community will not have access to these data sets.

7. To "release", on an annual basis, certified FIRE data from the Central Archive to the permanent archive, called the FIRE data archive of PCDS, for access by the at-large scientific community. The "transfer" process removes the access restraints to the at-large scientific community.

8. To provide for archival of the permanent FIRE data in the FIRE data archive by producing back-up copies of all data and taking other necessary precautions to insure the preservation of the FIRE data throughout the duration of FIRE.

9. To publish documentation, such as Users Manuals.

6.2.4 Project Office

FIRE data management structure vests the primary data processing function with the individual scientific investigators, the information and archival functions with the Central Archive, and the decision-making with the FIRE Working Groups. The Project Office must provide for liaison among these different groups. The specific data management functions of the project office are:

1. To provide liaison between the FIRE Working Groups (and individual principal investigators) and the data collecting agencies and agencies operating observing platforms required by FIRE.

2. To provide liaison between the FIRE Central Archive and the satellite and other data collecting groups to facilitate the acquisition of the data sets needed for FIRE.

3. To provide for a close working relationship among the FIRE Working Groups and the Central Archive by including a representative of the Central Archive on the Project Office staff who can attend FIRE Science Team meetings.

4. To provide interaction between the FIRE Working Groups, the Central Archive, and the Principal Investigators, a Data Management Working Group (DMWG) will be formed. The DMWG will be comprised of key members from both Working Groups and the Central Archive and will be chaired by the FIRE Data Manager.

6.3 Standard Data Format

There are three types of data acquisition activities in FIRE involving different combinations of observing platforms during four Intensive Field Observations (IFO) scheduled, two concentrating on cirrus and two concentrating on marine stratocumulus. These include collection of data from the surface, aircraft and satellites. FIRE observations are extended in space and time by the Extended Time Observations - Limited Area (ETO-LA), which include observations from the surface and satellites for the duration of FIRE. Finally, the larger scale is covered by Extended Time Observations - Extended Area (ETO-LA) from satellites. The FIRE data archive will contain the following types of information obtained from these different activities.

1. Reduced data -- observations converted to the physical quantity directly sensed by the instrument with quality control inspection and removal of bad data.

2. Calibration, quality and navigation information -- describes the conversion to physical units, the conditions of observation and the location of the observation.

3. Instrument documentation and data tape format description.

4. Analysis products -- physical quantities derived from the observations, including documentation on the analysis algorithm and any auxiliary data sets used in the analysis.

5. Data for special case studies which have been arranged for intercomparison of multi-platform observations.

6. Data selected for special processing to facilitate model studies.

7. Bibliography of FIRE publications.

The data acquired by the individual experimenters will be reduced to final numbers and forwarded to the Marine Stratocumulus Working Group and Central Archive. The format for the archive is the FIRE Standard Data Format given in Appendix C. This format is a flexible, self-contained data encoding format that allows for access to the data without previous knowledge of the contents or format. In addition, allows for a written description of pertinent remarks to be included in the data file.

Transfer of the final data between the investigators and the Central Archive may be accomplished by the mailing of appropriately prepared 9-track 1600 or 6250 bpi tapes. The electronic transfer

of data files over "data grade" telephone lines using acoustic-coupled computers is another good method of data transfer for small-tomedium length data files (these should be discussed with the PCDS).

Transfer of the data from the data archive to the investigators will be done either physically (using 9-track tapes) or interactively where systems are available.

6.4 Data Management Plan

The following describes the data management plan and the interaction between the WGs, PIs, Data Management Working Group (DMWG), Data Manager (DM), and PCDS:

1. PIs archive raw and submitted data for minimum of 5 years.

2. PIs submit catalog information in FIRE Standard Data Format to PCDS (with hard copy to DM).

3. PIs submit reduced and value-added data in FIRE Standard Format for PCDS (hard copy to DM).

4. Satellite data submitted to PCDS in native format via responsible PI.

5. PCDS will:

   (a) provide tape copy support for satellite data in native format.

   (b) provide tape copy support for other data in FIRE Standard Data Format.

   (c) maintain on-line catalog and inventory of FIRE data.

6. Case study data sets assembled by DMWG as directed by WGs.

7. WGs certify data for transfer to permanent archive.

6.5 Data Management Implementation

The following lists the specific tasks and responsibilities for the WGs, PIs, DMWG, and PCDS:

1. DMWG

   (a) defines FIRE Standard Format

   (b) defines sample catalog product in FIRE Standard Format

   (c) defines sample data product in Fire Standard Format

   (d) originates and distributes proposed listing for parameter units and conventions for reduced data.

2. PCDS

   (a) generates and distributes sample catalog and data products.

   (b) receives, maintains. and provides copies (upon request) of catalog and submitted data sets.

   (c) assembles certified FIRE case-study data sets

   (d) releases data products to permanent archive (also PCDS)

3. PIs

   (a) read, generate, and forward sample catalog and data products to PCDS (with hard copy to DM)

   (b) generate and forward catalog information to PCDS (with hard copy to DM)

(c) generate and forward reduced data products to PCDS (with hard copy of header to DM)

4. WGs

   (a) approves listing of parameter units and conventions for reduced data

   (b) define reduced data products for all PIs

   (c) define case study data sets

   (d) certify FIRE data

6.6 Data Schedule

6.6.1 Post-Experiment Debrief

After each experiment flight there will be a post-experiment debriefing of all the experimenters. This debriefing is intended to communicate and document pertinent subjective observations made during the completed mission and allow the experimenters an opportunity to modify subsequent plans or procedures for the following experiment. Each experimenter should have a "quick-look" capability for inspection of their sensor performance. A copy of the "quicklook" data (raw strip charts, tables, etc.) may be submitted to the Data Manager for possible comparison/correlation

with other experiment data.

6.6.2 Post-Mission Debrief

A post-mission debriefing will be held at the conclusion of the mission on Monday, July 20. Each experimenter will describe their sensor performance, a summary of sensor operating times, a sample of data obtained, and a description of the data format that is planned to be submitted to the data archive. The Marine Stratocumulus Working Group will review the missions and measurements obtained during the mission. If appropriate, it will prioritize key areas of data reduction and analysis, identify possible data collaboration and exchange, and modify the data reporting schedule.

6.6.3 Preliminary Data Analysis Workshop

A preliminary data analysis workshop will be held approximately three months after the conclusion of the mission. The experimenters will describe the performance of their sensors, a sample of the preliminary reduced data, an estimate of the sensor accuracy and precision, and report on key measurement results. At the time of the Data Analysis Workshop, the preliminary catalog information will be submitted to the PCDS in the FIRE Standard Data Format as documented in Appendix C. The Marine Stratocumulus

Working Group will review the measurements and analyses obtained to date, identify those areas requiring additional investigations, and determine the specific details of each investigation that is to be pursued.

6.6.4 Final Reduced Data Submittal

Approximately 9 months after the IFO, the experimenters will submit the final reduced data products to PCDS (with a hard copy to the Data Manager). The data products should be in FIRE Standard Format, as described in Appendix C. At the same time, updated catalog information should also be submitted.

6.6.5 Review of Results/Science Planning Workshop

Approximately one year after the IFO, a Science Workshop will be held to review the key research results. The Marine Stratocumulus Working Group will review each of the major scientific objectives (as described in Section 2.0) in light of the measurements and analyses obtained to date. The Marine Stratocumulus Working Group will integrate the individual measurements into several comprehensive case study data sets and where appropriate will compare the measurements with preliminary theory or model predictions. Some of the individual investigations may possibly be integrated into a broader cloud-radiation context. Results from the 1987 Marine Stratocumulus IFO will be used to provide new insight into the planning for the 1990 Marine Stratocumulus II IFO objectives and field plans.

6.6.6 Open Access to Data Archive

Eighteen to twenty-four months after the IFO, the FSET/WG approved data will be certified for release to the scientific community. Any proprietary rights to the data and data interpretation will be voided at this time.
The data management schedule is included in Table 5.

6.7 Data Protocol and Publication Plan

This data protocol and publication plan has been prepared to encourage an orderly and timely analysis, interpretation, and publication of the data obtained during the Marine Stratocumulus IFO. It is hoped that the development and distribution of this plan will enhance the atmospheric science output by encouraging the early publication of results and promoting cooperation among the investigators, thereby enriching the scientific interpretation of the data obtained from single and ensemble of instruments.
The FIRE Working Groups are responsible for the certification of data submitted to the permanent FIRE data archive, the PCDS. The certification process will normally take 18-24 months after acquisition. During the certification process period, the following set of data protocol and publication ground rules will be agreed upon and abided to by all FSET members as a condition of their participation in the FIRE project.

6.7.1 Data Protocol

1. FIRE Science Experiment Team members will have free access to all data acquired during the project. The normal vehicle for data dissemination will be a transfer of data via the FIRE Central Archive (FCA) at PCDS; however direct transfer of data between investigators is also encouraged.

2. Each investigator's data is proprietary until the data appear in publication or, if the data are included in the FCA, until this archive is published/released to the scientific community. FSET members who collect FIRE data are responsible for the reduction, analysis, interpretation and publication of their data and research results.

3. An investigator whose unpublished data are to be used in an investigation has the right to be included among the authors of any resulting publication. The investigator may refuse co-authorship but not the use of his data. The investigator must provide information concerning the quality of the data and may require that suitable caveats regarding the data be included in the publication. It is the responsibility of the sponsoring investigator to solicit the participation of the investigator whose data are to be used as early as possible during the formative stages of the investigation.

4. FSET members may release their own data to whomever they wish. They may not release the data of other investigators without consent.

5. Selected sets of reduced data obtained by investigators participating in collaborative research will be made available to Fire Working Group participants within ten months following acquisition.

6. In the Intensive Field Observations, instrument principal investigators are responsible for making "quick-look" data available within a short time after acquisition for use in quality assessment and mission planning.

7. The FIRE Working Groups will normally provide the forum in which collaborative investigations are planned and executed, however this is not meant to discourage collaborative investigations outside the scope of the Working Groups.

8. Any data sets resulting from collaborative investigations among FSET members will be made available to the FCA. This includes all collaborative efforts both within and outside the FIRE Working Groups.

TABLE 5: DATA MANAGEMENT SCHEDULE

1987 MARINE STRATOCUMULUS IFO

MONTHS	DATE	MILESTONE
-6	Dec. 25, 1986	PIs returm sample data tapes to PCDS
-4	Mar. 1, 1987	FSET approves parameter units and conventions for reduced data sets
0	June 29, 1987	Start of IFO
1	July 21, 1987	Post-Mission debrief
4	Oct., 1987	Preliminary Data Analysis Workshop PIs submit preliminary catalog data to PCDS FSET/WG defines reduced data product
+9	April, 1988	PIs submit reduced data sets to PCDS Submit updated catalog information to PCDS
+12	July, 1988	FSET/WG evaluation of reduced, value-added, and case study data sets
+18-24		WG certification of 1987 Marine Stratocumulus data for permanent archive

9. Investigations utilizing unpublished FIRE data must be sponsored by a FSETS member. Co-investigators and associates may participate in the investigation of an FSET member.

10. Scientists who are not FSET members, co-investigators or associates may participate in investigations using unpublished FIRE data provided they are sponsored by an FSET member and they make available whatever data they plan to use to the FCA at the beginning of the participation.

11. Proposed titles, descriptions of investigations, and paticipating researchers should be forwarded to the FSET Chairman and FIRE Project Office. These lists will be compiled and kept current by the FIRE Project Office. A periodic newsletter will be distributed to FSET members giving current status of investigations. The newsletter mechanism will be used to keep FSET members apprised of events, deadlines and program in the FIRE.

6.7.2 Data Publication

Early publication of results from the IFO is strongly encouraged by the FIRE Project. Towards this goal, the Project has developed the following minimum publication plan:

1. A synopsis of the key operational activities and possible results from the Marine Stratocumulus IFO will be prepared by project personnel for publication in an appropriate journal. This paper will be designed to be a "quick look" publication to inform the scientific community at an early stage of the implementation of the mission and possible highlighted observations.

2. Publication of results from the Marine Stratocumulus IFO will be in a special issue of an appropriate journal. The issue will contain (a) an overview paper and (b) atmospheric science papers.

   The overview paper will be co-authored by Project personnel and will include a statement of the goals of the particular field mission. It will describe the field site, the instrumentation involved in the mission instrument complement, the reasons for the particular aircraft expeditions/field deployment, flight plans, and other operational activities.

   The atmospheric science papers will be contributions from any of the FIRE investigators. They will be "stand-alone" papers that the investigators will prepare summarizing measurements, data interpretation, and perhaps data correlations. Collaborative papers between different groups are strongly encouraged.

3. A firm timetable for the publication of the special issue papers is established whereby all of the Marine Stratocumulus IFO papers will be submitted for publication prior to September 1, 1988.

4. Oral presentations of selected results by the investigators and the project may be presented together at an appropriate conference.

5. Additional publications or presentations by FIRE investigators beyond those identified above are expected and encouraged. Other publications should, however, be in harmony with the data protocol and publication plan contained in this document.

7.0 OPERATIONS

7.1 Functional Organization

The functional organization for implementing the Marine Stratocumulus IFO shown in Figure 7.1. Names, addresses, and phone numbers of the incumbents are provided in Appendix B. A brief description of incumbent responsibilities follows:

Program Manager - Responsible for overall program guidance, review and selection of projects and project elements, and funding.

Project Manager - Responsible for the overall management, coordination, and reporting of the project activities.

Agency Representatives - Responsible for the assisting the Program Manager in selection of projects, project elements, and agency funding and support.

Marine Stratocumulus Working Group - Responsible for defining the goals of the Marine Stratocumulus IFO and monitoring the progress of individual and collective research.

Mission Selection Team - During the Marine Stratocumulus IFO a Mission Selection Team (MST) will be formed. The MST will be comprised of no more than five FSET scientists representing the multiple goals of FIRE, it will be chaired by the FSET chairman or his designee, and shall have the following responsibilities:

1. Solicit and represent ideas of other FIRE scientists in operations decisions and scheduling.

2. Review on a daily basis the candidate missions proposed by the Mission Planning Team (see next paragraph) and select the planned operations and scheduling of all FIRE platforms for the following day.

3. Select on a daily basis a Mission Scientist and an Alternate Mission Scientist (see second paragraph) to

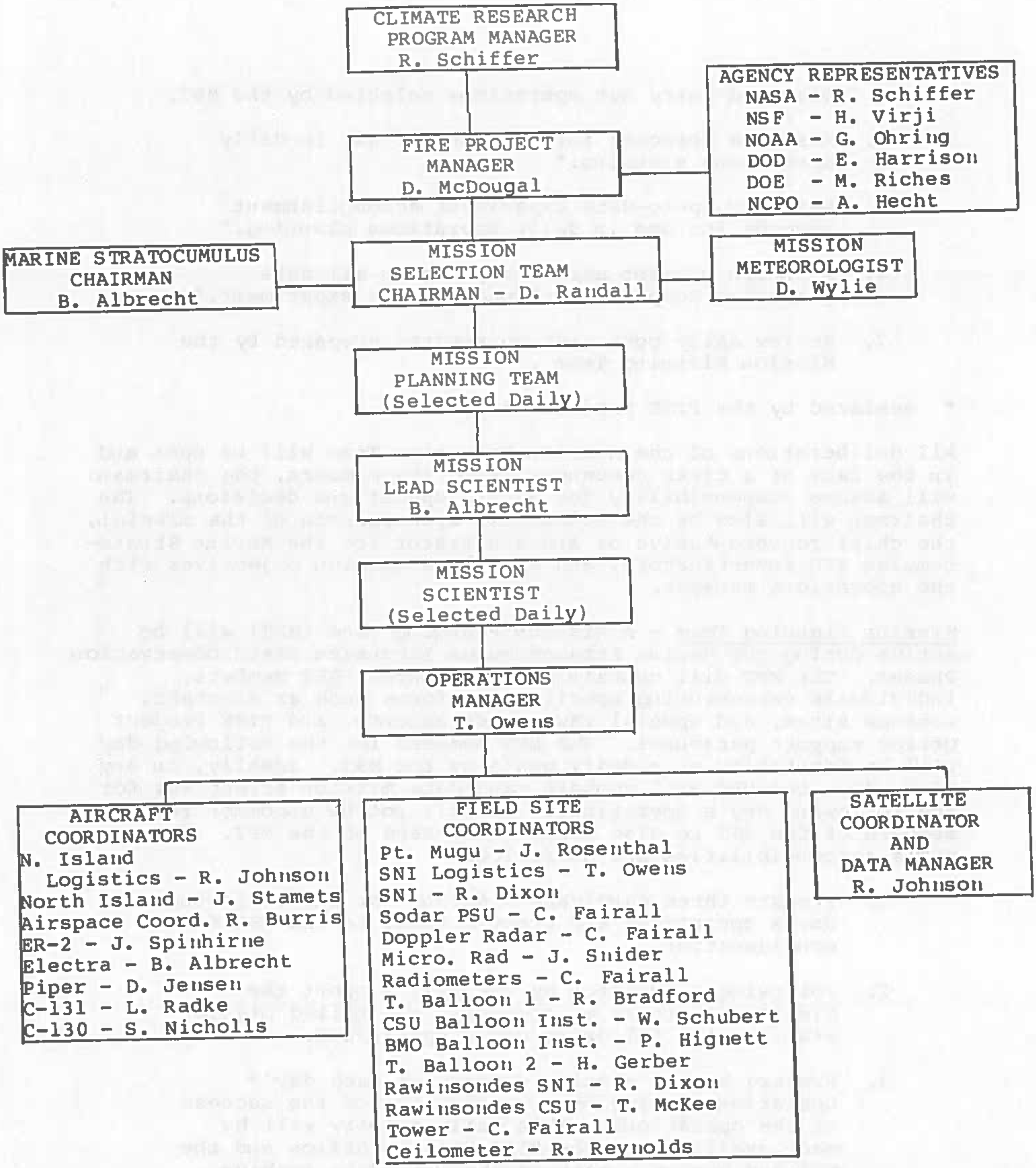


Figure 7.1 - Marine Stratocumulus IFO Functional Organization

plan and carry out operations selected by the MST.

4. Assemble forecast information for use in daily operations planning.*

5. Maintain up-to-date experiment accomplishment records for use in daily operations planning.*

6. Maintain current status reports on all data gathering components throughout the experiment.*

7. Review daily post mission reports prepared by the Mission Planning Team .

* assisted by the FIRE project office.

All deliberations of the Mission Selection Team will be open and in the lack of a clear concensus among its members, the chairman will assume responsibility for making operations decisions. The chairman will also be the scientific spokesperson of the mission, the chief representative of and arbitrator for the Marine Stratocumulus IFO investigators, and establish mission objectives with the operations manager.

Mission Planning Team - A Mission Planning Team (MPT) will be active during the Marine Stratocumulus Intensive Field Observation Phases. The MPT will contain at least three FSET members, individuals representing specific platforms such as aircraft, surface sites, and special rawinsonde ascents, and FIRE Project Office support personnel. The MPT members for the following day will be identified on a daily basis by the MST. Ideally, on any given day, the MPT will contain candidate mission scientists for the following day's operations. It will not be uncommon for members of the MST to also serve as members of the MPT. The MPT's responsibilities are as follows.

1. Prepare three candidate missions for the following day's operations and present these to the MST for consideration.

2. Following a decision by the MST, support the Mission Scientist in preparing a detailed mission plan for the following day's operations.

3. Prepare a post mission summary of each day's operations including an evaluation of the success of the operations. This daily summary will be made available to the FIRE Project Office and the MST and become a part of the FIRE data archive.

Mission Scientist - A Mission Scientist (MS) will be identified on a daily basis by the MST at the same time the following day's mission is selected. In the event that the MST plans to be aboard an aircraft during the mission, an Alternate Mission Scientist (AMS) will be selected by the MST and will perform ground-based functions during the execution of the mission. The MS will be in charge of the detailed planning of the following day's operations and the execution of that plan. He will be responsible for making any real time decisions required during the execution of the plan.

A Mission Scientist must have an overall grasp of the scientific objectives of FIRE as well as an appreciation of operational constraints of the various platforms and personnel.

A single operations room or area will be established and normally manned each day. A MS will be the central point of contact and coordination with the operations personnel and PIs.

The responsibilities and functions of the MS are:

1. Establish, post, and maintain a daily operations schedule;

2. Establish an active duty roster for operations and PI personnel;

3. Maintain log on mission status and activites;
4. Work with the Aircraft Coordinators to allow proper scheduling of crews for flight operations and aircraft access; and

5. Work with the Field Site Coordinators to allow proper scheduling of surface observations.

Mission Meteorologist - The Mission Meteorologist will be responsible for meteorological forecasting and planning for and participating in all aircraft flight missions. He is also responsible for the collection, distribution, and archiving of meteorological data products required to support the science investigators and mission operations.

Operations Manager - The Operations Manager will have overall responsibility for organizing, scheduling, and conducting field operations, preparation of mission plans, establishing mission objectives with the Mission Selection Team Chairman, determining special support requirements, conducting planning and debriefing sessions, and operational procedures. He is also responsible for designing the specific and operationally feasible flight profiles to meet the scientific objectives and for coordinating the experimental requirements of measurement platforms for resources, testing, and integration for all field measurements. Lastly, he is responsible for the setup, testing, and operation of the operations control site.

Data Manager - The Data Manager will be responsible for coordinating the types, scope, and quantity of data collected during the field measurement and its archiving.

Satellite Coordinator - The Satellite Coordinator will be responsible for providing information on the periods and locations of satellite observation within the Marine Stratocumulus IFO area. He is responsible for determining that the appropriate satellite observations are being collected, archived, and made available to the Marine Stratocumulus Working Group.

Aircraft Coordinators - The Aircraft Coordinators will be responsible for the in-flight coordination between the science investigators and the flight crew and the overall integration, testing, and operation of experiments aboard their respective aircraft.

San Nicolas Island Field Site Coordinators - The SNI Field Site Coordinator will have primary responsibility for coordinating complementary ground measurement activities and overall integration, testing, and operation of experiments on San Nicolas Island.

7.2 Aircraft Integration and Unloading Sites

The instrument integration and unloading will be done at the home institution of the aircraft, as shown in Table 7.2.

TABLE 7.2 AIRCRAFT INTEGRATION AND UNLOADING SITES

AIRCRAFT	LOCATION
NASA ER-2	Ames Research Center Moffett Field, California
NCAR Electra	NCAR Boulder, Colorado
University of Washington C-131	University of Washington Seattle, Washington
BMO C-130	British Meteorological Office Farnsborough, Hants United Kingdom
NOSC Piper Navajo	Montgomery Field San Diego, California

7.3 Logistics

7.3.1 Advance Party

Approximately six months and 2 weeks prior to the start of the Marine Stratocumulus IFO an advance party consisting of FIRE Project and Bionetics Corporation employees will arrive in San Diego, California to prepare for arrival of the main group. The advance party will perform the following functions:

1. Ensure accomodations are suitable and available on schedule;
2. Establish operations center/forecast center location;
3. Establish airbase 2 location;
4. Check status of advance equipment and supply shipments;
5. Ensure availability of supplies to be obtained in California;
6. Set up support system (e.g., communications, meteorological) if required;
7. Ensure availability of support lab space;
8. Ensure transportation available on schedule;
9. Ensure aircraft support on schedule; and
10. Receive additional equipment shipments.

7.3.2 Equipment Shipment

Arrangements and maintaining budget for the shipment of mission related equipment and supplies to and from California is the responsibility of each principal investigator. To allow for delays, clearances, and "red tape", shipments should be scheduled to arrive in California no later than 22 May 1987, if possible.

7.3.3 Personnel Deployment

Arrangements and maintaining budget for the deployment of personnel to and from the field sites in California are the responsibility of each principal investigator. In general, personnel associated with ground-based measurements should begin set-up of equipment 7 days prior to the first scheduled aircraft mission.

7.3.4 Accomodations

Lodging will be at the Oakwood Apartments, Coronado Island/Mission Bay, San Diego, California as coordinated by The Bionetics Corporation.

7.3.5 Insurance

Insurance coverage for the equipment and personnel is the responsibility of the organization of each principal investigator.

7.4 Platform/Instrument Representative

To ensure proper exchange of information on schedules, meetings, and instrument status, each PI is responsible for designating a single person each day as the spokesperson for his experiment. The designated person will be the contact point for the MS. This person will attend scheduled meetings, provide status on his experiment, participate in flight planning, and will be responsible for informing his co-workers of schedule changes.

7.5 Briefing, Planning, and Coordination Meetings

7.5.1 Mission Planning Team Meeting

Nominally, daily meetings will be held by the MPT to prepare candidate missions for the following day's operations. Prime and alternate experiment plans are to be developed based on scientific need, success (or failure) of previous experiments, weather forecast conditions, platform/instrument status, and remaining resources.

The following persons or their designated alternate are expected to attend:

1. Three FSET members as designated by the MST
2. Aircraft Coordinators
3. Field Site Coordinators
4. Other experiment representatives
5. Operations Manager
6. Other project support personnel

7.5.2 Mission Selection Team Meeting

Nominally, daily meetings will be held by the MST to review the candiate missions proposed by the MPT and to select the planned operations and scheduling of the FIRE platforms for the following day. The MST will select a Mission Scientist and an Alternate Mission Scientist, whose responsibilities will be to plan and implement the selected operations for the following day. The following persons or their designated alternate are expected to attend:

1. MST members

2. Mission Meteorologist

3. MPT members

4. Operations manager

7.5.3 Experiment Plan Briefing

In general, meetings will be scheduled on non-experiment days. The selected MS will finalize the detailed planning of the operations selected by the MST for the following day's operations and describe them to the experiment participants. The following persons or their designated alternate are expected to attend:

1. MS and/or AMS

2. Operations Manager

3. Experiment Representatives

4. Mission Meteorologist

5. Aircraft Coordinators

6. Field Site Coordinators

7. Aircrew Representatives

7.5.4 Weather Briefing

Two weather briefings will be scheduled on each non-flying day (see 7.5.2 Mission Selection Team Meeting and 7.5.3 Experiment Plan Briefing). A single morning briefing will be held on each flight day (see 7.5.5 Preflight Status Briefing). The briefing will be presented by the Mission Meteorologist.

7.5.5 Preflight Status Briefing

A meeting will be held at least two (2) hours before each flight experiment to review the latest weather information, review the flight plans, instrument status, and make a go/no-go decision. This meeting will not be used to attempt major alteration to the prime flight plan. If the prime flight plan cannot be used and the alternate is not suitable, then the mission will be cancelled. The following should be in attendance:

1. Mission Meteorologist

2. Aircraft Coordinators

3. Field Site Coordinators

4. Operations Manager

5. Mission Scientist and/or Associate Mission Scientist

6. Aircraft Representative.

7.5.6 Data Intercomparison Meetings

During the field mission, experimenters are encouraged to informally discuss their results with each other and exchange ideas. Meetings may be called intermittently for the intercomparison of data, to ensure the proper dissemination of supporting information among the participants, and to encourage current and future collaboration.

7.5.7 Mission Summary

After each flight a debriefing will be held to review all aspects of the mission from weather conditions to instrument performance. The mission scientist will have previously debriefed each of the participating aircraft and surface investigators. The following persons are expected to attend:

1. Operation Manager;

2. Aircraft Coordinators;

3. Field Site Coordinators;

4. Mission Scientist;

5. Alternate Mission Scientist;

6. Experiment Representatives.

7. Aircraft Representatives

7.6 <u>Work Schedules</u>

The number of hours per day and days per week worked by members of various instrumentation teams is the responsibility of the PIs. The work schedules of government technicians, government contract personnel, and pilots are subject to specific regulations. The number of aircraft crew members authorized to operate aircraft systems will limit access to the aircraft to a maximum of 16 hours per day. We intend to operate 7 days per week throughout the Marine Stratocumulus IFO Mission with an average work day of 8-10 hours. Baseline flight schedules are shown in table 2.

7.7 <u>Aircraft Access</u>

On non-flight and flight days the aircraft will normally be open and power available at 0700, or at least 3 hours before take-off, and will be secured at 1800. Access to aircraft outside of these times must be coordinated through the Aircraft Coordinator and requests should be made at least 4 hours in advance.

Only designated aircraft crew members will open the aircraft, apply power, and operate the power distribution panel controls. Experimental apparatus under power will not be left unattended. Under no circumstances will aircraft be left open and unattended.

7.8 Flight Personnel

The number of persons on the aircraft may vary between flights. In general the following persons or their alternates will be on the aircraft;

TBD

7.9 In-Flight Safety Procedures and Operations Requirements for Marine Stratocumulus IFO

1. No smoking while on-board the aircraft.

2. No alcoholic beverages on-board aircraft.

3. Each person must be in his/her assigned seat during each take-off and landing.

4. Each person must have flotation gear readily accessible and must know how to use it.

5. The passage way down the aircraft must be clear at all times.

6. All carry-on gear must be secured before take-offs and landings.

7. Only designated aircraft crew members will operate the power distribution panel controls.

8. In the event of a power outage, all instrumentation power switches must be set to "off" position before power distribution panel is reset. Experiments will be brought on-line in sequence, if necessary, to avoid transient overloads.

9. One person with each experiment must monitor the intercom at all times and remain with his experiment.

10. The Aircraft Coordinator is the interface between the flight crew and the experimenters.

11. Technical crew members are not to enter the flight deck without permission.

12. In the event of an unscheduled landing at an airport other than its field base of operations, the Aircraft Coordinator will be the spokesperson

for the technical crew members. However, the aircraft commander is responsible for all persons and the aircraft.

13. The aircraft commander is ultimately responsible for the safety of each flight and is expected to take whatever actions are required to ensure that safety regardless of flight plans and experimenters' desires.

7.10 Experiment Planning Schedule (Non-Flight Day)

The following is only a nominal schedule and subject to major or minor modification.

1300 - 1500 Planning session for next mission

- Weather briefing
- Review instrument status
- Weather criteria
- Develop prime and alternate flight plans
- Identify present or potential problem areas

1500 Work aircraft clearances; tentative evening work schedule; inform SNI and NWS of plans

7.11 Nominal Schedule for Flight Day

H - 4	0700	Aircraft open and power available to experimenters
H - 3	0800 - 0900	Weather briefing, determine experiment status, review flight plan, go/no-go decision
H - 2	0900 - 0930	File flight plan; inform SNI and NWS of plans
H - 1	1000	Weather update
H	1100	Take-off
H + 5	1600	Land, aircraft secured for refuling
H + 5 1/2	1630 - 1700	Aircraft scientist debrief
H + 6	1700	Experiment summary - Conference call to SNI

7.12 Flight Go/No-Go Criteria

Any one of the following conditions or circumstances will constitute a no-go decision:

1. One member of the required flight crew is ill and there is no adequate replacement;
2. Aircraft malfunction;
3. Failure of communication system on aircraft (must have two working VHF transceivers and one HF radio);
4. Failure of either INS or Omega navigation system if operations beyond VORTAC range;
5. Less than two functioning navigation systems for operations over land;
6. Unsafe equipment or materials on-board aircraft;
7. Intoxicated technical or aircraft crew member;
8. Forecast IFR flight conditions in both primary and secondary flight plan areas;
9. Forecast IFR conditions at field base plus or minus 2 hours of recovery time; and,
10. Non-operational status of critical experiment instrumentation system in accordance with previously established rules governing adequate use of mission resources.

7.13 <u>Mission Abort</u>

The following conditions or circumstances may cause a mission abort:

1. Illness among critical flight crew members;
2. Aircraft mechanical or electrical malfunction;
3. Communications or navigation equipment malfunction;
4. Development of adverse weather;
5. Injury to crew member;
6. Unruly conduct by crew member;
7. Attempt to alter experimental equipment power cables;
8. Changes or attempted changes to any aircraft system;
9. Interference with any aircraft crew member or failure to follow instruction of aircraft crew members.

7.14 Medical Considerations

7.14.1 General

Persons with potentially serious medical problems should inform the Operations Manager and work out contingency plans for medical attention if the need should arise.

As a precaution all participants are urged to bring with them the following:

1. Up to date medical history;

2. List of all medications being used;

3. List of all allergies;

4. Blood type and analysis if available.

Each person now on medication should bring a supply sufficient for the mission duration. Those persons who wear glasses whould bring an extra pair.

7.14.2 Flight

Persons with respiratory infections or stomach upset are requested not to fly. Flight plans will not be altered because of motion sickness. Persons susceptible to motion sickness should consult their physicians for medication.

If any potential technical crew member has any concerns about his general health, he sould consult his personal physician and seek advice on possible adverse effects of flight stress. No trained medical personnel will be on board during these tests.

7.15 Public Relations

FIRE operations may generate some degree of interest with the local news media. The MST Chairman and Project Manager will be the official spokesmen for purpose, plans, and objectives of this mission. Information on an individual experiment is the PIs responsibility. Any written material with reference to this mission must be coordinated with the MST Chairman and Project Manager before release to local news media.

7.16 Aircraft Tours

We may receive requests from the local news media, government officials, or local scientists to tour the aircraft and see the instrumentation. Such tours should be arranged through the Operations Manager who will contact the appropriate expedition personnel. P.I.'s may be asked to have a knowledgable person on board the aircraft as the spokesman for his experiment. Nominally, such tours will be scheduled with at least 24 hours notice and with minimum impact on our mission.

7.17 Operations Phase-Out

7.17.1 Equipment Return

As discussed in section 7.4.2, shipping is a P.I. responsibility. Crating and the filling out of the shipping forms are the responsibility of each P.I. "Piggybacking" with U.S. government shipments will also be permitted.

7.17.2 Post-Mission Calibration

If required, the participating aircraft will be available for a period of several days after returning from California for additional ground tests or calibrations on the instrumentation. Please make arrangements with the appropriate Aircraft Coordinator.

7.17.3 Unloading Sequence

In general, instrumentation will be removed from the aircraft in reverse order of loading. Modifications must be coordinated with the Aircraft Coordinator. At least one person associated with each experiment must be present to assist with the unloading.

7.17.4 Storage of Equipment

All PIs are expected to remove their hardware from the aircraft home base hangar within 1 week after aircraft unloading unless prior arrangements have been made with the Aircraft Coordinator.

with minimum impact on all missions.

7.17 Completion Phase-Out

7.17.1 Equipment Return

As discussed in Section 7.6.2, shipping is a P.I. responsibility. Crating and the lifting out of the shipping items are the responsibility of each P.I. Arrangements with U.S. Government shipments will also be permitted.

7.17.2 Instrumentation Calibration

If required, the participating aircraft will be available for a period of several days after returning from California for additional ground tests or calibrations on the instrumentation. Please make arrangements with the appropriate Aircraft Coordinator.

7.17.3 Offloading Procedures

In general, instrumentation will be removed from the aircraft in reverse order of loading. Modifications must be coordinated with the Aircraft Coordinator. At least one person associated with each experiment must be present to assist with the offloading.

7.17.4 Storage of Equipment

All PIs are expected to remove their hardware from the aircraft home base hangar within 1 week after aircraft offloading unless prior arrangements have been made with the Aircraft Coordinator.

APPENDIX A

DESCRIPTION OF INSTRUMENTATION

A.1 SATELLITE

TBD

A.2 AIRCRAFT

A.2.1 DESCRIPTION OF NASA ER-2 INSTRUMENTS

TABLE A.2.1.A: ER-2 LIDAR SYSTEM CHARACTERISTICS

Transmitter	
Laser	Nd: YAG, I + II
Wavelength	1.064, 0.532 μ m
Pulse energy	100, 50 mJ
Pulse repetition rate	3.47 Hz
Beam divergence	1 mrad
Receiver	
Telescope	Cassegrainian
Aperature	18 cm
Detectors	0.532 μ m PMT, dual polarization 1.064 μ m APD
Filters	1 nm FWHM
Data Acquisition	
Pre-amilifiers	40 MHz, 4 decade logarithmic
Digitizer	8 bit, 20 MHz
Data words	2048 dual channel

1. Cloud Lidar System (See also Section 3.2)

A unique element of the proposed radiation investigation is a lidar instrument which provides absolute range resolved measurements to complement passive observations. The lidar system operates at dual wavelengths and dual polarization. Backscattered return signals are digitized with a 7.5 m vertical range resolution and, at the nominal pulse repetition rate of 3.47 Hz, a return signal is acquired every 50 m of horizontal distance. The system characteristics are summarized in Table A.2.1.B. The lidar system has been flown on the NASA WB-57F aircraft and is currently integrated to and operational from the NASA ER-2 aircraft. The lidar system is mounted in the forward section of an ER-2 superpod which also contains the Multispectral Cloud Radio-

TABLE A.2.1.B: DESCRIPTION OF SPECTRAL CHANNELS OF MULTISPECTRAL CLOUD RADIOMETER

Channel Number	Central Wavenumber (cm^{-1})	Central Wavenumber (μm)	Spectral Resolution (μm)	Principal Function
1	13271	0.75350	0.00108	Optical thickness
2	13146	0.76070	0.00121	O_2 A-band altimetry, volume scattering coefficient
3	13099	0.76339	0.00112	O_2 A-band altimetry, volume scattering coefficient
4	7341	1.3623	0.0088	H_2O band, water vapor density, volume, scattering coefficient
5	5836	1.7136	0.0457	Cloud phase, particle size
6	4630	2.1599	0.0894	Cloud phase, particle size
7	932	10.73	0.90	Temperature

meter (MCR). Support systems for both instuments include the data system and tape recorder, mounting facilities, power system, and navigation and timing information. The co-location in a single pod permits a direct optical alignment and time synchronization between the lidar measurements and the cloud radiometer nadir pixels. A full description of the CLS is given by Spinhirne et al. (1982). Representative results from an earlier field program are described by Spinhirne et al. (1983).

2. Multispectral Cloud Radiometer

The Multispectral Cloud Radiometer is a seven-channel scanning radiometer whose spectral characteristics are summarized in Table A.2.1.B. The spectral channels were specifically selected from remote sensing of cloud properties. The instrument was designed so that it scans through nadir in a plane perpendicular to the velocity vector of the aircraft, where the scan extends up to 45° on either side of nadir. All channels are sampled simultaneously in order to permit a high degree of registration among wavelengths.

The optical system of the cloud radiometer is of non-dispersive filter-dichroic configuration. The optical path consists of a 12.38 by 17.5 cm scan mirror, canted 45° to the long axis of the instrument; a 12.38 cm Dall-Kirkham (Cassegrainian) telescope, and a complex configuration of dichroic filters, mirrors, lenses, filters and a single prism. The instantaneous field of view of the radiometer is 7 mrad, resulting in a ground resolution at nadir of 133 m. A more complete description of the MCR is given by Curran et al. (1983).

3. Thematic Mapper Simulator

The Thematic Mapper Simulator is a multispectral scanner which may be flown in the Q-bay of the ER-2 aircraft, and which simulates the spatial and spectral characteristics of the LANDSAT-4 Thematic Mapper bands. The Advanced Microwave Moisture Sounder (AMMS), which has flown in the past in the aircraft Q-bay, is not being proposed as a part of the present study. The U-2 modified TMS will be the Q-bay instrument for our study. This version of the TMS is available with a 11 μm split window channel and a 6.7 μm channel. For the proposed experiment, the 6.7 μm channel will be replaced with a 3.7 μm channel. The TMS will then serve the function of a high resolution imager with bands similar to the AVHRR satellite instrument. The characteristics of the TMS as configured for the experiment are listed in Table A.2.1.C.

TABLE A.2.1.C: THEMATIC MAPPER SIMULATOR CHARACTERISTICS

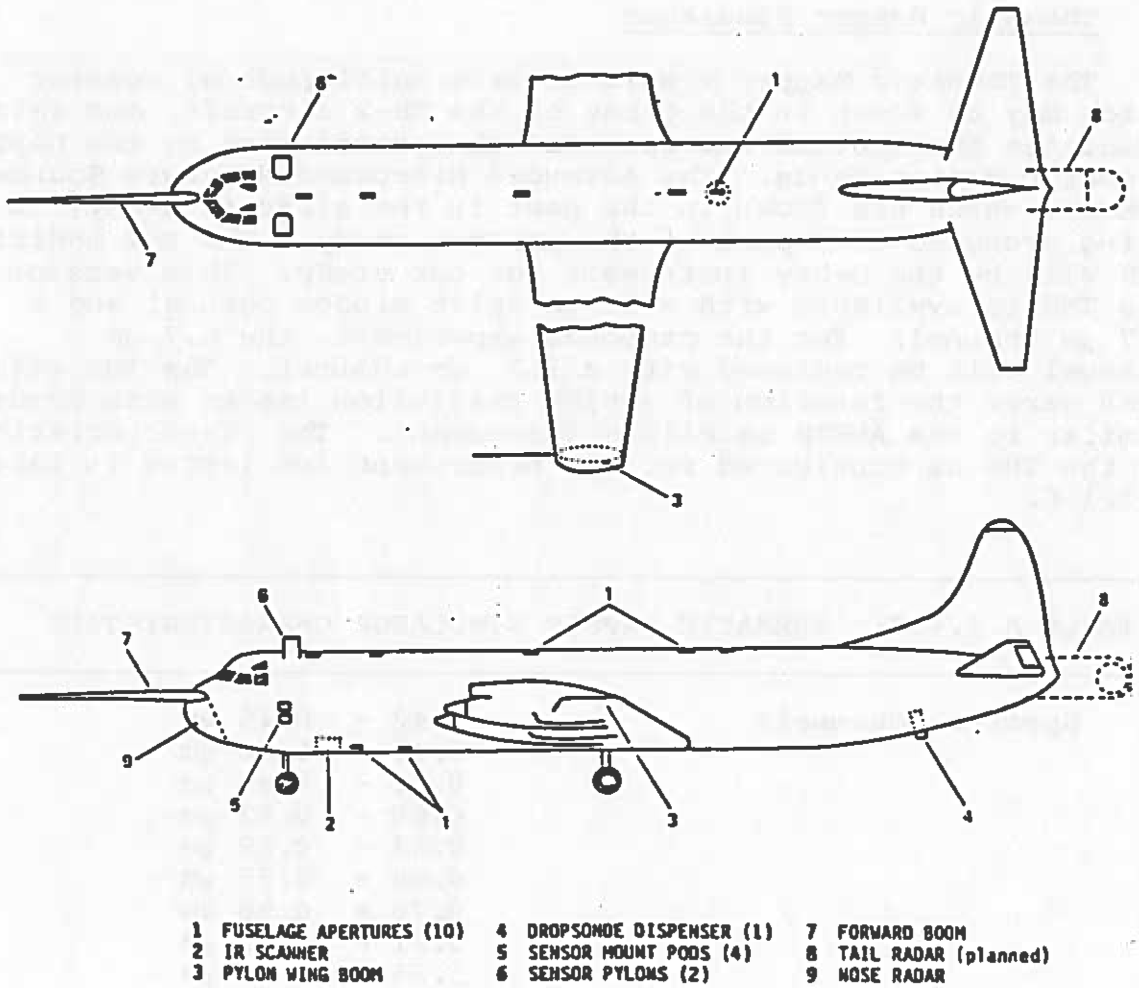
Spectral Channels	0.42 - 0.45 μm
	0.45 - 0.52 μm
	0.52 - 0.60 μm
	0.60 - 0.62 μm
	0.63 - 0.69 μm
	0.68 - 0.75 μm
	0.76 - 0.90 μm
	0.91 - 1.05 μm
	3.55 - 3.93 μm
	10.3 - 11.8 μm
	12.3 - 12 .8 μm
IFOV	5 mrad
Ground resolution	100 m (48 m IR)
Total scan angle	85.92°
Scan rate	6.25 scans/sec

A.2.2 - DESCRIPTION OF NCAR ELECTRA INSTRUMENTATION

The NCAR Electra (see Figure A.2.2) is a four-engine turbo-prop aircraft. It can remain aloft for 7-8 hours at 100 m sec^{-1}.

Its range with full fuel and optimum altitude is 3300 km. It carries the instruments listed in Table A.2.2. Further information is given by Phillips and Friesen (1984).

TABLE A.2.2: NCAR ELECTRA INSTRUMENTS



Characteristics of NCAR Airborne Infrared Lidar System - NAILS

General:

applications

- flight-track plots of BL top, backscatter profiles
- flight-track plots of cloud top or bottom structure
- flight tract data on clear air inversion height (via backscatter gradient)
- cloud physics backscatter, depolarization ration
- plume tracking using aerosol backscatter
- operational experience toward airborne Doppler lidar for winds

infrared
- eye safety factor 200 at telescope aperture (ANSI standard)
- eventual Doppler operation
- aerosol/molecular contrast
- laser efficiency

compact (system in King Air cabin above existing camera port)
- low-cost flight operation
- development without tying up aircraft
- down-looking only in King Air; outside pod with up/ down mirror (rotable in flight) for Electra

Optical:

laser
- LSI pulsed CO_2 with gas regenerator (wavelength 10.6 μm)
- 200 mJ/pulse at 50 Hz, 130 ns pulse length plus 2 μs tail
- head and power supply separate for flexible packaging
- total weight 212 lbs. plus rack, input 1 kW at 115 VAC 60 Hz

telescope
- 12.5", f/3 Dall-Kirkham
- pressure vessel to eliminate large IR window

detectors
- direct detection (no heterodyning at this stage)
- two for two polarization channels
- HgCdTe cooled by liquid nitrogen (hold time >10h)
- response to 15 MHz

transceiver layout
- single optical aperture in aircraft
- self-aligning system from optical beam switch outward
- required for later heterodyne development
- few optical elements

Performance
- range to continental cu 9 km with 100 mJ laser pulse demonstrated
- dead zone 300 m at full pulse energy, 100 m at reduced energy
- range to aerosol target 2 km for backscatter coeffieient of 5e-9 m-1 sr-1 calculated, 1.8 km on clear day demon- strated
- sensitive to 1-3 μm particle radius in typical aerosols

Signal Processing

digitizer
- 20-100 Mhz sample rate times 2 channels at 8-bit resolu- tion

- IEEE 488 interface plus block transfer data out interface
- 512 range gates per pulse per channel useful (3.84-km range), 1024 available
- oscilloscope display of signal return

preprocessing in digitizer
- sum waveforms in each channel (2, 4, 8,... pulses)
- max data transfer rate 32 kbytes/s (16-Hz data)
- horizontal resolution <10 m at 100 m/s cruise speed
- vertical resolution 20 m (± 10 m) limited by laser pulse

Data Processing

realtime display
- time-height (wrt aircraft) video 512x512 pixels by 4-bit color
- sum data in each range bin, each channel, for 1 to 4-Hz data
- output of summer 2 to 4 kbytes/s to video display
- display with new profile at moving cursor bar
- backscater values corrected for range-squared
- color sectioning for backscatter or depolarization
- vertical scale 3.8 km high, horizontal 36 km (6 min) for 2 Hz

data to ADS
- digital word (signed integer) for range to cloud
- digital word for cloud pulse height and width (relative)

postflight processing
- correction of backscatter for range-squared, optical geometry, and user-supplied attenuation algorithm
- time-height plots over user-selected scales of backscatter and/or depolarization, color or grayscale plots (or contours)
- time series of BL height determined by profile gradient algorithm
- x-y plots of BL height (from ADS position)

Mechanical

- sensor package on aft stb seat rails (King Air) or on lowboy rack (Electra) includes laser head, optics module, and telescope
- separate rack for data collection electronics
- laser cooling by glycol-air heat exchanger in data rack

TABLE A.2.2: NCAR Electra N308D

Aircraft Instrumentation (1)

VARIABLE MEASURED	SYMBOL	INSTRUMENT TYPE	MANUFACTURER & MODEL NO.	Combined Performance of Transducer, Signal Conditioning, and Recorder: Range	Accuracy	Resolution
Aircraft Latitude	ALAT	Inertial Nav. Sys.	Litton LTN-51	± 90°	≤ 1.0 nm per flt. hour	0.0014°
Aircraft Longitude	ALON	Inertial Nav. Sys.	Litton LTN-51	± 180°	≤ 1.0 nm per flt. hour	0.0014°
Aircraft Latitude	CLAT	Loran-C System*	Advanced Navigation Inc. ANI-7000	± 90°	0.19 km	0.0002°
Aircraft Longitude	CLON	Loran-C System*	Advanced Navigation Inc. ANI-7000	± 180°	0.19 km	0.0002°
Aircraft Ground Speed	XVI,YVI	Inertial Nav. Sys.	Litton LTN-51	0 to 400 m/s	≤ 1.0 knot per flt. hour	0.04 m/s
Aircraft Vertical Velocity	VZI	Inertial Nav. Sys.	Litton LTN-51	± 200 m/s	±0.10 m/s	0.012 m/s
Aircraft True Hdg.	THI	Inertial Nav. Sys.	Litton LTN-51	0 to 360°	±0.05°	0.00275°
Aircraft Pitch Angle	PITCH	Inertial Nav. Resolver	Litton APD 917055	45°	±0.05°	0.00275°

*Not worldwide coverage.

TABLE A.2.2: NCAR Electra N308D

Aircraft Instrumentation (1)

VARIABLE MEASURED	SYMBOL	INSTRUMENT TYPE	MANUFACTURER & MODEL NO.	Combined Performance of Transducer, Signal Conditioning, and Recorder: Range	Accuracy	Resolution
Aircraft Roll Angle	ROLL	Inertial Nav. Resolver	Litton APD 917055	45°	±0.05°	0.00275
Inertial Platform Heading	PLTHD	Inertial Nav. Resolver	Litton APD 917055	45°	±0.05°	0.00275°
Static Pressure	PSW PSB	Variable Capacitance	Rosemount, Inc 120F	300 to 1-35 mb	±1 mb*	0.07 mb
Indicated Airspeed	QCW QCB	Variable Capacitance	Rosemount, Inc 1221	0 to 125 mb	0.7 mb	0.006 mb
Total Air Temperature	TTF, TTB	Platinum Resistance	Rosemount, Inc 102E2AL	-60 to 40°C	±0.5°C	0.006°C
Total Air Temperature (Deiced)	TTFH	Platinum Resistance	Rosemount, Inc 102DB, 102CV	-60 to 40°C	±1.0°C	0.006°C
Total Air Temperature (Fast Response)	TTKP	Platinum Resistance	NCAR Developed	-60 to 40°C	±0.5°C	0.006°C
Dewpoint Temperature	DP	Thermoelectric Hygrometer	EG&G 137-C3-S3	-50 to +50°C	±0.5°C>0°C* ±1.0°C<0°C	0.006°C

NCAR Electra N308D

Aircraft Instrumentation (1)

VARIABLE MEASURED	SYMBOL	INSTRUMENT TYPE	MANUFACTURER & MODEL NO.	Combined Performance of Transducer, Signal Conditioning, and Recorder		
				Range	Accuracy	Resolution
Absolute Humidity	VLA	Lyman-alpha Hygrometer	NCAR Developed LA-3	-45 to +30°C	±5%**	0.2%
Radiometric Sfc. Temperature	BPRT	Bolometric Radiometer	Barnes Engr. Co. Optitherm	-20 to +75°C	±1.0°C	0.005°
Angle of Attack	AFIXL AFIXR	Fixed Vane (Strain Gauge)	NCAR Developed	±10°	±0.2° (relative)	0.003°
Angle of Sideslip	BFIXT BFIXB	Fixed Vane (Strain Gauge)	NCAR Developed	±10°	±.2° (relative)	0.003°
Infrared Radiation	TPYRG BPYRG	Pyrgeometer 4 to 45 μm (Silicon Dome)	Eppley PIR	0 to 600 W/m^2	--------	0.40 W/m^2
Visible Radiation	TPYR1 BPYR1	Pyranometer .285 to 2.800 μm (Clear Dome WG7)	Eppley PSP	0 to 1500 W/m^2	--------	0.12W/m^2
Ultraviolet Radiation	TUV BUV	Photometer .295 to .385 μm	Eppley TUVR	0 to 200 W/m^2	--------	0.12 W/m^2

*If Relative Humidity is >11%.
**With periodic baselining.

NCAR Electra N308D

Aircraft Instrumentation (1)

VARIABLE MEASURED	SYMBOL	INSTRUMENT TYPE	MANUFACTURER & MODEL NO.	Combined Performance of Transducer, Signal Conditioning, and Recorder		
				Range	Accuracy	Resolution
Geometric Altitude	HGM	Radio Altimeter	Sperry Rand RT-221	0 to 762m	±1.5m, 0-30m ±8m, 20-150m ±53m 150-762m	0.1m
Geometric Altitude	HGME	Radio Altimeter	Stewart-Warner	0 to 21,000m	±9.7m	0.1m
Cloud Liquid Water Content	XLWC	Hot-wire	Johnson-Williams LWH (Cloud Technology)	0 to 5 g/m^3	---------	0.005g/m^3
Cloud Liquid Water Content	PLWC	Heated-wire	PMS-CSIRO King Probe	0 to 5 g/m^3	---------	0.006g/m^3
Photography	-----	16 mm time lapse camera (Left and Right)	Flight Research Model III-B	Time lapse up to 10 frame/s	--------	---------
Cloud Droplet Spectrum	FSSP	Laser Spectrometer	Particle Measuring Systems, Inc.	0.5 to 45 μm	---------	Selectable 0.5,1,2,3,μm

NCAR Electra N308D

Aircraft Instrumentation (1)

VARIABLE MEASURED	SYMBOL	INSTRUMENT TYPE	MANUFACTURER & MODEL NO.	Combined Performance of Transducer, Signal Conditioning, and Recorder		
				Range	Accuracy	Resolution
Cloud Droplet Spectrum	200X	Laser Spectrometer	Particle Measuring Systems, Inc.	20 to 280 µm	----------	20 µm

*Available through special arrangements.
(1) Degradation of accuracies can be expected when flying through visible moisture or under icing conditions of certain sensors.

A.2.3. DESCRIPTION OF UW C131-A INSTRUMENTS

1. The Cloud Absorption Radiometer

The Cloud Absorption Radiometer (CAR) is a thirteen-channel scanning radiometer whose spectral characteristics are summarized in Table A.2.3. All of the wavelengths were selected to avoid the molecular absorption bands, so that the anticipated absorption would be due solely to water or ice particles and aerosol particles. The instrument scans in a vertical plane from 5° before zenith to 5° past nadir (190° aperture). This permits observations of the internal scattered radiation field within clouds in both zenith and nadir directions with as much as a 5° aircraft roll.

TABLE A.2.3: DESCRIPTION OF SPECTRAL CHANNELS OF THE CLOUD ABSORPTION RADIOMETER

Channel Number	Central Wavelength (μm^{-1})	Spectral Wavelength (μm)	Principal Function
1	0.503	0.016	Scaled optical thickness $(1-g)(\tau_c-\tau)$
2	0.673	0.020	Scaled optical thickness
3	0.744	0.019	Single scattering albedo
4	0.866	0.020	Single scattering albedo
5	1.031	0.020	Single scattering albedo
6	1.198	0.022	Single scattering albedo
7	1.247	0.046	Single scattering albedo
8	1.547	0.030	Single scattering albedo
9	1.640	0.041	Single scattering albedo
10	1.722	0.038	Single scattering albedo
11	1.996	0.039	Single scattering albedo
12	2.200	0.040	Single scattering albedo
13	2.289	0.023	Single scattering albedo

The optical system of the CAR is of the non-dispersive, filter dichroic configuration. The optical path consists of a 12.4 by 17.5 cm scan mirror, canted 45° to the long axis of the instrument, a 12.4 cm Dall-Kirkham (Cassegrainian) telescope, and a complex configuration of dichroic filters, collimating lenses, mirrors, beam splitters, filters and a filter wheel. The filter wheel contains optical channels 8 through 13. Every fourth scan the filter wheel rotates to measure a new wavelength interval. With this configuration the first seven channels are continuously and simultaneously sampled, while the eighth registered channel is selected from among the six channels on the filter wheel. The instantaneous field of view of the radiometer is 1° (17.5 mrad). A more complete description of the instrument as well as initial observations are given by King et al. (1985).

2. The University of Washington's Airborne Research Facility

For the past fourteen years the UW has utilized a B-23 aircraft for cloud and aerosol research. The CAR was integrated into this facility in 1983, and it was aboard this aircraft that the CAR was flight-tested and the first measurements with the CAR were obtained.

The B-23 has recently been replaced by a Convair-131A. This aircraft is now being equipped for cloud and aerosol research and the CAR is being mounted onto it.

The instrumentation on the C-131A can be sub-divided into the following broad categories: navigational and flight characteristics, meteorological (including radiation), cloud physics, aerosol, cloud and atmospheric chemistry and data processing and display.

(a) Aerosol

Aerosol in the size range of 0.01-45 μm are measured using several instruments that are all fed from a common batch sampler of air aboard the aircraft. The batch sampler consists of a stainless steel cylinder 90 liters in volume and 1.5 m high which has a freely-floating piston. Electric valves control the filling and emptying of ambient air samples into and from this cylinder. Ram air pressure forces the piston upwards, filling the cylinder with ambient air and closing the air inlet valve. Since the piston offers negligible resistance to the in-rushing air (the pressure above the piston is reduced), sampling of particles is close to isokinetic.

After the cylinder is full, air from its base passes into the various instruments. The instruments size the particles after any water on them has been evaporated by passage through a diffusion drier. Hence, these instruments provide the dry size spectra of particles from 0.01 to 11 μm. The Royco 245, on the other hand, measures particles in the size range 2 to 45 μm without any significant drying.

When such measurements are made in clouds, the particles that enter the diffusion drier, and are subsequently sized, are primarily cloud interstitial aerosol. This is because the cloud drops are removed by a cyclone which is switched into the first bend in the air inlet sampling tube for interstitial sampling. (The large bag sampler employed for filter sampling, on the other hand, removes cloud droplets greater than 5 μm radius via impaction.)

This system has been successfully used to measure cloud interstitial aerosol for several years (Radke, 1983).

(b) Cloud physics

The critical questions which the cloud physics instrumentation must resolve are (1) what is the liquid water content (LWC) and droplet size distribution and (2) does the cloud include hydrometeors and, if so, in what phase?

We measure the LWC by three independent techniques, the Johnson-Williams (J-W) hot wire, a new King/CSIRO hot wire and a PMS FSSP. The FSSP gives the droplet size distribution and the LWC is calculated. The FSSP and J-W values of LWC have historically been in excellent agreement. We have had no flight experience with the King probe, but it is believed to have even less drift and error than the J-W.

The nature of the hydrometeors and the concentrations of ice are determine from the 1-D and 2-D PMS Cloud (c) and precipitation (P) probes and the UW ice particle counter. These five probes provide both automatic and visual confirmation of the presence of ice particles and hydrometeors. The OAP-2D and P probes provide visual identification of crystal habit and some indication of crystal riming.

The aircraft is also equipped with bulk cloud water samplers. We intend to filter the cloud water and analyze the filter optically, described by Clark (1981), as another approach to examining the cloud's optical absorption characteristics.

A.2.4: DESCRIPTION OF THE BMO C-130

The British Meteorological Office (BMO) C-130 aircraft will be used to measure thermodynamics, radiation, cloud microphysics, and atmospheric turbulence. The following Table A.2.4. lists the insturmentation:

A.2.5 DESCRIPTION OF THE NOSC PIPER NAVAJO

The NOSC Piper Navajo is a twin prop aircraft. It has twin Lycoming 310 hp turbocharged engines with the following capabilities:

Maximum speed	227 kts
Cruising speed	215 kts
Range	830 nm - 1065 nm
Useful load	2,509 lbs
Maximum altitude	12,000 - 15,000 ft.

TABLE A.2.4: DESCRIPTION OF C-130 INSTRUMENTATION

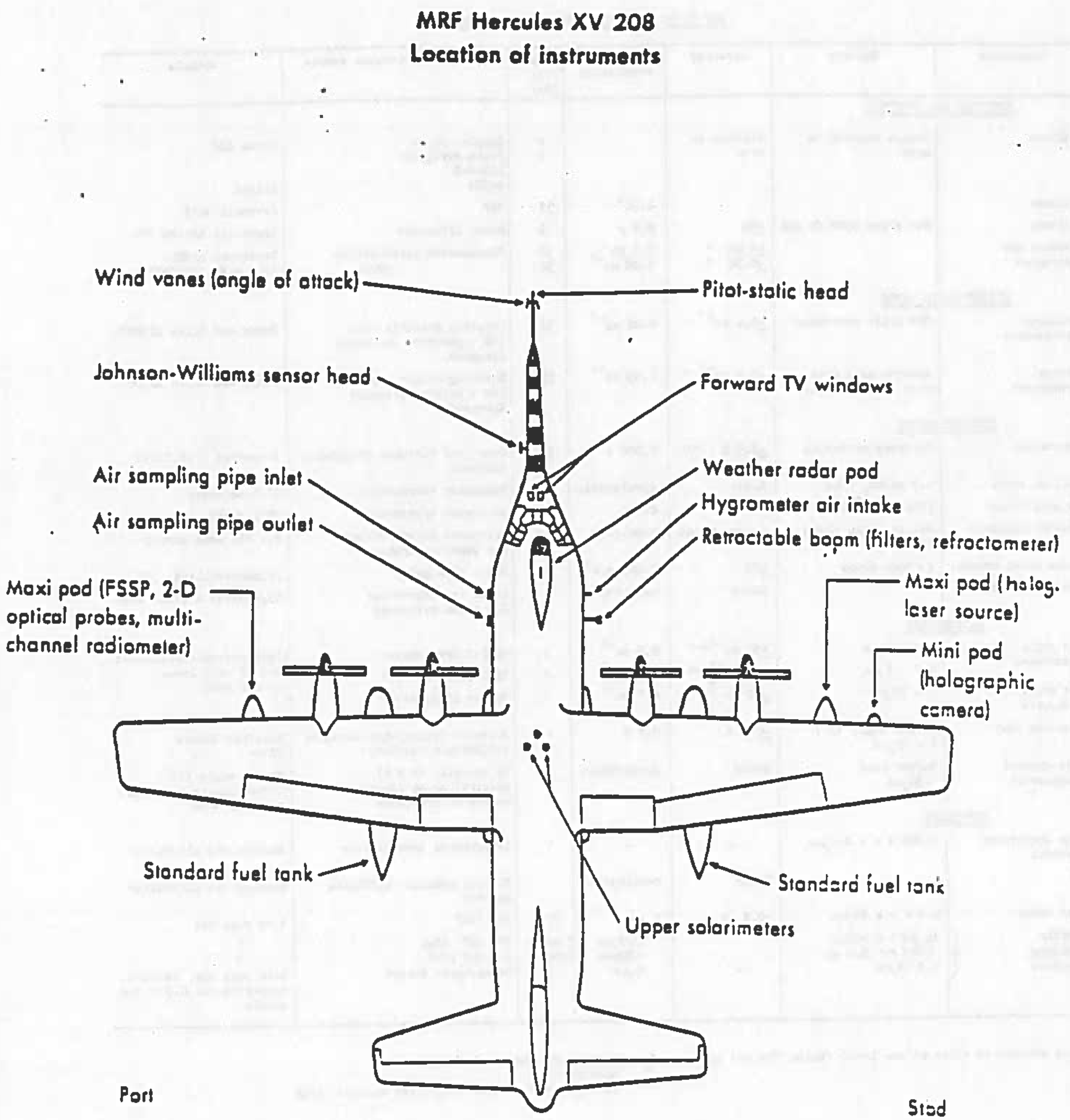
MRF C 130 INSTRUMENT SUMMARY FOR FIRE

Parameters	Remarks	Accuracy	Effective resolution	Sample freq (Hz)	Primary instrumental source	Details
POSITION AND ATTITUDE						
Position	Choice depends on area	Depends on area		2 4	Doppler radar Decca Navigator LORAN-C OMEGA	Decca 62M
Attitude			0.02°	32	INS	Litton
Altitude	Not above 3000 ft agl	±1%	0.8 m	2	Radar altimeter	Ferranti 1012 Honeywell AN/APN 171
Pressure and airspeed		±1 mb * ±0.3% *	0.5 mb 0.05 ms^{-1}	32 32	Compensated pitot-static probe	Rosemount 858L: 1301 A4EX, 1301D3EX transducers
FLIGHT LEVEL WINDS						
Horizontal components	INS drift corrected	±0.4 ms^{-1} *	0.06 ms^{-1}	32	Rotating sideslip vane INS - position reference Airspeed	Penny and Giles E23001
Vertical component	Assumes zero mean over length of run	±0.1 ms^{-1} *	0.03 ms^{-1}	32	Rotating attack vane INS - height reference Airspeed	Penny and Giles E23001
THERMODYNAMICS						
Temperature	Airspeed corrected	±0.3 K **	0.006 K	32	Open wire platinum resistance Airspeed	Rosemount 102EL/102EX
In-cloud temp.	4.3 μm CO_2 band	Under	development	32	Radiation thermometer	3° beam width
Dew point temp.	(Min ~ -45°C)	±0.5K	0.1 K	4	Automatic hygrometer	EG & G 137
Specific humidity	Not in thick cloud (> 0.5 g/m^3)	As dew point	0.02 g/kg	32	Microwave refractometer Dew point reference	9.4 GHz open cavity
Liquid water content	r < 30μm drops	±5%	0.003 g/m^3	4	Hot - wire probe	Johnson-Williams LWH
Total water content		Under	development		Lyman -α hygrometer Dew point reference	Hygrometer & evaporator
RADIOMETERS						
Wide angle shortwave	0.3 - 3 μm	±10 Wm^{-2}***	0.7 Wm^{-2}	1	Eppley pyranometer	Temperature compensated
	0.7 - 3 μm	±10 Wm^{-2}***	0.7 Wm^{-2}	1	Eppley pyranometer	One of each looks
Wide angle longwave	4 - 50 μm	±10 Wm^{-2}***	0.7 Wm^{-2}	1	Eppley pyrgeometer	up and down
Radiation temp	Narrow angle (2°) 8 - 14 μm	±0.3 K	0.1 K	4	Downward facing with airborne calibration facility	Modified Barnes PRT-4
Multi-channel radiometer	Narrow band 1-50 μm	Under	development	5	16 channels (4 x 4) Spectral range depends on choice of detectors	Narrow angle (1½°) Covers zenith and nadir to nadir + 60°
PARTICLES						
Light scattering aerosol	0.005 < r < 0.1 μm	-	-	1	Integrating nephelometer	Sampled via alleviator
CCN		Under	development		Thermal gradient diffusion chamber	Sampled via alleviator
Water drops	0.5 < r < 24 μm	±0.5 m	1 μm	10	PMS FSSP	Port wing pod
Particle imaging systems	12.5 < r < 400 μm		12.5 μm	As reqd	PMS OAP 2D-C	"
	100 < r < 3.2 mm		100 μm	As reqd	PMS OAP 2D-P	"
	r < 10 μm	-	10 μm	2	Holographic camera	Stbd wing pod, compact, instantaneous 0.5 litre sample

Quoted accuracies valid at low level (below 700 mb) only.

* In straight and level flight
** Outside cloud
*** In straight and level flight and outside cloud

Figure 1(a): View from above



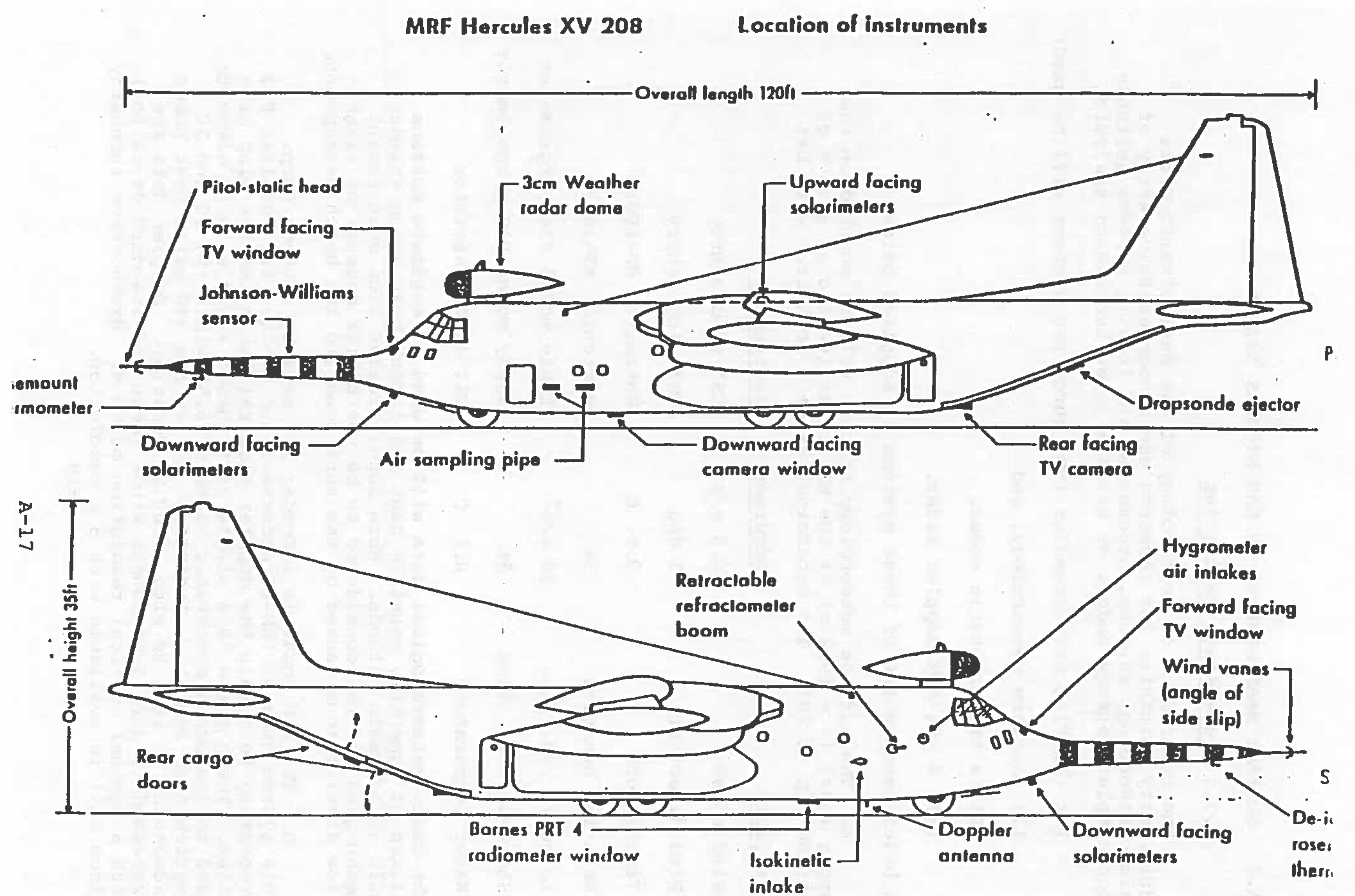

MRF Hercules XV 208
Location of instruments
Overall length 120ft
Pilot-static head
Forward facing TV window
Johnson-Williams sensor
3cm Weather radar dome
Upward facing solarimeters
Dropsonde ejector
Rear facing TV camera
Downward facing camera window
Air sampling pipe
Downward facing solarimeters
Overall height 35ft
Rear cargo doors
Barnes PRT 4 radiometer window
Isokinetic intake
Doppler antenna
Downward facing solarimeters
Retractable refractometer boom
Hygrometer air intakes
Forward facing TV window
Wind vanes (angle of side slip)

Figure 1(b)

A.3 SURFACE MEASUREMENTS ON SAN NICOLAS ISLAND

A.3.1 Penn State Facilities

The Department of Meteorology of the Pennsylvania State University maintains for research use a comprehensive array of micrometeorology sensors, processing and logging systems suitable for complete energy budget or surface layer turbulence analysis.

For the FIRE Stratocumulus IFO, three PSU systems will be used:

(1) surface meteorology, and

(2) a trimonostatic sodar.

(3) a 404 MHz doppler radar.

A brief description of these systems in supplied below:

a. The surface meteorology station will be mounted on the upper level (z = 19.2 m) of the NRL tower located at site-N of the NW tip of SNI. The meterological data collected will be:

Variable	Accuracy	Instrument
Wind speed	0.5 m/s	CSI wind sentry
Wind direction	5 deg	CSI wind sentry
Temperature	0.5 C	Rotronic MP-100F
Relative humidity	3%	Rotronic MP-100F
Longwave rad. flux	30 w/m^2	Epply model PIR pyrgeometer
Shortwave rad. flux	5%	Epply model PIR pyrgonometer
Water temperature	0.1 C	YSI 46040 themistor

The basic meteorological data will be used to estimate surface fluxes of momentum, sensible heat and latent heat using standard bulk aerodynamic methods. More sophisticated flux measurement techniques are not considered to be worthwhile because of slight flow distinctions caused by the surf zone and the beach escarpment.

b. The PSU sodar is a Xondar III made by Xontech Corp. This system uses an IBM-PC processor and employs full digital FFT processing to obtain the doppler spectral estimates for wind profiles. The antenna is a single unit phased array with 25 elements used to produce 3 monostatic beams of 6.50 width (0, 30 and 30 degrees from zenith). Individual pulses are 240 watts peak power (acoustic) at 1600 Hz with a 200 ms duration. Doppler data are processed to give 3-component winds (mean and standard deviation) with a nominal vertical resolution of 50 m. Backscatter intensity (from C_T^2) is available with 5 m resolution.

The instrumentation that will be used on the Point Sur is described in Table A.3.1.

A.3.2. Naval Postgraduate School Point Sur

Instruments on Point Sur

The R/V POINT SUR, owned by the National Science Foundation (NSF), is operated for the Central California Oceanographic Cooperative (CENCAL) by Moss Landing Marine Laboratories which is located on Monterey Bay. The vessel was built in 1980 by Rudolph F. Matzer and Associates, Inc., as was the R/V CAPE HATTERAS, and is especially suited for short to medium-length cruises. The R/V POINT SUR normally operates in waters off California, Oregon, and Washington with extended cruises to Mexico, Hawaii, and Alaska.

R/V POINT SUR is well equipped with all the necssary navigational, laboratory, and mechanical facilities that support biological, geological, chemical, and physical oceanographic research. Setting and recovering current meters, chemical sampling, diving, biological trawling, gear testing, and seismic reflection profiling are among a number of operations within the ship's capabilities.

MEASUREMENTS/OBSERVATIONS TO BE MADE FROM THE POINT SUR

Instrument	Measurement	Range	Accuracy	Data Output Rate	Remarks
CCCL WEATHER-PAK	SURFACE LAYER VECTOR WIND	0-30 ms^{-1}	10 cms^{-1}	10 min AVG	NPS
"	SURFACE LAYER AIR TEMPERATURE	0 to 30 C	.5 C	"	NPS
"	SURFACE LAYER RELATIVE HUMIDITY	0 to 100 %	3 %	"	NPS
Eppley pyranometer	solar	0 to 1000 Wm^{-2}	5 %	"	NPS
Eppley PIR	Longwave down	0 to 1000 Wm^{-2}	20 Wm^{-2}	"	NPS
Hot Film	velocity variance	.5 to 200 HZ	.5 cms^{-1}	"	NPS
Sonic Anemometer	velocity VARIANCE	.5 to 25 HZ	5 cms^{-1}	"	NPS
"	Temperature variance	.5 to 25 HZ	.5 °C	"	NPS
PMS ASASP	aerosol size distribution	.1-3 μm radius	-	"	NPS
PMS CSASP	"	.5-15 μm radius	-	"	NPS
Lyman-α hygrometer	humidity variance	.5 to 25 HZ	-	"	PSU
IR-hygrometer	humidity variance	.5 to 25 HZ	-	"	PSU
rawinsonde VIZ(~~loran~~)	vector wind profile (Loran)	0 to 70 Km	1 ms^{-1}	4-6 per day	NPS
"	Temperature profile	"	1 C	"	NPS
"	Humidity (RH) Profile	"	3 %	"	NPS
Forward Scat. Meter	IR Extinction (11 μm)	.001 to 1 gm/m3	.00~~[illegible]~~ g/m^3	10 min avg	NRL
HFS meter	visibility	.1 to 100 km	.1 ~~to 10~~ km	"	NRL
NRL Sampler	Radon concentration			"	NRL
Floating resistance THERM	Sea Surface temperature		.2 C	"	NPS
Paroscientific	Surface Pressure		.1 mb	"	NPS
Bridge observation	Pt. Sur Scientist	-	-	1 /hr	NPS

A.3.3 Colorado State University NCAR/CLASS Rawinsonde Measurements

Specifics of the CSU/CLASS rawinsonde measurements are summarized in the table below.

TABLE A.3.3: CSU/CLASS Rawinsonde Sensor Summary

Variable	Sensor	Range	Accuracy
Pressure	Wind capsule (Ni-Span-C)	1080 - mb	± 2 mb
Temperature	Rod-type thermistor	50° C to 90° C	± 0.4 C
Relative humidity	Carbon resistance element	5% to 100% (+40° C to -60° C)	± 4% (rms)
Wind vector	LORAN navaids	--	± 1 ms^{-1}

A.3.4 STEERABLE THREE-CHANNEL MICROWAVE RADIOMETER

The microwave radiometer is a three-frequency system which simultaneously measures liquid water in clouds and precipitable water vapor in the atmosphere. The system is completely passive and utilizes the natural emission of microwave energy by liquid water and water vapor. Measured quantities are total liquid water and water vapor integrated along the path through the atmosphere being observed by the instrument. In addition, profiles of water vapor density may be measured when the instrument's antenna is directed toward the zenith.

The system contains three independent microwave radiometers: the first operated at 20.6 GHz (wavelength 1.46 cm) which is sensitive primarily to water vapor; the second operates at 31.65 GHz (wavelength 9.48 mm) which is sensitive primarily to liquid water at any temperature; the third operates at 90.0 GHz (wavelength 3.33 mm) which is sensitive to both vapor and liquid. However, the 90 GHz channel is approximately seven times more sensitive to liquid water than is the 31.65 GHz channel; thus the third frequency increases the sensitivity of the instrument to small amounts of cloud liquid.

The three radiometers are coupled into an antenna system that is steerable in both azimuth and elevation. Therefore, the system may be used to study both spatial and temporal variability of liquid water in clouds and atmospheric water vapor. Three operating modes are possible with the instrument:

1. Fixed azimuth and elevation, typically the zenith,

2. Continuous 360 deg azimuth scans at a fixed elevation, and

3. Elevation scans at a fixed azimuth angle; the minimum elevation angle is 7.5 deg above terrain obstructions.

The maximum rate of scan is 0.5 deg/s; the antenna beamwidth is 2.5 deg. The system operating software is designed for unattended, continuous operation in the fixed-angle mode. However, the system should be manned for scanning operations.

System output data, integrated water vapor (in cm) and liquid water (in mm) are available in real time in tabulated form and on a strip chart. Data rates vary with the operating mode. Typical values are a 60 s rate at a fixed look-angle and a 5 s rate for the scan modes. However, data rates may be easily changed. Water vapor density profiles are available on demand. In addition to the real time outputs, raw radiometer data are archived on floppy disk for subsequent processing.

During the FIRE Intensive Field Operations (IFO) in July 1987, the microwave radiometer will be operated continuously. During Intensive Observation Periods (IOP) the system will be operated in both fixed and scan modes to measure the spatial and temporal variability in both water vapor and liquid water.

A.3.5 OPERATING CHARACTERISTICS

NOAA STEERABLE MICROWAVE RAIDOMETER

Frequencies:	20.6, 31.65, 90.0 GHz
Measured Quantities:	Path-integrated Water Vapor Path-integrated Cloud Liquid Water Vapor Density Profiles
Angular Resolution:	440 m at 10 km range (2.5 deg ant beamwidth)
Operating Modes:	Fixed Look-angle (typ zenith) Azimuth and Elevation Scans Max. scan rate 0.5 deg/s Min. elevation 7.5 deg above terrain
Data Rates:	Fixed-mode 60-120 s typ Scan-mode 5 s max
Anticipated Operation During MS IFO:	Continuous operation at zenith during IFO (unattended) Fixed or scan modes during IOP as required (attended)

A.3.6 Purdue Radiation Sensors

Not participating.

A.3.7 Colorado State University Tethered Balloon Instruments

See instrument list

A.3.8 MRU Cardington Tethered Balloon Instrumentation Summary

This will consist of a number (5 - 10) of identical probes. Each probe contains sensors to accurately measure probe attitude and cable orientation of a power source (lithium batteries), telemetry (400 MHZ) and weighs approximately 10 Kg.

The following measurements shown in Table A.3.8 are also made:

TABLE A.3.8: MRU Cardington Tethered Balloon Instrumentation

Parameters	Primary Sensors	Accuracy	Resolution	Sampling freq (Hz)
U,V,W,	3 axis Gill propeller anemometers +attitude data	1%	0.01 ms^{-1}	20
T	Thermistor, Platinum resistance	0.1K	0.01 K	20
q	Wet bulb thermistors	0.1K	0.01 K	20
P	Digiquartz transducer	1mb	0.1 mb	20

In addition, it is hoped that a single total water content sensor (evaporation - Lyman-α hygrometer) and a CSIRO pattern longwave radiometer will also be made available.

It should be noted that this system is currently being manufactured and is not yet fully tested. The data given above is the best currently available based on prototype probe performance. The batteries are expected to last at least 8 hr between recharges.

A.3.9 Naval Research Laboratory Tethered Balloon Instrumentation

TBD

APPENDIX B

FIRE Program, Project, and Marine Stratocumulus IFO Personnel

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Microwave Radiometer	Dr. Jack Snider NOAA/WPL 325 Broadway Boulder, CO 80303 (303) 497-6235 FTS 320-6235
Radiometer:	Dr. Roger Davies Department of Geosciences Purdue University West Lafayette, IN 47907 (317) 494-3702
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Rawinsondes (SNI):	Dr. Thomas McKee Department of Atmospheric Sciences Colorado State University Fort Collins, CO 80523
Tower:	Dr. Ken Davidson Code 63 Naval Postgraduate School Monterrey, CA 93940
Ship Point Sur:	TBD
Constant Level Balloons:	TBD
NWS Ceilometer:	Mr. Richard Reynolds Technical Manager Automatic Surface Observation System Room 1225 8060 13th Street Silver Springs, MD 20910 (301) 427-7975

APPENDIX C

STANDARD DATA FORMAT FOR FIRE

This appendix provides the rules to be followed in constructing data sets to be submitted to the FIRE Central Archive. These rules will be referred to as the FIRE Standard Data Format (SDF). They actually allow a family of formats, NOT just a single, fixed format. The FIRE SDF defines the structure of the data sets acceptable to the FIRE Central Archive, but the FIRE Science Experiment Team (FSET) must approve the actual data set content. The procedure for establishing this content for each investigator's data is outlined in a separate section of this appendix.

1. JUSTIFICATION

The FIRE SDF should provide an exchange format which will allow both the investigators and central archive programmers (actually the programs which they implement) to determine the basic logical structure of a data set with minimal necessary data and for future expansion to include additional types of data. The SDF should greatly facilitate the exchange of data between investigators and the use of the data by other scientists once the data are released to the public. Without such an exchange format, the multi-data studies required to make the FIRE a success would be very time-consuming and costly.

The exchange format is written in a way which will allow the FIRE Central Archive to minimise the amount of human intervention (programming, software maintenance, and data entry) needed to catalog, inventory, read, or copy the data sets submitted to the archive, while still allowing the investigators the flexibility to incorporate all needed data and to make modifications in the future. This should also allow the archive to provide more sophisticated access services than otherwise possible. Investigators may obtain subsets of data sets by specifying the type of records and the values of many data elements, such as the latitude, the longitude, and the time of the data, and not just by the physical storage medium, such as the specific tapes. Investigators may also take advantage of general purpose capabilities already developed at the archive facility. This will allow them to perform some initial initial analysis of the data with the archive's data manipulation and display capabilities.

Additionally, the archive can account for some of the differences between computer representations of nunerical values, instead of the investigator. The archive's programs will read data sets using either IBM or VAX integer representations and provide investigators with data subsets in their choice of either of these representations. The generic software routines needed to perform these routines are not directly usable, they should provide some guidance in developing software for reading other data in the standard data format. Since the staff of the archive facility will be familiar with the standard data format, they will also be able to provide limited assistance with any problems encountered.

2. DATA CHARACTERISTICS

The FIRE will produce several distinct types of data exhibiting very different characteristics: (a) digital satellite image data which are usually voluminous, are stored in various formats, and contain appended information, (b) digital ground and aircraft instrument data provided in both small and large volume data sets, each with a format nearly unique to the instruments which collected the data, and (c) photographs (analog data) produced by ground and aircraft observers to document the clouds present. Scientists must analyze all of these data types simultaneously in order to elucidate cloud and radiation processes and to obtain statistical descriptions of the cloud properties, and meet the scientific objectives of the FIRE. Some standardization of digital data formats is required to facilitate this analysis. The analog data will not be held by the central archive, and are not considered further in the appendix.

3. ARCHIVAL OF DATA

The data collected during FIRE will be held in a distributed archive. The archive holdings will include those of the individual investigators and those of the FIRE Central Archive. The holdings of the FIRE Central Archive will consist of certain subsets of the total data set selected by the FSET for special study or identified by the FSET as especially important. These data will be submitted to the central archive in the SDF, outlined in this appendix. This will facilitate team interaction and distribution of data. Investigators are also encouraged to adopt the standard format for individual holdings of data collected for the FIRE. This will allow investigators to take advantage of any formatting software developed for the SDF by other investigators or by the central archive.

Since the format standards described here allow some variations in the content of a data set, investigators or other providers of data to the FIRE Central Archive must submit a document describing the format along with a sample data tape, for approval by the FSET. This document may essentially be a dump of the first file on the tape, as described below. The FIRE Central Archive will, in turn, verify that the sample data tape corresponds to the documentation and conforms to the FIRE Standard Data Format. (Any format problems will be resolved by the FIRE Data Manager.) In addition to the format document, each investigator submitting data to the archive must provide the following: copies of and documentation for ancillary data sets used in data reduction, including calibration and navigation information, useful software for manipulating the data (such as tape read, navigation, or remapping programs), and up-to-date information for the central archive's catalog (in the format specified by the NASA Climate Data Catalog, NASA TM 86085).

Once a data set has been submitted in a specific format, all subsequent data of the same type must be submitted in the identical format. Changes of format can be implemented only by replacing all of the archive holdings or by labelling the new format data as different data. In either case, FSET approval for the change must be obtained. The investigator is allowed to replace missing data by dummy values to maintain the data structure. Similarly, if an investigator anticipates a need for future expansion of his/her data products, he/she is encouraged to include additional fields in the data record. These fields can be filled with the "missing" data flag until they are needed. This would eliminate the need for replacing all of the previously submitted archive holdings or labelling of the new data format as different data.

4. TAPE FORMAT SPECIFICATIONS

The FIRE data tape format is standardized only in terms of certain tape characteristics, file arrangements on the tape, a few file structure and data characteristics, and a few data organization guidelines. In order words, the actual data arrangement within a data file is not standardized except for certain imposed simplifications. This approach compromises between the minimum of reprocessing by the investigators and the maximum convenience of a single data format for data comparison/analysis. The required characteristics simplify the data structures sufficiently to eliminate most format problems with only modest inefficiency.

A FIRE Standard Data Format tape will contain a tape header file (volume ID), a volume table of contents (TOC) file, a test data file, a variable number (may be zero) of ancillary data files, and one or more data files. Each file will contain one or more physical records (blocks), consisting of a fixed number of bytes, as specified later in this appendix. A single end-of-file (EOF) mark will be written after each file and two EOFs (DEOF) will be written after the last data file on the tape. Thus the general layout of the tape is as follows:

Tape Header File
EOF
Volume Table of Contents
EOF
Test Data File
EOF
Ancillary Data File 1
EOF

Ancillary Data File 2
EOF
.
.
.
Ancillary Data File N
EOF
Data File 1
EOF
Data File 2
EOF
.
.
.
Data File M
EOF
EOF

All tapes shall be computer compatible magnetic tapes with the following physical characteristics.

Density:	1600 or 6250 bpi
Recording Mode:	NRZI
Number of Tracks:	9
Parity:	ODD

Note the following:

(i) The FIRE Central Archive will supply versions of the tapes to requesting investigators at either 1600 or 6250 bpi.

(ii) The physical records (blocks) within any one file shall be written entirely in a single fixed length that is selected for efficient data packing but is not less than 4000 and not larger than 12,000 bytes. The length of thes physical records is just a multiple of the length of the logical records. Further specifications for this size are provided in subsections describing each of the file types.

(iii) Only ASCII characters will be used in locations other than data fields. (All references to characters in this appendix shall mean ASCII characters specified as the Standard 7-bit character set of ANSI Standard X3.4-1977.) Numeric data values may be represented by 32-bit integers, 16-bit integers, or 8-bit integers using either IBM or VAX representations. Data are to be scaled so that no negative numbers are stored in actual data records.

(iv) All tapes must be in unlabled format; i.e., there should be no extra computer-specific records or files that identify a data file to a particular compter system.

4.1 Tape Header File (Volume ID)

The tape header file is always the first file on a data tape and is composed entirely of ASCII character data. It contains general information describing the tape contents and documentation of the tape structure. This file consists of one (or more if needed) physical record (block). This physical record (block) consists of 6400 characters arranged in 80-byte logical records (card images). All character information is to be provided left-justified; all numbers are to be provided right justified. All missing information is to be blank filled. The layout of this file is as follows:

Card Image #	Description
1	FIRE.ccccc.dddd.nnnnnn.v.yyyymmdd.yyyymmdd where ccccc = FIRE data collection element (ETO, CIIFO, MSIFO, ARCHV) dddd = abbreviation for source institution or investigator, such as GSFC, LARC, UWIS, PCDS nnnnnn = unique tape sequence number starting with 000001 v = tape version number stating with 0 yyyymmdd = year, month, and day of earliest data yyyymmdd = year, month, and day of lastest data
2	Producer's name or contact person for production questions such as problems reading or interpreting the data
3 - 7	Producer's address
8	Tape creation date (YYYYMMDD)
9 - 10	Internal input tape numbers used to create tape
11	Tape creation software version number as date of last change (YYYYMMDD)
12	Tape Density (1600 or 6250)
13	Computer system and operating system software used to generate the tape
14	Computer system representation used for numeric values on tape (VAX or IBM)
15	Translation table corresponding to the following character list: 0123456789=:> /STUVWXYZ, (-JKLMNOPQR*];+ABCDEFGHI.)[<

16 - 20	Plain language description of the contents of the tape
21	80 blank characters
22	Phrase "END OF GENERAL SEGMENT" left justified and blank filled
23	80 blank characters
23 - 11	For each (possibly zero or one) type of data logical record in the ancillary data files, a data description record (DDR) describing the contents of the logical data record: the variables, units, coverage and resolution (See below for format of the DDR. Note that each ancillary data file may contain only one type of data logical record. If additional types of data logical records are needed, additional files must be used.)
II+1	80 blank characters
II+2	Phrase "END OF ANCILLARY SEGMENT" left justified and blank filled
II+3	80 blank characters
II+4 - JJ	For each (possibly only one) type of data logical record in the observation data files, a data description record (DDR) describing the contents of the logical data record: the variables, units, coverage and resolution (See below for the format of the DDR. Note that each data file may contain only one type of data logical are needed, additional files must be used.)
JJ+1	80 blank characters
JJ+2	Phrase "END OF OBSERVATION SEGMENT" left justified and blank filled
JJ+3	80 blank characters
JJ+4 - KK	Blanks to fill current physical record

The data description record (DDR) provided for each type of data on the tape is structured as follows:

Characters	Description
1 - 14	Characters "RECORD NAME: "
15 - 22	A project unique short name for type of record type, left justified and blank filled
23 - 25	Characters " - "
25 - 65	A plain language description of the record type (40 characters, left justified and blank filled)
66 - 67	2 blank characters
68 - 72	Logical record size in bytes for this type of record, right justified and between 32 and 12,000 bytes
73 - 74	2 blank characters
75 - 79	Physical record size (block size) in bytes for this type of data record, right justified and

	between 4,000 and 12,000 (Note that this would be a multiple of the logical record size in characters 68 through 72 and is chosen for efficient tape processing. In other words, your data logical records may be small if you only have a few fields of data to represent, but you must block several of these together to produce a physical record of the specified size.)
80 - 80	Blank character
81 - 150	Investigator's name or person to contact for information about derivation techniques or other scientific information
161 - 560	Investigator's institution and address
561 - 640	15-Character unique abbreviation for name of mission/satellite/platform, followed by a ":" and 64 characters for the full name (left justify and blank fill)
641 - 880	10-Character short abbreviation for the instrument/sensor, followed by a ":" and 229 characters for the full name (left justify and blank fill)
881 - TT	For each actual or implicit (such as the channel numbers corresponding to data values which are implied by the order of the data) variable, presented in the order in which the variable will be encountered in the record with implicit variables placed before the variables which are functions of the implicit variables, the following:

16-Character field name (blank filled and left justified)
8-Character mnemonic for field name
4-Character field type and length (00 if the field is not actually stored in the record but implied, 1*1 for byte data, 1*2 for INTEGER*2 data, 1*4 for INTEGER*4 data.) (Note that 1*4 is the recommended type for data.)
12-Character measurement units (such as "MB", "DEGREES K", "WATTS")
8-Character Fortran Display Format for the field (Such as "12", "F6.2"; valid values are "I" "Iw", "Iw.w", "F", "Fw.d", "G", "Gw.d", "E", "Ew.d" where "w" is the field's width and "d" is the number of decimal places. Note that this information is used for the display of data and the reading of the test file; actual data are stored as binary integers.) 16 characters containing two scaling constants for computing the real data value (R) from the quentity (Q) stored in the data record, a 4-Character non-negative integer "N" followed by a 12-Character integer "A" to be used with the

following equation:

$$R = Q * (2.**(N-b)) + (A*1.0)$$

where b=7 for data values stored in 1-byte integers, b=15 for data values stored in 2-byte integers, and b=31 (usual value) for data values stored in 4-byte integers (Note that the values of "N" and "A" must be chosen carefully so that each ditinct value of R will be represented by a distinct non-negative value of Q when computed with the equation

$$Q = (R - A) * (2**(b-N))$$

where b is as noted above. Also, because of possible rounding errors, before unscaling, Q should be checked for the "missing" data flag. Suggestions for selecting "N" and "A" are in the conclusion to this appendix.) (If data are non-linear, a look-up table may be appropriate. In this case the look-up table itself may be stored as data.)
12-Character precision/error (using units and display format)
12-Character resolution (using units and display format)
12-Character minimum allowable value (using display format specified above)
12-Character maximum allowable value (using display format specified above)
128-Character functional dependency, in the format variable_name_1:variable_value_1,...., variable_name_n:variable_value_n where variable_value_1 uses the display format of the variable (For example for a grid with 4 temperature values, variable TMP1 might be defined as a function of "LAT: 1.25,LONG: 1.25", variable TMP2 as a function of "LAT: 1.25,LONG: 1.50", variable TMP3 as a function of "LAT: 1.50,LONG: 1.25", and TMP4 as a function of "LAT: 1.50,LONG: 1.50", where the LAT display format is defined as F6.2 and LONG display format is defined as F7.2), blank filled

TT*1 - PP Characters "INSTRUMENT DESCRIPTION:" followed by an instrument description in plain language, including mawnufacturer, platform, spectral channels, sensitivity, noise level, spectral, time and space resolution, and filled with blanks so that the description ends on a card boundary

PP*1 - LL	Characters "TEMPORAL CHARACTERISTICS:" followed by a plain language description of observations in time period, and filled with blanks so that the description ends on a card boundary
LL+1 - MM	Characters "SPATIAL CHARACTERISTICS:" followed by a plain language description of observation site or location, navigation information, coordinate system used, and filled with blanks so that the description ends on a card boundary
MM+1 - NN	Characters "CALIBRATION INFO:" followed by calibration information including source, uncertainties, and calibration factors and filled with blanks so that the information ends on a card boundary
NN+1 - QQ	Characters "REFERENCES:" followed by a bibliography of instrument specifications, calibration, analysis methods, and algorithms and filled with blanks so that it ends on a card boundary
QQ+1 - QQ+80	Characters "SOFTWARE:" left justified and blank filled
RR+81 - RR	Software (in FORTRAN 77) for data manipulation, such as tape reading, navigation, remapping, and look-up tables (FORTRAN data statements) for applicable fields

4.2 Volume Table of Contents File

The Volume Table of Contents File (TOC) is always the second file on a data tape and is composed entirely of ASCII character data. It contains text describing the tape contents. This textual information is arranged in the form of a table showing a file by file listing of contents. The TOC consists of one or more physical records (blocks), consisting of 6400 characters arranged in 160-byte logical records (card images) All character information is provided left-justified; all numbers right justified; unused characters are blank filled. The following characters shall be provided for each data file on the tape:

Characters	Contents
1 - 4	Data file sequence number on tape (right justified)
6 - 11	Data sequence number within data set (right justified)
13 - 20	Record type in the file (8 character short name as defined in the header file)
22 - 35	Date and GMT of earliest observation in file (YYYYMMDDHHMMSS)
37 - 50	Date and GMT of latest observations in file (YYYYMMDDHHMMSS)

52 - 77	Northern most latitude covered by data in file (using convention -90.00 to +90.00 with -90.00 the South Pole and +90.00 the North)
59 - 64	Southern most latitude covered by data in file (using convention -90.00 to +90.00)
66 - 72	Western most longitude covered by data in file (using convention - 180.00 to 180.00, where Eastward from Greenwich is positive direction)
74 - 80	Eastern most longitude covered by data in file (using convention -180.00 to 180.00)
81 - 150	Where appropriate, description of viewing geometry in file, using ranges where necessary, blank filled

The data file sequence number indicates the file number containing the listed data. This number allows identification of any data file and any data record on the tape by comparison to the sequence numbers given in each record. The data sequence number refers to a numbering of observations within an observation set (e.g., image number, orbit number, flight number) that is used by the investigator to relate the observations on this data tape to other observations on other data tapes. In order to keep the table of contents compact enough to be useful as a guide to data on the tape, the information about geographic coverage and time/space resolution need only approximate the true features of the data.

4.3 Test Data File

The Test Data file is written entirely in ASCII and represents the complete contents of the first data file of the tape. It contains the contents of the first observation data file on the tape, in the format specified by the DDR. This file should be easily read and can be used to validate the contents of the first observation data file.

4.4 Ancillary and Observation Data Files

The data records of any one file contain only data for one defined record type. The record type is documented in the first physical record of the file. This physical record contains the same 160-byte descriptive information about the data in the file as the corresponding record in the TOC file. This descriptive information is composed entirely of ASCII character data. This information is spread over the logical records and blank-filled as necessary to maintain it on the logical record boundaries for the file. (For example, if the data records for this type of data have a logical length of 160 bytes, the first logical record is just the file descriptor. If the data records for this type of data have a logical record length of 80 bytes, the first 2 logical records of the file would contain the file descriptor record. The last 68 bytes of the third logical record would be filled with blanks.)

It is highly recommended that the following variables (using the same names for ease of data set comparison) be included in all data records. These would be described in a DDR in the same way as the other variables. Some of these variables are for preventing loss of synchronization by I/O errors; others are for ease of selection of data meeting the experiment needs.

FNUM	Data file number on tape, in I*4
RNUM	Data record sequence number within the file, in I*4
TSEQ	Data record sequence number within tape, I*4
DSEQ	Data record sequence number within data set, in I*4
YEAR	Year of the data observation, in I*4 (for example 1986)
MONTH	Month of the data observation, in I*4 (1 through 12)
DAY	Day of the data observation, in I*4
HOUR	Hour of the data observation, in I*4
MIN	Minutes of the data observation, in I*4
SEC	Seconds of the data observation, in I*4
MSEC	Milliseconds of the data observation, in I*4
LAT	Latitude of the observation using the convention noted above
LONG	Longitude of the observation using the convention noted above appropriate
????	Other appropriate location fields, such as altitude, or fields indicating viewing geometry, such as solar zenith angle, relative azimuth, viewing zenith angle, or other equivalents)

The data sequence numbers within a file are simply reference numbers indicating the position of the data in that record within the file. Likewise, the data sequence numbers within a tape indicate the position of the data in that record within the whole tape. If more than one data tape is produced, a data sequence number for the position within the whole data set is desirable.

Bad or missing data must be represented by the largest possible integer value (e.g., (2**31)-1 for 32-bit words) for each data type used. Data arrangement must align the records (logical and physical) on 32-bit word boundaries.

5. STANDARD FORMAT FOR SATELLITE DATA

Satellite data can be submitted to the FIRE Central Archive in two different formats. The first tape format is essentially the original tape format of the satellite data. These data are submitted in this format in order to avoid reprocessing this large volume of data. Certain modifications of the formats may be necessary, however, to insure the presence of all of the proper ancillary information or to change features which produce special handling difficulties. (No changes for the latter purpose are anticipated.) The FIRE Central Archive will support the satellite data sets which are submitted in this format with catalog information giving a high-level description of the data, a simple inventory giving some information about the contents of each tape in the data set (basically time and instrument/mission information), and straight tape copying capabilities (i.e., the archive will make a copy of any available tape for an investigator, but will not further subset it.)

The second type of satellite data tapes which can be submitted to the FIRE Central Archive are satellite tapes formatted in the SDF. These data sets will be identified by the FSET, especially for the key case studies, to facilitate intensive data comparisons. The FIRE Central Archive will support satellite data tapes submitted in the SDF with the full capabilities developed for the other FIRE data sets.

Investigators supplying satellite data to other investigators or analyzing certain subsets of the satellite data at the request of the FSET are also encouraged to put their data into the SDF.

These large volume satellite data sets may be submitted in the 8-bit, 16-bit or 32-bit INTEGER type. Bad or missing data must still be represented by the largest possible integer value for each data type used. Data arrangement must align the records on 32-bit word boundaries.

6. GUIDLINES FOR ORGANIZATION OF DATA ON TAPES

Because of the diversity of the FIRE data sets and planned analyses, specification of a single "best" way to organize these data is impractical. However, certain basic principles can be followed which are described in the following subsections.

6.1 Use of file Divisions

The arrangement of the data on a single data tape should follow a "natural" sequence, usually a time sequence of spatially correlated observations. The division of the sequence into files on the tape should produce a moderate number (10 - 100) of files. Too few files are vulnerable to I/O errors while too many files waste tape in EOF marks. (This guideline refers primarily to data sets which fill one or more data tapes.) Time records should be broken into at least daily files.

6.2 Geographical Location Information

Satellite data form an image of a region at one time. Location information may be supplied as a function of pixel coordinate or interleaved with the data values. The latter is more convenient if the relation between pixel coordinate and location is variable;

the former is more convenient if the relation is fixed, at least within the file. Aircraft data should be presented as time records to which location tags are appended.

6.3 Multi-Component Data

Many FIRE data sets are composed of measurements from multi-Channel instruments or from groups of instruments making coincident measurements. Although many investigators may wish to examine particular components of such data sets and would, therefore, prefer the components in separate files, the heart of the FIRE concept is the analysis of many simultaneous or coincident observations of the same cloud. Since most multi-Component data are naturally collected with the different variables interleaved, these data should be organized by time period into files containing multiple variables that are interleaved to give all observations at each location at each instant of time.

6.4 Data and Analysis Products

Data (raw or reduced through straightforward processing) should be compiled separately form analysis products and ;laced on separate data tapes. However, subsequent studies of the initial analysis products can be enhanced by repeating and interleaving the original data on the data product tapes. Therefore, multiple forms of the same data may be required.

7. PROCEDURE FOR DECIDING FINAL TAPE FORMAT

The procedure for establishing the precise format used by each investigator has a few remaining steps. The FSET shall decide the data types, analysis product types, and other desired combinations of these that will be produced by all data suppliers.

- (i) The FSET will consider modifications to this appendix and approve the final form of the formats;
- (ii) Each investigator will submit a sample data tape to the FIRE Central Archive in the standard data format;
- (iii) The FSET will approve the final version of each investigator's data sets
- (iv) Each investigator will submit documentation for the FSET approved data tapes in the standard data format (SDF) to the FIRE Central Archive.

8. CONCLUSION

The FIRE Standard Data Format should allow descriptive information on the contents of a data set to be recorded with a data set (i.e., on the data set tape). It should also allow the data to be easily decoded, using simple computer programs.

This appendix concludes with some suggestions on selecting the scaling values for the data.

CHOOSING SCALING VALUES

In order to scale the data so they are 1-byte, 2 byte, or 4-byte positive integers, the following equation is used:

Q = (R - A) * (2**(b-N))

where R is the actual (real) data value, b=7 for 1-byte integers, b=15 for 2-byte integers, and b=31 for 4-byte integers, and Q is rounded to a positive integer. The value of A and the value of N are chosen to be integers which will allow the full range of the data to be represented, as well as give a positive value for Q.

For example, if the data are actually positive integers that can be easily represented in 32-bit (4-byte) integers, then there is no reason to scale the real data. Therefore, A=0 and N=31 are reasonable values.

If otherwise, A should be chosen so it is the largest integer less than or equal to the minimum allowable value of the data (e.g., the minimum value of the data minus A should be non-negative). And N should be chosen so it is the least non-negative integer so that the following is true:

(Maximum - A) / (2**N) < 1

Therefore, for a variable with a minimum value of 0.00 and a maximum value of 300.00, the value of A should be set at 0. The value of N should be set as 9. [Note 300.00/(2**8) is not.] So the quantity Q stored in a 32-bit word of the data record for R=0.00 is Q=0. For R=300.00, Q=300.00*(2**22). For R=150.00, Q=150.00*(2**22).

As another example, consider latitude with a minumum value of -90.0 and maximum value of 90.0. the value of A would be set as -90. (Note that this negative number does not appear in the data.) The value of N would be 8 [since (90.0-(-90))/(2**8) is less than 1 but (90.0-(90))/(2**7) is not]. So for R=-90.0, what is actually stored on the tape is (-90.0 -(-90)/(2**23) or 0.

APPENDIX D

TIMES OF SATELLITE OVERPASS

The satellite overpass times for the San Nicolas Island area of the NOAA 9, NOAA 10, ERBS, SAGE II and LANDSAT satellites are included in this appendix.

SAN NICOLAS ISLAND, CA
LAT= 33.23 LONG= 240.53

NOAA 9

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GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	LONG	SATELLITE SOL. TIME	SITE SOL.TIME	PRIMARY DAYS
87	6	20	22	28	34.17	73.44	178.29	34.12	ASCENDING	34.40	245.72	14.81	14.49	*
87	6	21	10	55	55.81	98.44	55.93	109.54	DEC	31.49	250.91	3.61	2.93	*
87	6	21	12	35	64.22	292.02	127.12	93.19	DEC	36.07	227.03	3.69	4.61	*
87	6	21	22	18	46.27	71.23	170.07	31.82	ASCENDING	35.13	248.24	14.81	14.31	*
87	6	22	10	44	63.11	96.92	56.51	111.03	DEC	31.19	253.57	3.59	2.75	*
87	6	22	12	25	57.70	290.84	126.74	99.11	DEC	36.12	229.55	3.67	4.43	*
87	6	22	22	7	55.37	70.14	171.12	29.60	ASCENDING	35.81	250.78	14.79	14.13	*
87	6	22	23	48	64.99	263.64	18.76	50.56	ASCENDING	31.14	226.67	14.87	15.80	*
87	6	23	10	33	68.89	95.46	57.28	112.50	DEC	30.95	256.25	3.59	2.57	*
87	6	23	12	14	49.38	288.94	127.80	97.85	DEC	35.32	232.04	3.66	4.24	*
87	6	23	21	56	62.43	68.25	171.60	27.41	ASCENDING	36.65	253.26	14.76	13.95	*
87	6	23	23	37	58.20	262.16	18.84	48.25	ASCENDING	31.41	229.34	14.86	15.62	*
87	6	24	12	3	38.19	288.00	126.29	98.91	DEC	34.60	234.59	3.64	4.06	*
87	6	24	21	46	67.95	66.45	172.54	25.18	ASCENDING	37.55	255.72	14.76	13.76	*
87	6	24	23	26	49.49	260.61	18.94	45.95	ASCENDING	31.74	232.08	14.86	15.43	*
87	6	25	11	53	23.80	285.57	126.98	100.79	DEC	33.97	237.13	3.64	3.88	*
87	6	25	23	15	37.96	258.89	11.18	43.78	ASCENDING	32.11	234.64	14.84	15.26	*
87	6	26	11	42	6.62	286.30	124.58	102.57	DEC	33.43	239.71	3.62	3.78	
87	6	26	23	4	22.97	256.62	11.87	41.48	ASCENDING	32.53	237.26	14.83	15.07	
87	6	27	11	31	12.74	105.32	56.36	104.37	DEC	32.82	242.28	3.61	3.51	
87	6	27	22	54	5.44	259.19	7.61	39.11	ASCENDING	33.12	239.84	14.83	14.89	
87	6	28	11	20	29.69	102.85	55.80	106.12	DEC	32.37	244.89	3.61	3.33	
87	6	28	22	43	14.05	75.26	170.28	36.88	ASCENDING	33.63	242.43	14.81	14.71	
87	6	29	11	18	43.17	108.20	55.86	107.77	DEC	31.97	247.53	3.59	3.15	
87	6	29	22	32	38.16	72.50	169.36	34.60	ASCENDING	34.31	244.97	14.80	14.52	
87	6	30	10	59	53.37	98.61	55.51	109.43	DEC	31.62	250.17	3.58	2.97	
87	6	30	12	39	65.79	292.54	127.87	93.81	DEC	37.12	226.34	3.68	4.64	
87	6	30	22	21	43.28	71.80	178.76	32.34	ASCENDING	34.92	247.54	14.80	14.34	
87	7	1	10	48	61.21	97.11	56.12	111.02	DEC	31.31	252.83	3.58	2.78	
87	7	1	12	29	59.69	291.30	126.75	94.98	DEC	36.36	228.05	3.66	4.46	
87	7	1	22	11	53.05	69.88	171.87	30.15	ASCENDING	35.70	250.04	14.77	14.16	
87	7	1	23	52	66.64	263.84	18.44	51.16	ASCENDING	31.03	225.93	14.84	15.84	
87	7	2	10	37	67.38	95.67	56.06	112.56	DEC	31.06	255.51	3.58	2.60	
87	7	2	12	18	51.92	289.50	127.02	96.96	DEC	35.54	231.34	3.65	4.28	
87	7	2	22	0	60.62	68.77	172.44	27.99	ASCENDING	36.41	252.57	14.75	13.98	
87	7	2	23	41	60.28	262.34	18.45	48.89	ASCENDING	31.29	228.61	14.83	15.66	
87	7	3	12	7	41.60	288.56	126.37	98.07	DEC	34.88	233.89	3.63	4.10	
87	7	3	21	49	66.52	66.95	173.47	25.88	ASCENDING	37.29	255.83	14.75	13.80	

SAN NICOLAS ISLAND, CA
LAT= 33.23 LONG= 240.53

NOAA 9

GMT					VIEWING	AZIMUTH	RELATIVE	SOLAR	SATELLITE	SATELLITE POSITION		SATELLITE	SITE	PRIMARY
YR	MO	DA	HR	MN	ZENITH	FR. NORTH	AZIMUTH	ZENITH	DIRECTION	LAT	LONG	SOL. TIME	SOL. TIME	DAYS
87	7	3	23	30	52.13	260.77	10.49	46.61	ASCENDING	31.60	231.26	14.83	15.47	
87	7	4	11	56	28.32	286.40	126.84	108.79	DEC	34.16	236.41	3.63	3.91	
87	7	4	23	19	41.46	259.02	10.64	44.34	ASCENDING	31.97	233.91	14.83	15.29	
87	7	5	11	46	11.28	286.83	124.71	102.64	DEC	33.61	238.99	3.61	3.73	*
87	7	5	23	0	27.53	250.85	9.13	42.08	ASCENDING	32.50	236.50	14.82	15.11	*
87	7	6	11	35	7.77	105.71	55.95	104.49	DEC	32.98	241.56	3.68	3.55	*
87	7	6	22	57	10.91	256.99	9.21	39.82	ASCENDING	32.95	239.12	14.82	14.92	*
87	7	7	11	24	25.47	102.04	54.09	106.25	DEC	32.52	244.17	3.50	3.37	*
87	7	7	22	47	8.74	77.17	172.82	37.63	ASCENDING	33.45	241.72	14.80	14.74	*
87	7	8	11	14	39.68	108.28	54.25	108.01	DEC	32.11	246.80	3.58	3.19	*
87	7	8	22	36	25.91	73.10	170.79	35.39	ASCENDING	34.11	244.26	14.79	14.56	*
87	7	9	11	3	50.75	90.74	54.70	109.73	DEC	31.75	249.44	3.50	3.08	*
87	7	9	12	43	67.28	293.06	127.50	93.11	DEC	37.37	225.66	3.67	4.68	*
87	7	9	22	25	39.93	72.42	172.26	33.23	ASCENDING	34.71	246.83	14.77	14.38	*
87	7	10	10	52	59.21	90.12	56.13	111.39	DEC	31.29	252.06	3.57	2.82	*
87	7	10	12	32	61.54	291.86	127.24	95.12	DEC	36.60	228.16	3.65	4.50	*
87	7	10	22	15	50.56	70.40	172.66	31.03	ASCENDING	35.47	249.34	14.77	14.20	*
87	7	10	23	55	60.17	264.05	9.49	52.02	ASCENDING	30.92	225.19	14.83	15.00	*
87	7	11	10	41	65.79	96.50	56.73	113.00	DEC	31.82	254.73	3.57	2.64	
87	7	11	12	22	54.31	290.04	127.57	97.11	DEC	35.76	230.64	3.63	4.32	
87	7	11	22	4	50.69	69.30	174.17	28.91	ASCENDING	36.17	251.07	14.75	14.02	
87	7	11	23	45	62.20	262.54	9.42	49.78	ASCENDING	31.17	227.87	14.83	15.70	
87	7	12	12	11	44.78	288.03	128.00	99.11	DEC	34.98	233.15	3.63	4.14	
87	7	12	21	53	85.01	67.46	175.31	26.78	ASCENDING	37.04	254.34	14.74	13.84	
87	7	12	23	34	54.62	260.96	9.39	47.54	ASCENDING	31.47	230.53	14.83	15.51	
87	7	13	12	0	32.37	287.09	127.35	101.05	DEC	34.36	235.70	3.61	3.96	
87	7	13	23	23	44.75	260.39	8.25	45.31	ASCENDING	31.95	233.14	14.82	15.33	
87	7	14	11	50	16.26	283.84	128.92	102.99	DEC	33.68	238.24	3.60	3.77	
87	7	14	23	12	31.89	258.76	8.09	43.08	ASCENDING	32.34	235.78	14.82	15.15	
87	7	15	11	39	4.20	106.19	55.17	104.90	DEC	33.16	240.04	3.60	3.59	
87	7	15	23	1	15.63	256.53	8.40	40.93	ASCENDING	32.78	238.39	14.80	14.97	
87	7	16	11	28	20.63	101.85	52.58	106.73	DEC	32.68	243.44	3.58	3.41	
87	7	16	22	51	3.31	83.91	179.09	38.72	ASCENDING	33.27	241.00	14.80	14.79	
87	7	17	11	17	35.96	100.29	52.90	108.56	DEC	32.26	246.07	3.58	3.23	
87	7	17	22	40	21.51	73.80	172.96	36.53	ASCENDING	33.92	243.55	14.79	14.60	
87	7	18	11	7	47.95	99.94	54.49	110.35	DEC	31.75	248.67	3.58	3.05	
87	7	18	12	47	68.68	293.57	128.43	93.41	DEC	37.63	224.97	3.67	4.72	
87	7	18	22	29	36.33	73.00	174.52	34.42	ASCENDING	34.51	246.12	14.77	14.43	

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GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	SATELLITE POSITION LONG	SATELLITE SOL. TIME	SITE SOL. TIME	PRIMARY DAYS
87	7	19	10	56	57.07	98.31	54.87	112.88	DEC	31.42	251.32	3.57	2.87	
87	7	19	12	36	63.28	291.74	128.85	95.47	DEC	36.73	227.43	3.65	4.54	
87	7	19	22	18	47.88	70.94	174.92	32.28	ASCENDING	35.25	240.64	14.77	14.24	
87	7	19	23	59	69.62	264.94	7.38	53.23	ASCENDING	30.96	224.41	14.84	15.93	
87	7	20	10	45	64.11	96.79	55.43	113.77	DEC	31.13	253.99	3.57	2.69	*
87	7	20	12	26	58.52	290.57	128.59	97.51	DEC	35.99	229.94	3.63	4.37	*
87	7	20	22	8	56.61	69.85	176.56	30.23	ASCENDING	35.94	251.17	14.75	14.07	*
87	7	20	23	48	64.81	263.51	7.15	51.83	ASCENDING	31.20	227.09	14.83	15.74	*
87	7	21	10	34	69.71	95.32	56.14	115.39	DEC	30.89	256.67	3.57	2.50	*
87	7	21	12	15	47.73	288.63	128.99	99.57	DEC	35.20	232.44	3.63	4.18	*
87	7	21	21	57	63.40	67.98	177.79	28.17	ASCENDING	36.79	253.65	14.75	13.89	*
87	7	21	23	38	58.95	262.04	6.90	48.84	ASCENDING	31.48	229.76	14.83	15.56	*
87	7	22	12	4	36.15	287.71	128.38	101.56	DEC	34.56	234.99	3.61	4.01	*
87	7	22	21	46	68.73	66.18	179.39	26.21	ASCENDING	37.78	256.11	14.73	13.71	*
87	7	22	23	27	47.84	260.50	6.64	46.65	ASCENDING	31.81	232.41	14.83	15.38	*
87	7	23	11	53	21.15	285.89	129.37	103.57	DEC	33.87	237.53	3.61	3.83	*
87	7	23	23	16	35.87	258.80	6.58	44.53	ASCENDING	32.19	235.05	14.81	15.20	*
87	7	24	11	43	4.57	286.38	126.52	105.49	DEC	33.33	240.12	3.60	3.65	*
87	7	24	23	5	20.31	256.49	6.81	42.36	ASCENDING	32.62	237.67	14.81	15.02	*
87	7	25	11	32	15.62	101.28	50.21	107.43	DEC	32.84	242.72	3.59	3.47	*
87	7	25	22	54	2.46	265.61	4.43	40.21	ASCENDING	33.21	240.24	14.81	14.84	*
87	7	26	11	21	32.02	101.96	52.71	109.34	DEC	32.28	245.31	3.59	3.29	
87	7	26	22	44	16.93	74.78	175.74	38.14	ASCENDING	33.73	242.84	14.79	14.67	
87	7	27	11	10	44.98	100.09	52.73	111.19	DEC	31.89	247.94	3.59	3.11	
87	7	27	22	33	32.46	73.82	177.38	36.84	ASCENDING	34.31	245.41	14.79	14.49	
87	7	28	11	0	54.77	98.49	53.03	112.97	DEC	31.55	250.59	3.57	2.93	
87	7	28	12	40	64.92	292.27	130.31	95.97	DEC	36.98	226.74	3.67	4.68	
87	7	28	22	22	45.01	71.50	177.64	33.97	ASCENDING	35.04	247.94	14.79	14.30	
87	7	29	10	49	62.30	96.99	53.57	114.73	DEC	31.25	253.25	3.57	2.75	
87	7	29	12	29	50.50	291.09	130.10	98.06	DEC	36.23	229.25	3.65	4.43	
87	7	29	22	12	54.39	70.40	179.37	31.99	ASCENDING	35.71	250.40	14.77	14.13	
87	7	29	23	52	65.72	263.70	5.29	52.69	ASCENDING	31.08	226.35	14.85	15.81	
87	7	30	10	38	68.24	95.53	54.25	116.45	DEC	31.00	255.93	3.57	2.57	
87	7	30	12	19	50.47	289.21	130.50	100.18	DEC	35.42	231.74	3.65	4.25	
87	7	30	22	1	61.66	68.50	179.43	30.06	ASCENDING	36.54	252.96	14.75	13.95	
87	7	30	23	41	59.14	262.21	4.97	50.54	ASCENDING	31.36	229.02	14.85	15.63	
87	7	31	12	8	39.78	288.28	129.94	102.22	DEC	34.77	234.29	3.63	4.07	
87	7	31	21	50	67.34	66.68	177.72	28.14	ASCENDING	37.44	255.42	14.75	13.77	

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YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	SATELLITE POSITION LONG	SATELLITE SOL. TIME	SITE SOL.TIME	PRIMARY DAYS
87	6	24	2	26	58.15	70.11	136.92	82.56	ASCENDING	35.92	251.31	19.14	18.44	*
87	6	24	4	6	64.42	263.67	43.64	100.60	ASCENDING	31.29	227.36	19.21	20.10	*
87	6	24	16	27	43.75	287.99	159.57	47.36	DEC	34.87	233.66	7.97	8.45	*
87	6	25	3	44	47.90	260.36	43.53	96.90	ASCENDING	31.85	232.69	19.19	19.74	*
87	6	25	16	5	11.16	256.26	158.59	51.93	DEC	33.64	238.79	7.95	8.09	*
87	6	26	3	22	19.43	257.93	42.69	93.00	ASCENDING	32.74	237.94	19.19	19.37	*
87	6	26	15	44	24.94	101.23	18.98	56.48	DEC	32.60	243.99	7.93	7.72	
87	6	27	3	1	19.37	74.37	136.80	89.03	ASCENDING	33.81	243.12	19.17	19.01	
87	6	27	15	22	51.30	99.01	19.30	61.06	DEC	31.75	249.24	7.93	7.36	
87	6	27	17	1	68.37	293.04	159.30	40.29	DEC	37.38	225.61	8.00	9.02	
87	6	28	2	39	47.45	71.78	137.10	85.00	ASCENDING	35.07	248.24	19.13	18.65	
87	6	28	15	0	65.42	95.79	18.58	65.56	DEC	31.22	254.59	7.91	6.99	
87	6	28	16	40	55.62	289.57	159.76	44.88	DEC	35.70	230.58	7.98	8.65	
87	6	29	2	18	63.48	68.88	137.01	80.83	ASCENDING	36.54	253.29	19.11	18.28	
87	6	29	3	58	58.93	262.00	43.69	99.13	ASCENDING	31.42	229.49	19.19	19.95	
87	6	29	16	18	33.53	296.46	159.72	49.40	DEC	34.35	235.67	7.95	8.30	
87	6	30	3	36	38.46	259.50	42.80	95.33	ASCENDING	32.19	234.76	19.18	19.58	
87	6	30	15	57	3.20	97.27	13.32	53.97	DEC	33.20	240.83	7.93	7.93	
87	7	1	3	14	4.77	259.78	39.34	91.44	ASCENDING	33.15	239.98	19.17	19.22	
87	7	1	15	35	37.15	100.60	19.18	58.53	DEC	32.23	246.05	7.91	7.57	
87	7	2	2	52	32.14	73.27	137.17	87.44	ASCENDING	34.29	245.14	19.15	18.85	
87	7	2	15	13	58.19	98.11	19.21	63.11	DEC	31.45	251.32	7.90	7.20	
87	7	2	16	53	64.06	291.26	160.11	42.36	DEC	36.61	227.53	7.99	8.86	
87	7	3	2	31	54.83	70.58	137.35	83.38	ASCENDING	35.63	250.24	19.11	18.49	
87	7	3	4	11	66.97	264.31	43.19	101.40	ASCENDING	31.19	226.22	19.19	20.16	
87	7	3	16	31	48.43	288.37	160.12	46.96	DEC	35.14	232.58	7.96	8.50	
87	7	4	2	9	67.89	67.11	136.67	79.19	ASCENDING	37.30	255.22	19.09	18.13	
87	7	4	3	49	52.22	261.10	42.90	97.75	ASCENDING	31.71	231.57	19.17	19.79	
87	7	4	16	10	21.02	285.76	160.06	51.49	DEC	33.86	237.69	7.92	8.14	
87	7	5	3	27	26.54	258.82	41.83	93.90	ASCENDING	32.56	235.82	19.16	19.42	
87	7	5	15	48	17.70	102.12	18.37	56.07	DEC	32.78	242.88	7.91	7.78	*
87	7	6	3	6	11.39	73.68	136.16	89.97	ASCENDING	33.58	242.02	19.14	19.06	*
87	7	6	15	27	46.86	99.75	19.03	60.68	DEC	31.89	248.12	7.90	7.41	*
87	7	7	2	44	42.63	72.15	137.63	85.93	ASCENDING	34.81	247.15	19.12	18.70	*
87	7	7	15	5	63.81	96.44	18.18	65.21	DEC	31.32	253.45	7.88	7.05	*
87	7	7	16	45	58.85	290.03	160.63	44.49	DEC	35.99	229.51	7.96	8.71	*
87	7	8	2	23	60.77	69.38	137.71	81.85	ASCENDING	36.23	252.22	19.09	18.34	*
87	7	8	4	2	62.02	262.70	42.98	100.17	ASCENDING	31.30	228.35	19.17	20.00	*

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GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	SATELLITE POSITION LONG	SATELLITE SOL. TIME	SITE SOL. TIME	PRIMARY DAYS
87	7	8	16	23	39.41	287.15	160.71	49.09	DEC	34.60	234.58	7.94	8.35	*
87	7	9	3	41	43.78	260.26	41.93	96.42	ASCENDING	32.04	233.64	19.16	19.63	*
87	7	9	16	2	7.29	294.71	160.55	53.63	DEC	33.40	239.73	7.91	7.99	*
87	7	10	3	19	12.36	259.07	39.85	92.57	ASCENDING	32.95	238.87	19.14	19.27	*
87	7	10	15	40	30.92	191.45	18.75	58.27	DEC	32.40	244.93	7.90	7.62	*
87	7	11	2	57	25.40	73.33	137.51	88.60	ASCENDING	34.05	244.05	19.13	18.91	*
87	7	11	15	18	54.55	98.83	18.60	62.83	DEC	31.58	250.19	7.88	7.26	
87	7	11	16	58	66.48	292.35	160.78	42.04	DEC	37.04	225.50	7.96	8.92	
87	7	12	2	36	51.01	71.00	138.16	84.52	ASCENDING	35.35	249.16	19.11	18.55	
87	7	12	4	16	69.29	264.94	42.42	102.64	ASCENDING	31.10	225.08	19.17	20.21	
87	7	12	14	56	68.48	95.57	17.82	67.41	DEC	31.07	255.55	7.88	6.89	
87	7	12	16	36	52.45	288.80	161.38	46.65	DEC	35.41	231.49	7.94	8.56	
87	7	13	2	14	65.63	68.17	138.17	80.41	ASCENDING	36.86	254.19	19.07	18.19	
87	7	13	3	54	56.04	261.81	41.97	99.03	ASCENDING	31.58	230.44	19.15	19.85	
87	7	13	16	15	28.13	285.87	161.58	51.26	DEC	34.09	236.60	7.92	8.19	
87	7	14	3	32	33.15	259.57	40.77	95.22	ASCENDING	32.39	235.71	19.15	19.48	
87	7	14	15	53	10.06	103.51	18.56	55.86	DEC	32.97	241.77	7.90	7.83	
87	7	15	3	11	3.10	84.52	147.51	91.32	ASCENDING	33.26	240.95	19.13	19.12	
87	7	15	15	31	41.84	100.55	18.20	60.45	DEC	32.04	246.99	7.89	7.47	
87	7	16	2	49	37.22	72.41	138.39	87.31	ASCENDING	34.55	246.07	19.11	18.76	
87	7	16	15	10	60.94	97.09	17.20	65.01	DEC	31.42	252.32	7.87	7.11	
87	7	16	16	50	61.78	291.18	161.60	44.23	DEC	36.41	228.47	7.94	8.77	
87	7	17	2	27	57.71	69.84	138.78	83.21	ASCENDING	35.93	251.14	19.09	18.40	
87	7	17	4	7	64.80	263.37	41.98	101.66	ASCENDING	31.20	227.22	19.15	20.07	
87	7	17	16	28	44.44	287.54	162.36	48.84	DEC	34.86	233.49	7.93	8.41	
87	7	18	2	6	69.69	66.95	138.73	79.07	ASCENDING	37.52	256.15	19.06	18.04	
87	7	18	3	45	48.53	260.97	40.79	97.94	ASCENDING	31.89	232.52	19.15	19.70	
87	7	18	16	6	14.57	284.26	162.94	53.46	DEC	33.62	238.62	7.91	8.05	
87	7	19	3	24	20.18	256.56	41.86	94.12	ASCENDING	32.65	237.80	19.13	19.34	
87	7	19	15	45	23.92	102.47	17.93	58.07	DEC	32.57	243.82	7.89	7.69	
87	7	20	3	2	19.10	75.97	140.75	90.17	ASCENDING	33.72	242.98	19.12	18.97	
87	7	20	15	23	50.66	98.57	16.42	62.66	DEC	31.84	247.10	7.87	7.32	*
87	7	20	17	3	68.69	292.96	162.78	41.90	DEC	37.37	225.44	7.97	8.98	*
87	7	21	2	41	46.72	71.37	139.22	86.12	ASCENDING	35.08	248.07	19.10	18.61	*
87	7	21	15	1	66.08	96.22	16.56	67.28	DEC	31.16	254.41	7.87	6.96	*
87	7	21	16	41	56.05	290.03	162.58	46.45	DEC	35.80	230.45	7.93	8.63	*
87	7	22	2	19	63.13	68.67	139.48	81.98	ASCENDING	36.54	253.12	19.08	18.25	*
87	7	22	3	59	59.42	262.49	40.74	100.72	ASCENDING	31.46	229.31	19.16	19.92	*

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GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	LONG	SATELLITE SOL. TIME	SITE SOL. TIME	PRIMARY DAYS
87	6	19	10	26	65.38	239.24	157.51	113.40	DEC	28.19	231.55	1.91	2.45	
87	6	20	0	27	22.69	127.25	151.98	58.95	ASCENDING	31.96	242.40	16.66	16.40	
87	6	20	8	57	25.16	49.99	34.22	121.65	DEC	34.67	242.64	1.14	.97	*
87	6	21	0	30	31.40	311.12	30.52	61.34	ASCENDING	35.14	237.81	16.52	16.67	*
87	6	21	9	9	30.02	234.79	144.05	120.91	DEC	31.59	237.83	1.05	1.17	*
87	6	21	23	11	62.73	121.11	148.57	42.97	ASCENDING	28.60	248.75	15.78	15.20	*
87	6	22	0	51	59.76	316.07	34.10	63.70	ASCENDING	38.55	233.76	16.46	16.07	*
87	6	22	7	41	60.63	43.88	48.90	123.16	DEC	38.69	247.49	.24	23.69	*
87	6	22	9	21	61.81	238.59	143.18	120.06	DEC	28.72	232.58	.89	1.37	*
87	6	22	23	23	32.13	124.71	146.54	45.41	ASCENDING	31.49	243.40	15.63	15.39	*
87	6	23	7	53	33.47	49.07	50.90	123.31	DEC	35.28	243.48	.11	23.86	*
87	6	23	23	35	22.71	310.36	37.81	47.84	ASCENDING	34.53	238.65	15.49	15.39	*
87	6	24	8	5	20.45	234.39	127.04	123.34	DEC	32.15	238.77	.02	.09	*
87	6	24	22	7	66.16	120.48	138.33	29.46	ASCENDING	28.08	249.78	14.76	14.11	*
87	6	24	23	47	56.10	315.19	40.97	50.33	ASCENDING	37.90	234.48	15.43	15.78	*
87	6	25	6	36	63.64	42.96	65.18	119.96	DEC	39.35	248.17	23.15	22.61	*
87	6	25	8	17	57.69	237.95	126.68	123.23	DEC	29.25	233.60	23.07	.28	*
87	6	25	22	18	40.13	124.19	136.88	31.86	ASCENDING	30.80	244.44	14.61	14.31	*
87	6	26	6	48	40.58	48.16	67.39	120.87	DEC	35.91	244.30	23.09	22.80	*
87	6	26	22	30	13.02	309.78	46.65	34.29	ASCENDING	33.93	239.52	14.47	14.50	
87	6	27	7	0	9.00	234.88	108.95	121.66	DEC	32.75	239.70	23.00	23.00	
87	6	27	21	2	69.17	119.94	117.98	16.80	ASCENDING	27.57	250.82	13.74	13.03	
87	6	27	22	42	51.81	314.34	49.28	36.78	ASCENDING	37.25	235.22	14.40	14.70	
87	6	28	5	32	66.26	42.03	79.20	113.29	DEC	40.02	248.83	22.11	21.52	
87	6	28	7	12	52.86	237.32	109.57	122.31	DEC	29.79	234.60	22.85	23.20	
87	6	28	21	14	46.93	123.50	119.43	18.94	ASCENDING	30.34	245.41	13.50	13.22	
87	6	28	22	55	68.66	319.40	52.55	39.28	ASCENDING	40.77	231.66	14.35	14.90	
87	6	29	5	44	46.50	47.26	81.92	114.79	DEC	36.54	245.09	22.06	21.72	
87	6	29	21	26	4.38	312.68	65.38	21.18	ASCENDING	33.33	240.40	13.44	13.42	
87	6	30	5	56	1.39	32.60	64.67	116.20	DEC	33.32	240.60	21.97	21.92	
87	6	30	21	38	46.75	312.46	61.50	23.54	ASCENDING	36.54	235.91	13.37	13.62	
87	7	1	4	27	68.57	41.08	90.66	104.05	DEC	40.69	249.45	21.08	20.44	
87	7	1	6	8	47.17	235.80	94.75	117.50	DEC	30.27	235.65	21.83	22.11	
87	7	1	20	10	52.68	122.94	67.93	10.29	ASCENDING	29.79	246.40	12.56	12.14	
87	7	1	21	50	66.35	318.47	64.39	25.95	ASCENDING	40.10	232.27	13.32	13.82	
87	7	2	4	39	51.65	46.35	93.90	105.97	DEC	37.17	245.86	21.03	20.64	
87	7	2	6	20	69.27	240.33	92.93	118.71	DEC	27.57	230.18	21.67	22.31	
87	7	2	20	21	10.35	126.80	77.87	11.11	ASCENDING	32.74	241.31	12.41	12.33	

SAN NICOLAS ISLAND, CA
LAT= 33.23 LONG= 240.53

ERBS

2 4 3

GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	LONG	SATELLITE SOL. TIME	SITE SOL. TIME	PRIMARY DAYS
87	7	3	4	52	12.06	48.84	94.28	107.83	DEC	33.92	241.49	20.95	20.83	
87	7	3	20	34	40.73	311.49	95.06	12.45	ASCENDING	35.91	236.71	12.34	12.53	
87	7	4	5	5	40.46	235.04	81.64	109.60	DEC	30.82	236.62	20.80	21.08	
87	7	4	19	5	57.55	122.28	3.86	16.19	ASCENDING	29.25	247.40	11.54	11.06	
87	7	4	20	46	63.73	316.86	91.06	14.17	ASCENDING	39.36	232.83	12.28	12.73	
87	7	5	3	35	55.95	47.43	103.64	95.29	DEC	37.82	246.61	20.00	19.55	
87	7	5	5	15	66.28	239.19	79.71	111.31	DEC	28.01	231.28	20.65	21.22	
87	7	5	19	17	20.53	126.41	7.30	14.38	ASCENDING	32.16	242.23	11.39	11.25	*
87	7	6	3	47	22.07	48.92	105.42	97.45	DEC	34.53	242.35	19.93	19.75	*
87	7	6	19	29	33.59	310.49	167.14	12.80	ASCENDING	38.29	237.53	11.31	11.45	*
87	7	7	3	59	32.59	234.26	70.96	99.53	DEC	31.39	237.58	19.78	19.95	*
87	7	7	18	1	61.66	121.62	17.70	28.70	ASCENDING	28.72	248.42	10.56	9.98	*
87	7	7	19	41	60.73	315.93	160.77	11.62	ASCENDING	38.70	233.51	11.25	11.69	*
87	7	8	2	31	59.61	44.50	111.82	83.39	DEC	38.47	247.33	18.97	18.47	*
87	7	8	4	11	62.88	238.52	68.50	101.58	DEC	28.53	232.31	19.63	20.14	*
87	7	8	18	13	29.87	125.75	18.77	26.39	ASCENDING	31.58	243.17	10.42	10.17	*
87	7	9	2	43	30.91	48.39	114.26	85.75	DEC	35.14	243.20	18.90	18.67	*
87	7	9	18	25	25.20	309.39	161.09	24.14	ASCENDING	34.67	238.37	10.28	10.37	*
87	7	10	2	55	23.57	233.47	62.11	88.03	DEC	31.96	238.53	18.76	18.87	*
87	7	10	16	57	65.20	120.95	28.20	42.27	ASCENDING	28.20	249.45	9.54	8.90	*
87	7	10	18	37	57.26	315.01	159.64	21.90	ASCENDING	38.05	234.22	10.22	10.57	*
87	7	11	1	26	62.77	42.85	118.41	70.71	DEC	39.20	247.93	17.94	17.39	*
87	7	11	3	6	58.97	237.84	59.22	90.30	DEC	29.06	233.33	18.61	19.06	*
87	7	11	17	8	38.05	125.03	30.31	39.88	ASCENDING	31.02	244.12	9.39	9.09	
87	7	12	1	38	38.47	47.69	121.95	73.20	DEC	35.76	244.02	17.88	17.59	
87	7	12	17	20	15.58	307.97	148.86	37.51	ASCENDING	34.07	239.23	9.26	9.29	
87	7	13	1	50	13.78	232.63	54.40	75.62	DEC	32.53	239.45	17.74	17.78	
87	7	13	15	52	68.31	120.29	35.71	55.98	ASCENDING	27.68	250.48	8.53	7.82	
87	7	13	17	32	53.21	314.10	145.06	35.09	ASCENDING	37.40	234.96	9.19	9.49	
87	7	14	0	22	65.52	41.94	125.65	57.58	DEC	39.87	248.59	16.91	16.31	
87	7	14	2	2	54.42	237.16	51.17	78.03	DEC	29.60	234.33	17.59	17.98	
87	7	14	16	4	45.08	124.30	38.09	53.60	ASCENDING	30.46	245.09	8.37	8.01	
87	7	14	17	44	69.28	319.34	142.38	32.69	ASCENDING	40.93	231.43	9.16	9.69	
87	7	15	0	34	44.85	46.01	129.31	60.14	DEC	36.39	244.82	16.85	16.51	
87	7	15	16	16	5.02	303.93	143.97	51.22	ASCENDING	33.47	240.11	8.23	8.21	
87	7	16	0	46	5.63	231.35	47.51	62.64	DEC	33.12	240.37	16.72	16.70	
87	7	16	16	28	48.44	313.20	136.49	48.78	ASCENDING	36.76	235.72	8.17	8.41	
87	7	16	23	17	67.93	41.01	133.93	44.26	DEC	40.54	249.21	15.88	15.23	

SAN NICOLAS ISLAND, CA
LAT= 33.23 LONG= 240.53

ERBS

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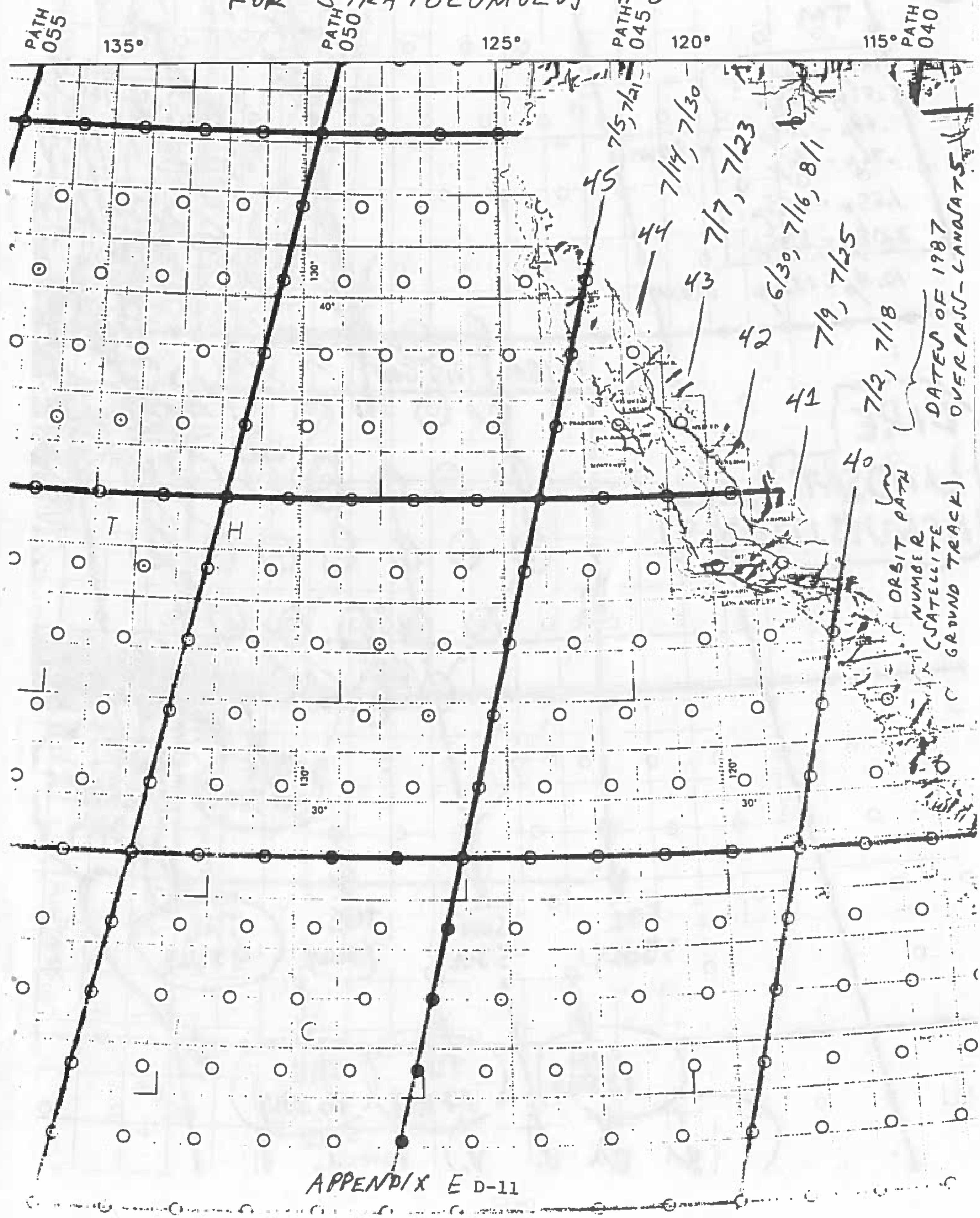
GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	SATELLITE POSITION LONG	SATELLITE SOL. TIME	SITE SOL. TIME	PRIMARY DAYS
87	7	17	0	58	49.01	236.49	43.64	65.19	DEC	30.14	235.33	16.62	16.91	
87	7	17	14	59	51.07	123.58	44.78	67.23	ASCENDING	29.91	246.08	7.36	6.93	
87	7	17	16	40	67.07	319.38	133.19	46.34	ASCENDING	40.25	232.04	8.12	8.61	
87	7	17	23	29	50.23	46.08	137.38	46.85	DEC	37.03	245.60	15.83	15.43	
87	7	18	15	11	6.20	131.45	51.08	64.89	ASCENDING	32.87	241.01	7.21	7.13	
87	7	18	23	41	10.47	51.21	141.04	48.45	DEC	33.71	241.26	15.75	15.68	
87	7	19	15	23	42.75	312.32	129.66	62.54	ASCENDING	36.13	236.51	7.08	7.33	
87	7	19	23	53	42.58	235.84	35.70	51.99	DEC	30.69	236.31	15.60	15.83	
87	7	20	13	55	56.15	122.86	81.47	80.55	ASCENDING	29.37	247.08	6.34	5.86	*
87	7	20	15	35	64.57	317.45	126.20	60.13	ASCENDING	39.59	232.68	7.03	7.53	*
87	7	20	22	25	54.76	45.23	148.13	33.69	DEC	37.67	246.35	14.81	14.35	*
87	7	21	0	5	67.23	230.66	33.18	34.48	DEC	27.90	230.94	15.40	16.02	*
87	7	21	14	7	16.05	128.28	55.25	78.30	ASCENDING	32.29	241.93	6.19	6.05	*
87	7	21	22	37	19.89	50.30	151.11	36.26	DEC	34.32	242.13	14.73	14.55	*
87	7	22	14	19	35.99	311.46	123.20	76.04	ASCENDING	35.90	237.32	6.06	6.25	*
87	7	22	22	49	34.99	235.74	25.84	38.78	DEC	31.25	237.27	14.59	14.75	*
87	7	23	12	51	60.49	121.53	58.28	93.34	ASCENDING	28.90	248.15	5.32	4.78	*
87	7	23	14	31	61.67	316.53	119.79	73.69	ASCENDING	38.93	233.35	6.01	6.49	*
87	7	23	21	20	58.62	44.34	167.27	21.54	DEC	38.32	247.07	13.78	13.28	*
87	7	23	23	1	63.94	239.02	23.81	41.32	DEC	28.42	231.98	14.43	14.95	*
87	7	24	13	2	26.88	125.09	60.01	91.24	ASCENDING	31.79	242.92	5.18	4.98	*
87	7	24	21	33	28.82	49.43	168.02	23.85	DEC	34.93	242.98	13.71	13.48	*
87	7	25	13	14	29.04	310.62	116.26	89.10	ASCENDING	34.88	238.15	5.04	5.17	*
87	7	25	21	44	26.13	234.76	10.26	26.19	DEC	31.82	238.22	13.57	13.68	*
87	7	26	11	46	64.22	120.90	67.20	105.24	ASCENDING	28.38	249.17	4.31	3.70	
87	7	26	13	26	58.32	315.63	113.05	86.88	ASCENDING	38.27	234.05	4.98	5.38	
87	7	26	20	16	61.93	43.44	144.40	14.08	DEC	38.98	247.77	12.76	12.20	
87	7	26	21	56	60.16	238.38	9.77	28.59	DEC	28.94	233.00	13.42	13.87	
87	7	27	11	58	35.63	124.63	68.78	103.37	ASCENDING	31.21	243.87	4.16	3.90	
87	7	27	20	28	36.64	48.56	154.03	15.05	DEC	35.55	243.81	12.70	12.40	
87	7	28	12	10	18.96	309.81	108.14	101.45	ASCENDING	34.27	239.00	4.03	4.10	
87	7	28	20	40	16.10	234.68	22.95	16.39	DEC	32.40	239.15	12.56	12.60	
87	7	29	10	42	67.47	120.26	78.34	115.75	ASCENDING	27.86	250.21	3.30	2.63	
87	7	29	12	22	54.41	314.76	105.28	99.43	ASCENDING	37.62	234.78	3.96	4.30	
87	7	29	19	11	64.78	42.52	95.20	18.65	DEC	39.64	248.44	11.68	11.12	
87	7	29	20	52	53.77	237.74	18.29	18.04	DEC	29.48	234.01	12.41	12.80	
87	7	30	10	54	43.12	124.04	79.50	114.23	ASCENDING	30.65	244.84	3.15	2.83	
87	7	30	12	34	69.89	319.89	102.18	97.36	ASCENDING	41.16	231.31	3.93	4.50	

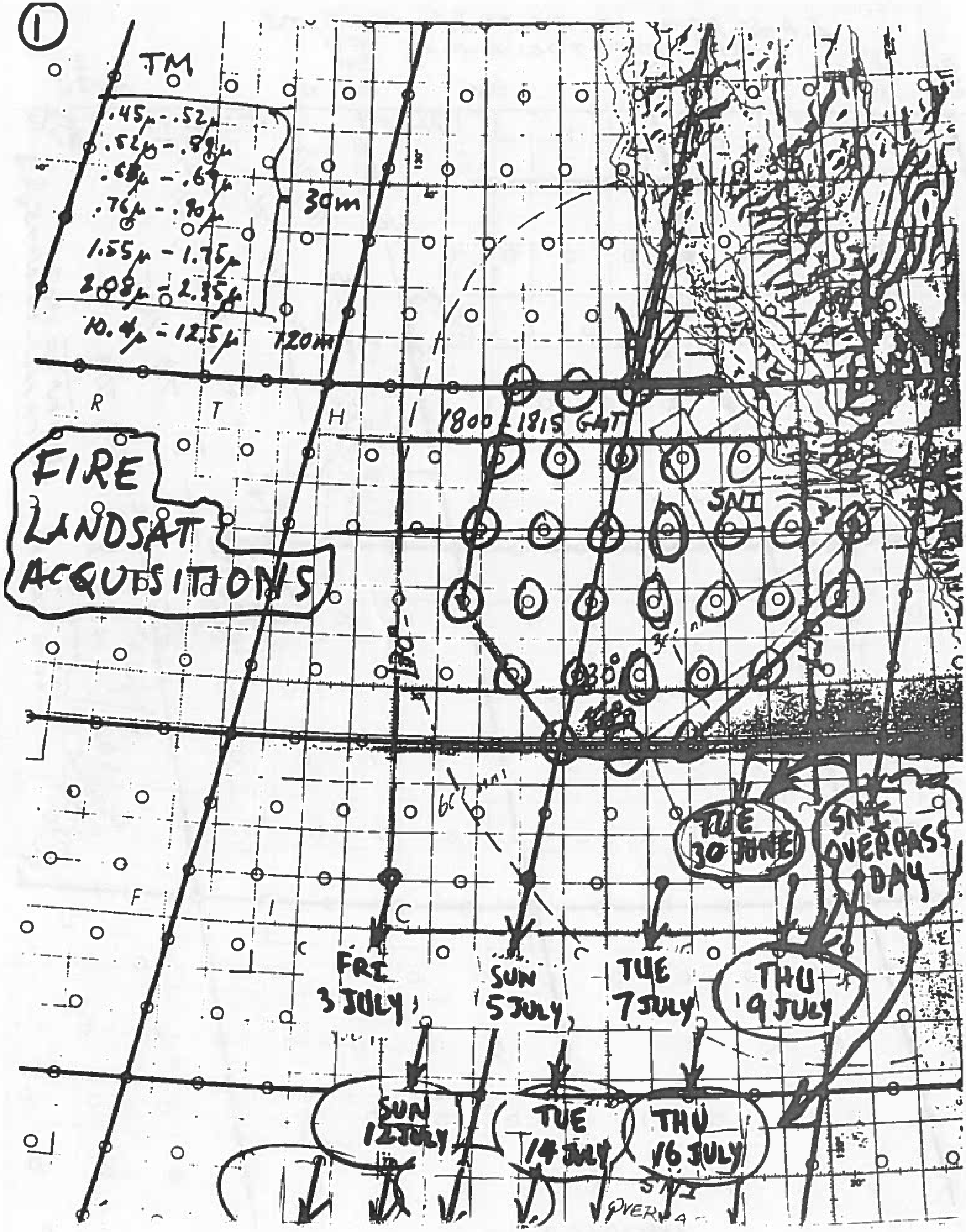
SAGE II

LAT(DEG)	LONG(DEG)	DATE	TIME	DIST(KM)	IEVENT
24.88	-117.91	3/ 1/1987	14:14:29.38	911.66	SUNRISE
30.33	-120.32	3/ 2/1987	14:26:58.31	322.12	SUNRISE
34.98	-122.93	3/ 3/1987	14:39:13.99	424.29	SUNRISE
38.98	-125.62	3/ 4/1987	14:51:19.17	893.13	SUNRISE
39.51	-118.81	3/31/1987	13:42:10.39	724.54	SUNRISE
28.33	-121.36	4/ 1/1987	13:56:20.68	566.13	SUNRISE
33.29	-112.92	4/25/1987	2: 9:20.46	567.86	SUN SET
28.82	-117.24	4/26/1987	2:21:28.32	494.42	SUN SET
26.10	-117.10	5/14/1987	13: 3:25.01	790.30	SUNRISE
30.50	-122.24	5/15/1987	13:15:26.02	414.12	SUNRISE
34.60	-127.46	5/16/1987	13:27:21.32	802.26	SUNRISE
41.13	-118.72	7/ 4/1987	3:31: 3.49	905.44	SUN SET
37.61	-124.41	7/ 5/1987	3:42:48.25	710.19	SUN SET
30.12	-111.06	7/ 7/1987	2:29:43.99	819.68	SUN SET
25.87	-116.43	7/ 8/1987	2:41:42.79	831.60	SUN SET
24.83	-116.32	7/25/1987	13:10:14.93	946.38	SUNRISE
29.28	-121.28	7/26/1987	13:22:20.50	466.92	SUNRISE
33.48	-126.23	7/27/1987	13:34:21.24	675.48	SUNRISE
40.90	-122.46	9/16/1987	2:20:14.25	931.97	SUN SET
37.06	-126.19	9/17/1987	2:32:10.07	795.30	SUN SET
26.89	-116.99	10/ 7/1987	13:43:28.23	707.59	SUNRISE
32.04	-117.35	10/ 8/1987	13:55:58.44	111.71	SUNRISE
36.49	-121.61	10/ 9/1987	14: 9:18.26	455.32	SUNRISE
40.31	-123.77	10/10/1987	14:20:29.32	918.51	SUNRISE
37.64	-111.41	11/ 1/1987	13:50:29.99	861.01	SUNRISE
32.96	-116.06	11/ 2/1987	14: 2:56.93	274.43	SUNRISE
27.75	-120.82	11/ 3/1987	14:15:29.85	609.40	SUNRISE
27.91	-120.19	11/ 5/1987	1:16: 3.77	578.09	SUN SET
32.31	-125.09	11/ 6/1987	1:28:27.20	575.56	SUN SET
38.95	-126.38	11/29/1987	1: 8:16.67	970.21	SUN SET

STD LATITUDE 33.0
STD LONGITUDE -119.0
RADIUS 1000.0

LANDSAT OVERPASS ORBITS FOR STRATOCUMULUS IFO

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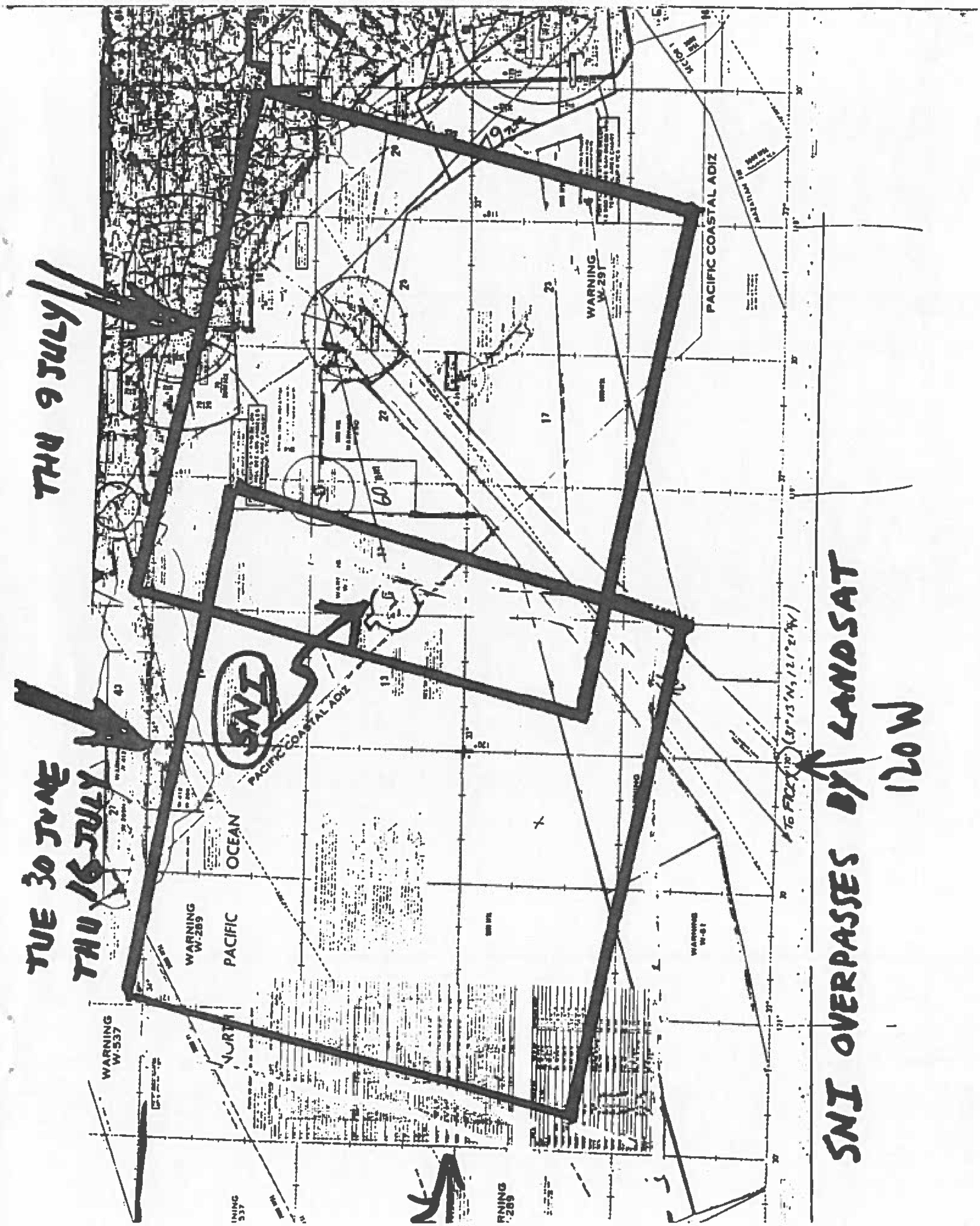
TM
.45µ - .52µ
.52µ - .60µ
.63µ - .69µ
.76µ - .90µ
1.55µ - 1.75µ
2.08µ - 2.35µ
10.4µ - 12.5µ
30m
120m
1800 - 1815 GMT
FIRE LANDSAT ACQUISITIONS
SNI
TUE 30 JUNE
SNI OVERPASS DAY
FRI 3 JULY
SUN 5 JULY
TUE 7 JULY
THU 9 JULY
SUN 12 JULY
TUE 14 JULY
THU 16 JULY


THU 9 JULY
TUE 30 JUNE
THU 16 JULY
SNI
SNI OVERPASSES BY LANDSAT
120W
(31°13'N, 121°21'W)
PACIFIC COASTAL ADIZ
PACIFIC OCEAN
WARNING W-289
WARNING W-291
WARNING W-537
WARNING W-61

APPENDIX E

DESCRIPTION OF SAN NICOLAS ISLAND

San Nicolas Island is located approximately 60 miles off the coast of Point Mugu and is part of the Pacific Missile Test Center's Sea Test range. Approximately 350 employees, including military and civilian, staff the outlying landing field and the Naval Facility at San Nicolas Island.

San Nicolas Island is the site of about $30 million worth of communication and missile-tracking instrumentation operated by the PMTC Range Directorate. It is all closely coordinated with those on the mainland at Point Mugu. San Nicolas' 10,000-foot runway with ground-controlled approach facilities accommodates supersonic target aircraft and planes from the mainland during operations. The island offers an unobstructed area over which the Navy can test its new weapon system.

Most Pacific Missile Test Center activity is conducted over a rectangular plot of ocean 200 miles long and 80 miles wide with the majority of operations conducted between San Nicolas Island and Point Mugu. Data and internal and external actions of the flight test vehicle are transmitted by telemetry to computers at Point Mugu where the engineers and scientists study its actions.

San Nicolas Island is one of California's key wildlife and environmental preservation areas. The natural resources of San Nicolas Island are managed by a joint agreement between the Departmment of the Navy Department of the Interior and California's Department of Fish and Game. Unique endemic animals on San Nicolas Island include the small species of fox, the white-footed deer mouse, the island night lizard and the rock wren among others.

The western gull is another protected species that inhabits the island. They are located in the area designated as the Western Gull Rookery where they come every year to bear their young. San Nicolas also provides a breeding area for sea lions and sea elephants and is one of the few places in the world where both species occur naturally. Fish in the waters are a mixture of northern and southern species, including the yellow tail and rock bass.

The Spanish explorer, Sebastian Vizcaino, is generally credited with the discovery of San Nicolas Island on December 6, 1602. It was reported that the Northern Channel Islands, which include San Nicolas Island, were thickly populated by Indians of San Nicolas, referred to as Nicolino, may have been of Shoshonean stock, and perhaps settled on the island long before the beginning of the Christian era.

Later in 1857 a sheep ranch began which eventually overgrazed the land, leaving only 4,000 vegetated acres by 1930. In 1933

President Hoover gave jurisdiction of the island to the Navy. After temporary administration by the Army from 1942 to 1947, Point Mugu regained control of the island for use by the Navy.