FIRE

CIRRUS INTENSIVE FIELD OBSERVATIONS

1986 OPERATIONS PLANS

OCTOBER 1986

CIRRUS INTENSIVE FIELD OBSERVATIONS

OPERATIONS PLAN

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1.0 INTRODUCTION

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

The goals of FIRE are (1) to seek the basic understanding of the interaction of physical processes in determining the properties of cirrus and marine stratocumulus systems over 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 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 retrieval algorithm models. 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 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.

Though the results of the LA studies will be significant in and of themselves, it is their relationships to the other parts of FIRE cirrus cloud studies that is most important. For example, preliminary cirrus cloud modeling results have shown that the linkage between fine-scale radiative, microphysical and dynamic processes are important in determining the overall character of a cirrus cloud in a given environment. However, knowledge of these processes and the coupling between them in actual cirrus is to a large extent speculative. The LA studies will very significantly increase our understanding of these processes and the interactions between them.

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 Intensive Field Observations (IFO) data gathering component consists of separate field missions to study cirrus clouds over the mid-continent U.S. and marine stratocumulus clouds off the southwestern coast of California. The cirrus mission will be performed in the fall of 1986 in central Wisconsin; the marine stratocumulus mission will be performed in the summer of 1987 in the vicinity of San Nicolas Island, California. Each three-week mission will combine 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 spring of 1988 and marine stratocumulus in June 1989.

The Cirrus IFO program will support research requiring high time and space resolution information on cirrus cloud systems. These data will also be instrumental in developing parameterizations relating cloud-scale processes to climate-scale variables and in better understanding the 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 the Fall, 1986 and the second in early Spring, 1988. Each will be three to six weeks in duration. A target of sixteen case study samples should be attainable in this two stage experiment setting. The observing periods will provide the opportunity to sample pre-warm frontal and jet stream cirrus in 1986 and convectively generated cirrus and jet stream cirrus in 1988.

The planned use of two phases for the intensive field program is important. Relatively little is presently known about cirrus cloud systems since no major experiments have been performed. Consequently, research on cirrus clouds has been stifled because of the lack of observational data. The two-phase field program with one complete year in between has been designed to enable experiment planners to incorporate information gained and lessons learned from the first phase into the second phase of the experiment. This is especially inportant when investigating a phenomenon about which relatively little is quantitatively known from either an observational or theoretical viewpoint.

This Operations Plan will fully describe the experiment and operations plans for the Cirrus IFO data gathering component.

2.0 SCIENCE OBJECTIVES

2.1 General

The Cirrus IFO will gather data to support high spatial and temporal resolution studies of cirrus cloud fields. The observations will be of sufficient accuracy and resolution for validation of radiative transfer models, ISCCP cloud property retrievals, cloud models and GCM cloud parameterizations. Diagnosis of cloud processes requires careful measurement of environmental conditions and cloud structure as the cloud field evolves. The two new and unique aspects of this field study for FIRE are inclusion of simultaneous "cloud truth" observations to validate retrievals of cloud properties from satellite measurements and the observations of upwelling and downwelling radiation at the surface, near the cloud boundaries and at other levels in the atmosphere in conjunction with simultaneous satellite radiance measurements. The intensive measurements must be coordinated with satellite observations so that diagnostic results can be extended to scales of 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 free troposphere and whole boundary layer heating rates.

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 diagnostic studies to forecast studies to determine both the sensitivity of such diagnoses to measured variables and the crucial statistical quantities which are needed to constrain the parameterization and which should therefore be determined from the observations. Model studies should also be used to plan subsequent observation sequences.

2.2 Specific

The specific goals and research strategy of FIRE with respect to cirrus 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 cirrus. The Cirrus IFO is the common element through which the required coupling is made.

In support of the strategy for achieving the FIRE goals, the following observational objectives are adopted for the Cirrus IFO:

1. Characterize the physical structure of cirrus cloud fields and the corresponding structure of the associated radiative fields and their dependence on conditions in the large-scale meteorological environment. This includes providing data sets relating:

   (a) Appearance of the cloud field, including cloud topology and texture, to the bulk microphysical properties of the clouds, primarily vertically integrated ice water path.

   (b) Bulk microphysical properties of the clouds to the corresponding large-scale meteorological conditions including ambient temperature, humidity, vertical motion, and horizontal wind field.

   (c) Bulk microphysical properties of the clouds to their corresponding radiative properties, including the broadband properties, the visible albedo, and the 10-12 {m infrared emittance.

   (d) Cloud radiative properties to the corresponding upwelling and downwelling broadband radiative fluxes.

   (e) Upwelling and downwelling broadband radiative fluxes to the corresponding angularly and spectrally dependent radiance fields.

In each of these data sets, the spatial resolution will be sufficient to address issues of horizontal structure/variability (e.g., cloud fraction and cloud field organization) and spatial averaging, i.e., the cloud and radiative observations will be made primarily at scales ranging from) 1 km.

2. Characterize the fine-scale microphysical, radiative, dynamic, and thermodynamic structure of cirrus clouds at various stages of their life cycle as functions of their large scale meteorological environment. This includes providing data sets relating:

(a) Fine-scale microphysical cloud structure, including ice water contents, particle size distributions, and particle habits, to the bulk microphysical properties of the cloud.

(b) Fine-scale microphysical structure of the cloud to the dynamic and thermodynamic structure of the cloud with special emphasis on the scales and magnitudes of vertical motion in the cloud.

(c) Convective structure of the cloud, as in (b) to the ambient environmental conditions, including cloud temperature, large-scale vertical motion, and vertical wind shear.

(d) Fine-scale microphysical structure of the cloud to the radiative properties of the cloud (broadband, visible and 10-12 {m) and the corresponding broadband radiative fluxes.

(e) Fine-scale microphysical structure of the cloud to the corresponding spectrally and angularly dependent radiance fields.

In each of these data sets, the full spatial and temporal resolution of the relavent observations will be retained to the extent possible. This may be contrasted to the previous data sets (1) where a more statistical approach will be applied when representing the observations. This will enable detailed descriptions of the horizontal and vertical distributions of the above parameters and the temporal variations thereof.

3. Characterize relationships between cloud properties inferred from satellite observations at various scales, especially products of the ISCCP algorithm, and those observed directly (or inferred) from very high resolution measurements (e.g., aircraft and surface based lider and passive radiometric instrumentation). The cloud properties include cloud top height, cloud fraction, cloud optical depth (visible), and 10-12 {m infrared cloud emittance.

Achievement of the observational objectives will ensure adequate data bases for analysis efforts concerned with a variety of properties over a range of scales. Furthermore, it will ensure adequate data bases for evaluation and improvement of models, from detailed cloud and radiative models up to current cloud, and radiative parameterizations on the scale of a general circulation model grid volume. It also will provide information crucial for evaluation and improvement of cloud retrieval algorithms and, thus, provide a basis for improving the intepretation of the ISCCP products.

3.0 PLATFORMS, INSTRUMENTS, AND MEASUREMENTS

3.1 Satellite

Satellite data are required on a daily basis for the period one week prior to the Intensive 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 37.5°N to 47.5°N and 80°W to 102.5°W as follows:

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

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

iii. NOAA TOVS Sounder Data, 20 spectral bands, 2 satellites, day and night.

iv. GOES VAS Imager Data, 1 km resolution visible channel and 8 km resolution infrared data, every 30 minutes through the 3-week experiment period. This data will insure an average separation of AVHRR/TOVS data from GOES data of 7.5 minutes. If two GOES satellites are available, data from both satellites is required. In addition, the two satellites should be time synchronized with each other to provide simultaneous coverage of the FIRE IFO regions.

v. GOES VAS Sounder Data. During the FIRE IFO period, the GOES VAS data will be obtained from both GOES satellites. 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.

vi. LANDSAT Thematic Mapper Data. For the IFO data period, 10 LANDSAT Thematic Mapper scenes will be collected. Each scene covers a 180 km square region. At 42.5°N (approx. Madison, WI) 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, LANDSAT will sample 3 adjacent orbit

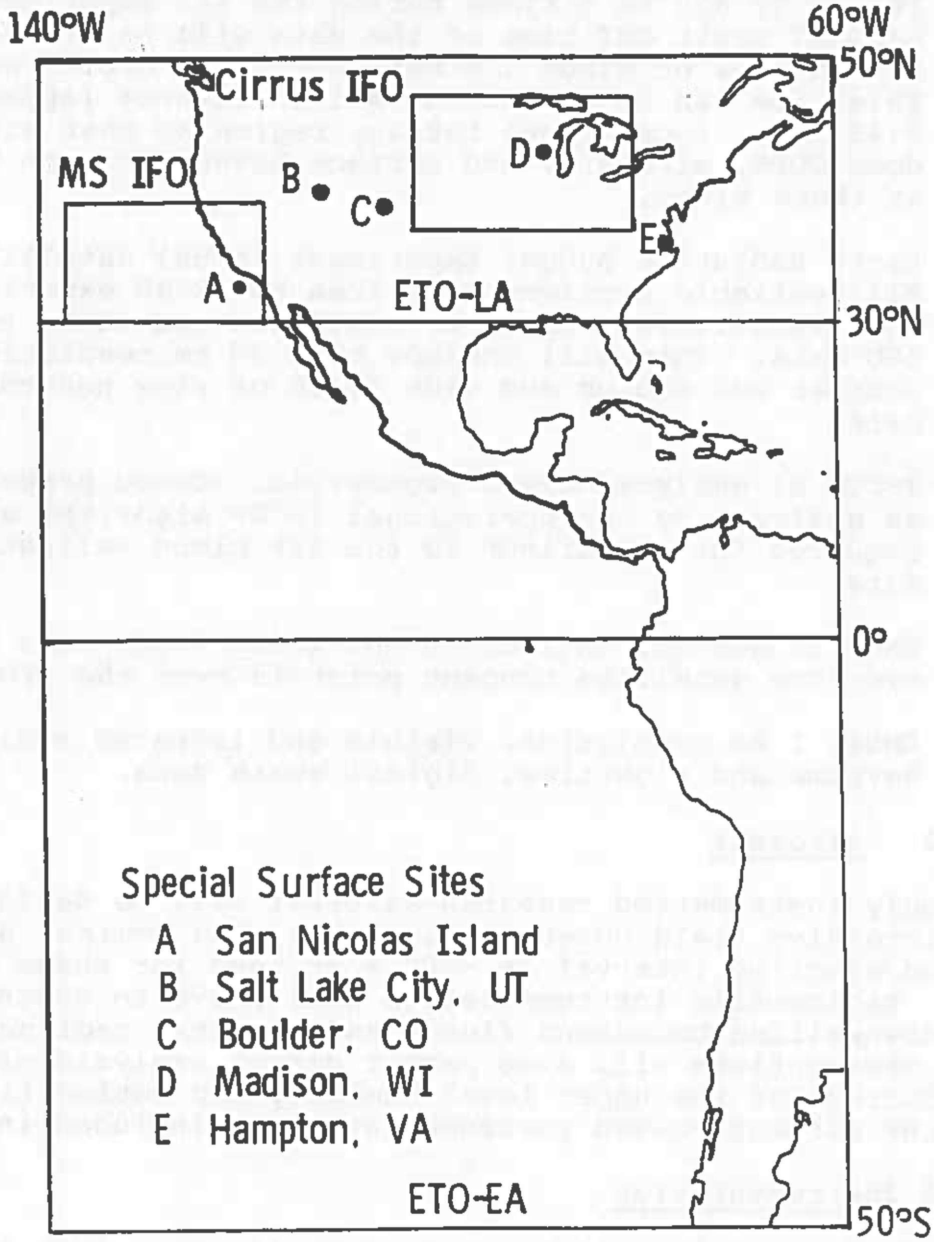


Figure 3.1 - FIRE ETO and IFO Regions and Special Surface Sites

paths as follows: path 1 on days 1 and 17, path 2 adjacent to the cast 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 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. 9:45 a.m. local time) for any region so that simultaneous GOES, aircraft, and surface based data can be taken at these times.

vii. 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 and medium and wide field of view nonscanner data.

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

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

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

3.2 Aircraft

Three highly instrumented research aircraft will be deployed during the intensive field observing program. The nominal horizontal resolution/sampling interval is ~100 m or less for these airborne systems. 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 upper level humidity and motion fields. The list of the aircraft-based instrumentation is included in Table 1.

NASA/ER-2 Instrumentation

The NASA/ER-2 aircraft will be used primarily as a high level (well above cloud top) areal cloud mapping platform. Besides allowing high resolution definition of the cloud and upwelling radiance fields, it will also obtain data spectrally comparable to a number of satellite systems. This will permit detailed intercomparisons with the satellite systems.

TABLE 1: CIRRUS AIRCRAFT IFO MEASUREMENTS

OBSERVATION	INSTRUMENT	PRINCIPAL INVESTIGATOR
Spectral Radiances at TM Channels	Barnes MMR Radiometer	Roger Davies/Purdue
Shortwave Fluxes (Up & Down)	Kipp Albedometer	Roger Davies/Purdue
Longwave Irradiances (Up & Down)	Eppley Pyrgeometers (2)	Roger Davies/Purdue
IR Temperature	Barnes PRT-5 Radiometer	Roger Davies/Purdue
Solar Irradiance	Eppley Pyrheliometer	Roger Davies/Purdue
Aerosol	PMS 2D-C	Steve Cox/CSU
Aerosol	PMS 2D-P	Steve Cox/CSU
Aerosol	PMS FSSP	Steve Cox/CSU
	JW LWC	Steve Cox/CSU
Frost Point	Frost Point Indicator	Steve Cox/CSU
Solar Irradiance	Pyranometers (4; Up & Down)	Steve Cox/CSU
Radiation	Pyrgeometers (2; Up & Down)	Steve Cox/CSU
Icing Rate	Rosemont Icing Rate Detector	Steve Cox/CSU
	CSU Radiometer	Steve Cox/CSU
	Bugeye Radiometer	Steve Cox/CSU
Ice Crystal	Ice Crystal Spectrometer	Andy Heymsfield/NCAR
	Hydrometer	Andy Heymsfield/NCAR
Cloud Droplet	Spectrometer	Andy Heymsfield/NCAR
Water	Liquid Water Content	Andy Heymsfield/NCAR
Aerosol	Aerosol Spectrum	Andy Heymsfield/NCAR
Temperature	Temperature Indicator	Andy Heymsfield/NCAR

TABLE 1: CIRRUS AIRCRAFT IFO MEASUREMENTS (Cont'd)

OBSERVATION	INSTRUMENT	PRINCIPAL INVESTIGATOR
Dewpoint	Dewpoint Indicator	Andy Heymsfield/NCAR
	Lyman Alpha Hygrometer	Andy Heymsfield/NCAR
	VIS and IR Radiometers (4; Up and Down)	Andy Heymsfield/NCAR
	Barnes PRT-5	Andy Heymsfield/NCAR
Decelaration	Decelarator	Andy Heymsfield/NCAR
Solar Irradiance	Eppley Pyranometer (4)	George Kukla/Columbia
Cloud Height/Optical Thickness	ER-2 Cloud Lidar System	Jim Spinhirne/GSFC
Radiances	ER-2 Multi Spectral Cloud Radiometer	Jim Spinhirne/GSFC
Radiances	ER-2 Cloud Absorption Radiometer	Mike King/GSFC
	ER-2 Radiometer	Francisco Valero/ARC
Radiosonde	Class Portable Radiosonde System	David Starr/ SUNY Albany
Cloud-Top Height, Polarization	Polarization Ruby Lidar	Ken Sassen/Utah
Radiation (Net, Up, Down)	Pyrradiometer	Ken Sassen/Utah
Narrowband Emissivity	Mid IR Radiometer	Ken Sassen/Utah
Cloud-Top Height	Lidar	Pat McCormick/LARC
Cloud-Top Height	Lidar	Freeman Hall/NOAA-ERL
Winds	Doppler Lidar	Freeman Hall/NOAA-ERL
	Passive Radiometer	Freeman Hall/NOAA-ERL
Wind Profile	Microwave Wind Profiler	Jerry Nordenberg/ Astronautics
Cloud-Top Height	Lidar	Eloranta/Wisconsin
Winds	Doppler Radar	Roger L'Hermitte/ Miami

The following instrumentation is available for operation from the ER-2 platform (see Appendix A.2.1 for more details):

i. 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 a 50 m horizontal sampling interval.

ii. 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.

iii. Thematic Mapper Simulator (TMS) - 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/LAC simulator in addition to its use as a LANDSAT/5 thematic mapper siumulator.

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

v. Narrow spectral bandpass, narrow field of view downlooking 2 channel IR radiometer.

vi. Hemispherical solar flux radiometers upward and downward looking.

vii. Narrow spectral bandpass hemispherical solar flux radiometer.

viii. Temperature and Pressure Probes.

ix. INS Wind System.

x. Downlooking Vinton 90 mm camera.

xi. HIS spectral interferometer.

NCAR Sabreliner Instrumentation

The NCAR Sabreliner aircraft will be used in the vicinity of the cloud layer with the purpose of obtaining in situ data on the microphysical, thermodynamic, and radiative structure of the target cloud field. Flight levels just above, within, and below the target cloud will be required in order to measure spectral radiances, irradiances, and the cloud layer microphysical properties. In this mode, multiple flight levels will be used in order to sample the vertical profiles of radiative fluxes and meteorological state parameters.

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

i. Particle Measuring System (PMS) - 2 Knollenberg 2-dimensional spectrometer probes (2D-C probe: 50-1600 μm range, 2D-P: 100-3400 μm range). -1 Knollenberg forward scattering spectrometer probe (FSSP: 5 - 50 μm range).

ii. Radiation Sensors - 2 Pyranometers (.3 - 3 μm, 0 1400 w/m^2, 1 upward looking and 1 downward looking. -2 Pyranometers (.7 - 3 μm, 0 - 1000 w/m^2 upward looking, 0 - 700 w/m^2 downward looking). -2 Pyrgemeters (0 - 300 w/m^2 upward looking, 200 - 600 w/m^2 downward looking).

iii. Flight Level Temperature Indicator (-70°C - + 30° C).

iv. Frost Point Indicator (-90° C - 0° C).

v. Altitude Pressure Indicator (0 - 35000 AGL).

vi. Rosemont Icing Rate Detector.

vii. CSU Radiometer Electronics Module.

viii. Bug Eye.

NCAR King Air Instrumentation

The NCAR King Air aircraft will be used for profiling and as an in situ sampling platform. The NCAR King Air will specialized in microphysical measurements and air motion sensing within the cirrus cloud layer. Its capabilities represent an important addition to describing the cirrus cloud layer properties.

The following instrumentation is available on the NCAR King Air:

Parameters	Instrument
Winds	Gust probe, inertial navigation system
Temperature	Rosemount, NCAR, reverse flow, fast response, radiation
Water Vapor	Lyman-Alpha hygrometer
Liquid Water	Knollenberg (3), and Johnson-Williams
Droplet Distribution	Liquid water

Parameters	Instrument
Shortwave and Longwave Irradiances	Barnes PRT-5, Eppley Pyranometers and pyrgeometers
Sea Surface Temp.	Barnes PRT-5
Ozone	Pearson-Stedman
Aerosols	Partial sampler (entended rod), Lidar

3.3 Surface

There are two components of the surface based observing system: cloud lidar/radiometric sites and meteorological sounding systems. The cloud lidar/radiometric instrumentation will be deployed at four field sites.

A list of the surface-based instrumentation in included in Figure 3.3.

Field Site 1 Instrumentation (Oshkosh, WI)

The following instrumentation will be operated by personnel from the Environmental Research Laboratory, NOAA:

i. Scanning ruby, doubled ruby and doubled Nd YAG lidar (694, 347, 532 nm) with dual polarization receiver.

ii. Scanning, narrow beam, visible (400 - 750 nm) radiometer.

iii. Scanning, narrow beam, near infrared (1.04 - 2.2 μm) radiometer.

iv. Precision spectral pryanometers.

v. Cloud imaging cameras.

The corresponding directly calculable cloud properties are (i) cloud base and top heights, areal cloud fraction, particle phase, ice crystal orientation, and cloud optical thickness at 694, 347, and 523 nm; (ii) cloud optical thickness at multiple wavelengths from 0.4-2.2 μm; (iii) surface radiation budget; and (iv) cloud type and amount.

Field Site 2 Instrumentation (Wausau, WI)

The following instrumentation will be operated by personnel from the University of Utah:

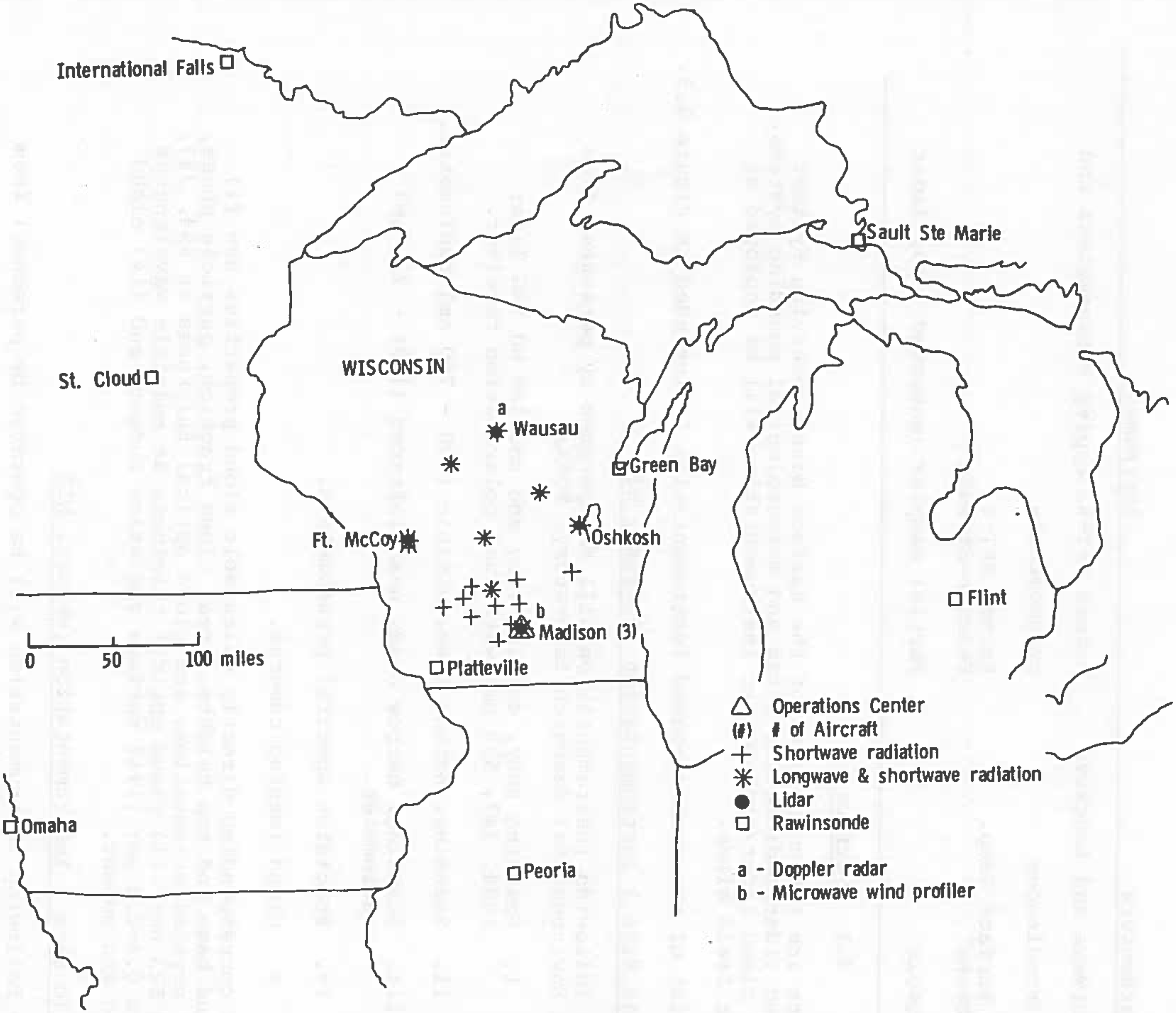


Figure 3.3 Surface Based Instrumentation

i. Scanning ruby (694 nm) lidar with dual polarization receiver

ii. Scanning narrow beam infrared (10-12 μm) radiometer

iii. All-sky, 35 mm fisheye camera

vi. Pyranometers

v. Pyrheliometer (solar tracking)

The corresponding directly calculable cloud physical properties are (i) cloud base and top heights, areal cloud fraction, particle phase, ice crystal orientation, and cloud optical depth at 694 nm; and (ii) cloud type and amount. The corresponding inferentially calculable cloud properties are (i) broadband visible cloud optical thickness and ice crystal habits; (ii) cloud emittance at 10-12 μm and broadband infrared cloud emittance; and cloud [ice] water content [occasionally].

Field Site 3 Instrumentation (Ft. McCoy, WI)

The following instrumentation will be operated by personnel from the Langley Research Center, NASA:

i. Scanning ruby, doubled ruby and doubled Nd YAG lidar (694, 347, 532 nm) with dual polarization receiver.

ii. Scanning CO_2 doppler lidar (9-11 μm)

iii. Vertically pointing, narrow beam, infrared (10-12 μm) radiometer

iv. Narrow beam, visible, sun photometer (solar tracking)

The corresponding directly calculable cloud properties are (i) cloud base and top heights, areal cloud fraction, particle phase, ice crystal orientation, and cloud optical thickness at 694, 347, and 532 nm; (ii) ice particle fall speeds, turbulent intensity and vertical profiles of horizontal convergence/divergence; and (iii) broadband visible cloud optical thickness. The corresponding inferentially calculable cloud properties are (i) broadband visible cloud optical thickness and ice crystal habits; (ii) local vertical profile of vertical wind speeds and ice crystal habits; (iii) cloud emittance at 10-12 μm and broadband infrared cloud emittance; and (iv) areal cloud fraction.

Field Site 4 Instrumentation (Madison, WI)

The following instrumentation may be operated by personnel at the University of Wisconsin: (This section is being prepared by

Dr. Donald P. Wylie of the University of Wisconsin.)

Meteorology Sounding Systems

Because of the importance of relating the observed cloud and radiative fields to the large scale meteorological conditions and the difficulty of obtaining good estimates of large scale vertical motion at cirrus cloud levels, it is proposed that two independent wind sounding systems be deployed over the intensive field observing region. The first is the conventional rawinsonde network that will be operated by NOAA/NWS. Coordinated on-demand launches will be required of all these sites during times when aircraft missions are in progress. The affected stations would be St. Cloud, MN; International Falls, MN; Green Bay, WI; Omaha, NB; Peoria, IL; Sault St. Marie, MI; and Flint, MI. In addition, at least one and possibly two stations will be required in the observing region (western edge). Data from the supplementary rawinsonde sites will allow the analysis of these data to resolve subsynoptic scale (mesoscale) spacial structure in the larger scale forcing, e.g., vertical motion, in association with observed variations in the cloud field at this scale. In addition, these data will provide a tie-on point between the aircraft observations and the sonde observations.

The second upper-level wind system is a VHF wind profiling system being developed by Astronautics, Inc., Madison, Wisconsin for possible use by NOAA/ERL. This system is unaffected by problems of sonde tracking and drift and may provide an accurate direct measurement of ambient vertical motion over each unit. In addition, horizontal wind speeds and directions can be observed which may then be used to infer larger scale vertical motions in much the same way as is done for rawinsonde observations. Continuous sampling allows time averaging that ensures a much greater degree of representativeness than rawinsonde observations offer. To achieve high accuracy at cirrus cloud levels, wind profilers should be operated at a frequency of 50 MHz. Ideally, three of these sites would be operated within the field region provided resources can be found to support this activity. At the very least, one profiler would be very useful to provide a detailed description of the convective structure of the overlying cirrus cloud. Astronautics, Inc. of Madison, Wisconsin is currently developing a prototype microwave wind profiler operating at 200 Mhz. Astronautics expects it will be operational in time for the IFO. Discussions are underway to include it within the IFO operations.

4.0 EXPERIMENT DESIGN

4.1 Sites

The preliminary site selected for the first experiment will be a $(\sim 150\text{ km})^2$ area in central Wisconsin (Figure 3). Wisconsin was chosen for a number of reasons. Climatologically, this area has a relatively high and reliable frequency of cirrus cloud occurrence (~35%), especially pre-warm frontal cirrus during this fall time period. The northerly location together with the selected time period will ensure that cloud overflights are possible with at least two research aircraft, i.e., relatively low cirrus layers (<12 km) will occur. Furthermore, complications in the analysis of vertical motion fields due to orographic effects are minimized by using this site. This site is within the view of both GOES satellites and is close to Lake Superior and Lake Michigan, which provide uniform backgrounds for aircraft-satellite cloud data intercomparisons.

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

1. Operations Center - consisting of a centralized communications facility and housing the Mission Selection and Mission Planning Teams. This center will be located in Air National Guard Building 408, Truax Field, Madison, WI.

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 forecast center will be physically located as part of the Operations Center, Truax Field.

3. Surface Lidar/Radiometric Site 1 - consisting of the NOAA/ERL cloud lidar, doppler lidar, passive radiometric instrumentation as well as the support personnel and facilities for these systems. This site will be located in the vicinity of Wittman Field, Oshkosh, WI.

4. Surface Lidar/Radiometric Site 2 - consisting of the University of Utah cloud lidar, passive radiometric instrumentation from the University of Utah, and Columbia University, and the University of Miami dopplar radar the support personnel and facilities for these systems. This site will be located in the vicinity of Central Wisconsin Airport near Wausau, WI.

5. Surface Lidar/Radiometric Site 3 - consisting of the Langley Research Center (LaRC) cloud lidar and passive radiometric instrumentation, and rawinsondes as well as the support personnel and facilities for these systems. This site will be located at Fort McCoy.

6. Surface Lidar/Radiometric Site 4 - consisting of the University of Wisconsin cloud lidar and passive radiometric instrumentation from the University of

Wisconsin and Purdue University as well as the support personnel and facilities for these systems. This site is on the University of Wisconsin campus. Additional Radiometric Instrumentation will located at Truax Field.

7. Conventional Rawinsonde Network - consisting of the NOAA/NWS stations at St. Cloud, MN; International Falls, MN; Green Bay, WI; Omaha, NB; Peoria, IL; Sault St. Marie, MI; and Flint, MI.

8. Special Rawinsonde Site - consisting of the NCAR/GAMP CLASS launching facility and the operator to be located at Plattville, WI and the mobile LaRC launching facility to be located at Ft. McCoy.

9. Aircraft Base - housing the NASA ER-2, the NCAR King Air and Sabreliner, the flight and ground crews, instrument scientists and technicians, and facilities for maintenance and operation of these aircraft. This base will be at the Air National Guard, Truax Field, Madison.

10. Surface Radiation Budget Network - consisting of 13 additional stations located within the 4 - station Lidar grid with shortwave radiometric instruments (call stations) and longwave radiometric instruments at 3 locations (see figure 4.1)

The Operations Center, Forecast Center and Aircraft Base will all be colocated at Air National Guard, Truax Field. The University of Wisconsin McIDAS system will have a remote station at the Forecast Center. It will be linked to the main system via a telephone line. This will allow greater flexibility in coping with potential data access and processing problems under the real time constraints of field operations. In this case, a reliable communication link to the Operations Center would be in place and would include two-way data transmission and display capabilities - see section 4.7. Surface Lidar/Radiometric Site 4 will be located in relatively close proximity to the Operations Center. This will facilitate the active participation of the investigators at Surface Lidar/Radiometric Site 4 on the mission Selection and Planning Teams, especially with respect to evaluation of previous missions.

The IFO operations will begin its full up operations on <u>October 13 (DO)</u>. All of the sensors should be deployed at their respective sites (Madison, Oshkosh, Wausau, Fort McCoy). The IFO will continue for 3 weeks until November 2. There are, however, several modifications to this schedule and set up to ensure that the appropriate intercomparisons can be made among like sensors. The modifications are described below and summarized in Table 2.

TABLE 2: SCHEDULE AND SENSOR LOCATIONS FOR CIRRUS IFO

Relative Date	Date	Madison	Oshkosh	Wausau	McCoy	Radiation Budget Network	Platteville
DO-3	10/10	1. All surface radiation sensors at ANG 2. U. Miami Doppler radar at Astronautics 3. Astronautics wind profiler 4. U. Wisc. lidar	1. ERL lidar 2. LaRC lidar 3. U. Utah lidar				
DO	10/13	1. Purdue sensors at ANG 2. CSU sensors at ANG 3. Wind profiler 4. U. Wisc. lidar 5. Aircraft at ANG	1. ERL lidar 2. LaRC lidar 3. U. Utah lidar 4. U. Miami Doppler radar 5. Cox radiation sensors	1. U. Columbia radiation sensors	1. LaRC radiation 2. LaRC rawin-sondes	1. Whiltock radiation sensors	1. NCAR/CLASS rawin-sondes
DO+3	10/16	As Above	1. ERL lidar 2. Cox radiation sensors	1. Utah lidar 2. U. Columbia radiation sensors 3. U. Miami Doppler radar	1. LaRC lidar 2. LaRC radiation sensors 3. LaRC rawin-sondes	As Above	As Above
DO+20	11/2	Last day of Operations					

First, at DO-3 (October 10), all of the surface radiation sensors will be located at Madison to begin a 3-day period of intercomparison. The pryranometers will probably be located at the University of Wisconsin; the remainder of the radiation sensors will be located at the air National Guard (ANG) facility. The University of Miami doppler radar will locate at Astronautics for intercomparisons with Astronautics' microwave wind profiler. It is hoped that at times of the doppler radar-microwave wind profiler observations, the University of Wisconsin lidar will also operate at its university campus location. The NOAA/ERL infrared doppler lidar, Langley Research Center (LaRC visible lidar, and the University of Utah lidar will also begin their intercomparison at Oshkosh. Second, at DO (October 13), the Cirrus IFO will begin the 3-week operation with all of the sensors and platforms at their deployed locations, with the following exception. The doppler radar will be located at Oshkosh for intercomparisons with the ERL doppler lidar, LaRC lidar and Utah lidar. Finally on DO+3 (October 16), the doppler radar and the University of Utah visible lidar will relocate to Wausau for normal IFO operations. The LaRC lidar will relocate to Fort McCoy for its normal IFO operations.

4.2 Simultaneous Satellite/Aircraft/Surface Site Observations

Preliminary estimates of times of potential conincident satellite observations within the field site and surrounding region, (27-5N to 47.5N and 80W to 102.5W, will be included in the operations plan. This will allow targeting of specific "most opportune" times for aircraft and surface operations.

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 surface lidar and either LANDSAT or NOAA AVHRR-HRPT observations. The LANDSAT and HRPT data provide the highest spatial resolutions (28.5 meter and 1.1 km respectively) allowing the most direct comparisons of lidar and satellite radiance data. For GOES and LANDSAT satellite data, these times are invariant from day to day (within less than a minute). For the NOAA polar orbiter data (TOVS, AVHRR, ERBE), ERBS satellite (ERBE, SAGE-II), and for the DMSP satellite however, the exact time of overpass will vary by as mush as an orbital period (approx. 100 minutes). A summary of the time coincidence for each satellite is given below:

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 only the GOES East 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. Two GOES satellites may be operational by fall, 1986.

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 LANDSAT overpass times for Madison, Wisconsin.

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 Madison, Wisconsin 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 for Madison, Wisconsin.

4.2.4 Earth Radiation Budget Satellite (ERBS)

The primary surface/satellite coincidence target for this satellite is the SAGE II solar occultation 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 Madison, WI region.

4.2.5 Defense Meteorlogical Satellite Program (DMSP)

To be supplied by J. Bushing, AFGL.

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 operated away from the experiment region to avoid possible flight through the aircrafts' engine exhaust over the test area and thereby contaminate the scientific measurements. In addition, during experiment flights, the aircraft will operate under Visual Flight Rules (VFR) conditions and will generally avoid clouds during the warmup phase of each flight.

Therefore, in order to have the flexibility to efficiently conduct the Cirrus IFO, the Mission will require approval from the FAA and military authorities to operate each of the aircraft in a prescribed volume of airspace in and about the state of Wisconsin and Lake Michigan.

All flight operations will be in accordance with existing rules and regulations governing aircraft operations in U.S. airspace. The appropriate aviation officials in Chicago, Minneapolis and Madison 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-line.

4.4 Experiment Plans

The sampling strategy involves obtaining observations of the same targets from multiple platforms. Synchronized high resolution multispectral satellite observations will be obtained from multiple platforms viewing the scene from different angles. Coincident observations will also be obtained from three aircraft where one is essentially a satellite platform simulator with additional capabilities and the other two aircraft are equipped with in situ radiative, microphysical, and air motion sensing instrumentation. Special lidar, radar, and radiometric observations will be obtained from surface based sites as will conventional observations of meteorological parameters. The strategy calls for high density observations over limited times (2-3 hours) both in small $(10\text{-}150\ \mathrm{km})^2$ fixed regions where surface based observations are being collected and over surrounding regions as weather and satellite operations permit. Observations over the fixed region will serve the purposes

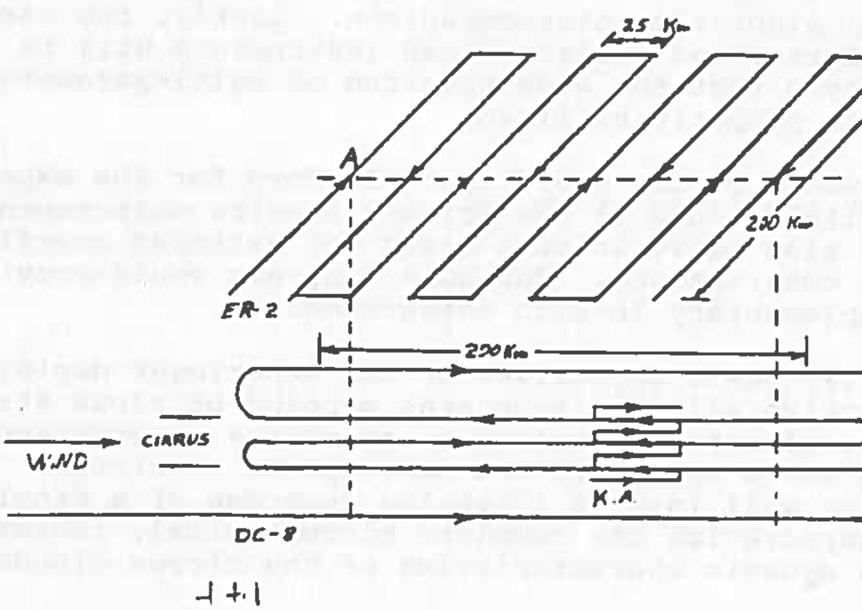


Figure 1. Area Mapping

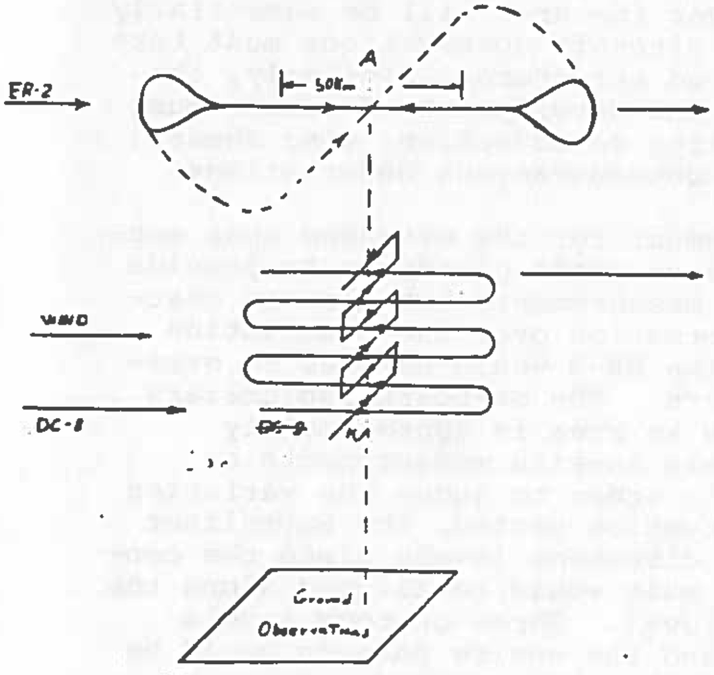


Figure 2. Ground Coordination

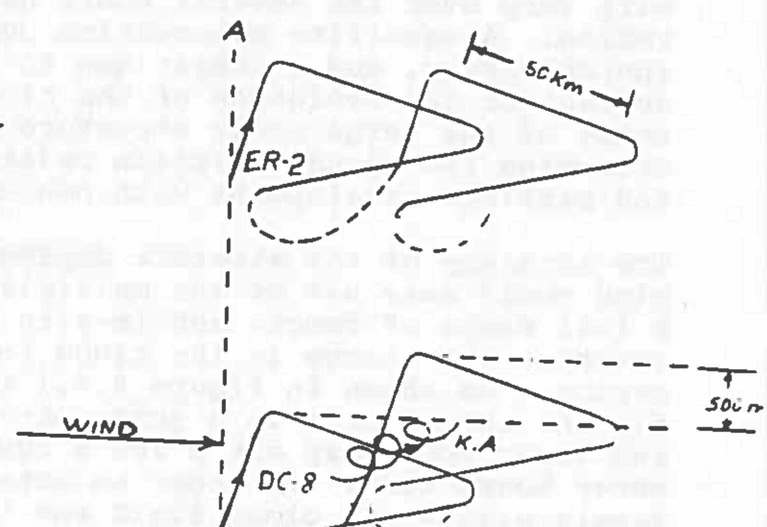


Figure 3. Aircraft Stacking

FLIGHT PATTERNS

of the intensive case studies while missions over the surrounding regions, particularly over water, will provide important data for cloud retrieval algorithm intercomparison. Lastly, the various satellite, airborne, and surface-based instruments will be inter-compared to ensure that the wide spectrum of multi-parameter observations are properly utilized.

The NASA ER-2 would be the overflight platform for the experiment. The NCAR Sabreliner would be the primary in-situ measurement platform but would also serve in some cases for extended overflight or underflight observations. The NCAR King Air would provide additional complementary in-situ measurements.

There will be two basic objectives of the experiment deployments. The first objective will be large area mapping of cloud structure for the purpose of intercomparison to satellite observations and to study large scale structure and development of cirrus. The second objective will involve intensive coverage of a single area in order to characterize the complete microphysical, radiative, structural and dynamic characteristics of the cirrus clouds.

a. Area Mapping

A basic difficulty with the use of aircraft for mapping cloud characteristics over an extended area is that the cloud structure will vary over the several hours necessary for the complete observation. A satellite observation over the area will be essentially instantaneous, and a comparison to aircraft observations must take account of the evolution of the cloud structure. Similarly, the study of the large scale structure and development of cirrus must determine the cloud evolution relating to advection, wind shear, and particle development with non-contemporaneous observations.

The strategy of the aircraft deployment for the extended area mapping would make use of the multiple aircraft platforms to provide a full range of remote and in-situ measurements but also to characterize the change in the cloud formation over the observation period. As shown in Figure 4.4.1 the ER-2 would be used to overfly the chosen area in a grid pattern. The on-board radiometers and lidar would map out a 200 x 200 km area in approximately three hours time. In order to obtain in-situ measurements at levels within the cloud field and in order to judge the variation of cloud structure during the observation period, the Sabreliner would fly repeated flight lines at different levels along the center axis of the ER-2 pattern. The axis would be aligned along the wind vector at the primary cirrus level. Three or four levels through the cloud would be flown, and the entire pattern could be flown twice during the three hour observation period. Prior to the flights lines within the observation area, the Sabreliner would fly an extended flight line of 200 km upwind in order to observe the region that would be advected into the principal area. The King Air aircraft could be used to fly repeated vertical profiles at a central location to provide a time history of the vertical development.

The area chosen for the mapping coverage would typically be at a location within an extended area of pre-frontal cirrus with preference given to a location which included the FIRE ground based observation site. A forecast and decision for deployment would be required some four hours in advance of the initiation of observations. A time and site for the start of observations as indicated by point A on the first figure and a direction of the principal wind vector would be designated to enable aircraft coordination. An essential operational factor would be unrestricted flight clearance for the in-situ aircraft within the designated area.

b. Intensive Coverage

The experiment would be designed to provide the maximum coverage of measurements at one specific site or cloud formation and would entail close cooperation between aircraft and ground based observations. The first mode of operation would involve a direct coordination between the ground based field observation site and the aircraft. The ER-2 would fly 50 km flight lines centered on the ground observation site. Two tracks would be along the principal cirrus wind vector followed by third cross track line and then a repeat of the pattern. The NCAR Sabreliner and King Air would fly tracks at multiple levels withing the cirrus layer with the two aircraft operating along crossed directions and at offset altitude levels. The pattern would be repeated for at least two vertical ascents by the in-situ aircraft. Prior to and following the flight lines over the ground observation site, the ER-2 and NCAR Sabreliner would fly extended lines upwind and downwind, respectively, of the field site.

A second deployment mode for coverage of a limited cloud would involve direct coordination between the ER-2 and NCAR Sabreliner. The objective would be maximum simultaneity and coverage between the ER-2 remote measurements and the in-situ and remote measurements of the NCAR Sabreliner for a single cloud formation. The triangular pattern would permit an extended area coverage and multiple view angles. The two aircraft would fly in a stacked configuration with turns adjusted to maintain coordination. The NCAR Sabreliner would fly the pattern at different levels within the cirrus layer. The actual triangular pattern would be shifted in time and direction along the wind vector of the principal cirrus level. The King Air aircraft would be deployed to make repeated vertical ascents through the center of the pattern. The cloud conditions most appropriate for the coordinations with ground based observations would be an extended area of cirrostratus. The aircraft coordination pattern would be appropriate for most conditions including broken and patchy cirrus cover. Unrestricted flight clearance over the limited study areas would be highly desirable or necessary.

4.4.1 FIRE Cirrus IFO Aircraft Mission Descriptions

Three aircraft are currently scheduled for the first FIRE Cirrus Intensive Field Observation period; they are the NASA ER-2, the NCAR Sabreliner and NCAR King Air. These aircraft would participate in both single and multiple aircraft missions during the IFO period. Schematic representations of the flight plans and the specific objectives of the various types of missions are given below, however, first a few general comments will be made pertaining to all types of missions.

Aircraft missions will generally be conducted between the hours of 1200 and 1600 and between 0000 and 0400 LST. This timing of aircraft missions will allow coordination with NOAA satellite overpasses; in addition several GOES infrared and visible images will be available during the performance of each mission. These coincident aircraft and satellite data sets will be an important FIRE contribution to the development of interpretative and evaluation techniques for satellite cloud data sets.

At the outset of the experiment, at least two missions per aircraft will be targeted to fly in the 0000 - 0400 LST window. This specification is being made to insure in situ data will be available to be applied to the problem of nighttime cloud detection from satellites. Ideally these night missions will be made near full moon conditions to allow some visual monitoring of the conduct of the flights.

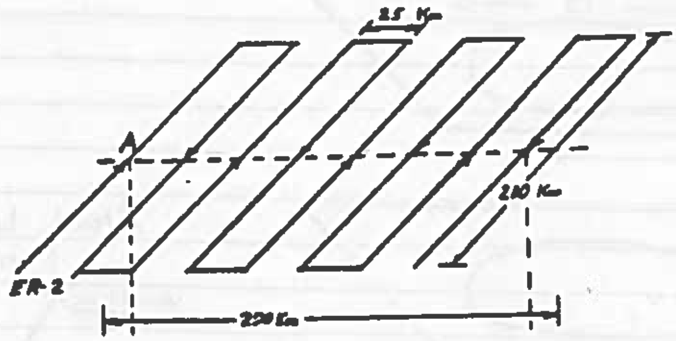
In addition to the nighttime aircraft flights, special attention will be given to the collection of cirrus cloud aircraft data over uniform, low albedo backgrounds. In view of the proximity of the experiment to Lake Michigan some aircraft operations will be planned over the Lake itself although no "ground support" data such as lidar will be available. Of a lower priority is the collection of data over high albedo backgrounds such as underlying cloud decks or snow cover; these latter instances should be viewed as targets of opportunity and, if convenient, sampled to expand our data base of verified cases of remotely sensed cirrus clouds.

A routine mini flight pattern will be flown by both the Sabreliner and the King Air both directly after takeoff and immediately before landing. This pattern will serve as a pre and post flight intercomparison over a fixed target; ideally a lake surface and surrounding beaches and fields will provide uniform targets for the down-looking radiometers. In addition, when both the King Air and the Sabreliner are scheduled for coordinated missions, they will attempt to intercompare as many systems as possible on a coordinated flight path shortly after takeoff.

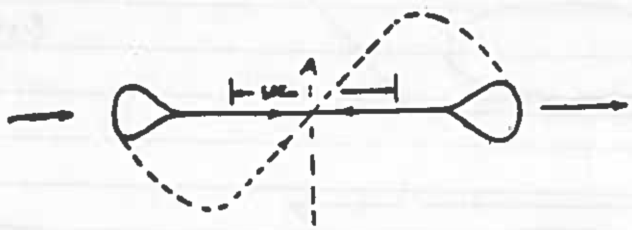
4.4.1.1 Flight Patterns

4.4.1.1.2 ER-2 Flight Patterns

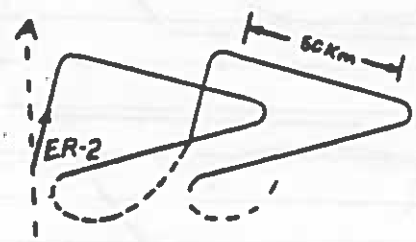
PATTERN ER2-I



PATTERN ER-2-II



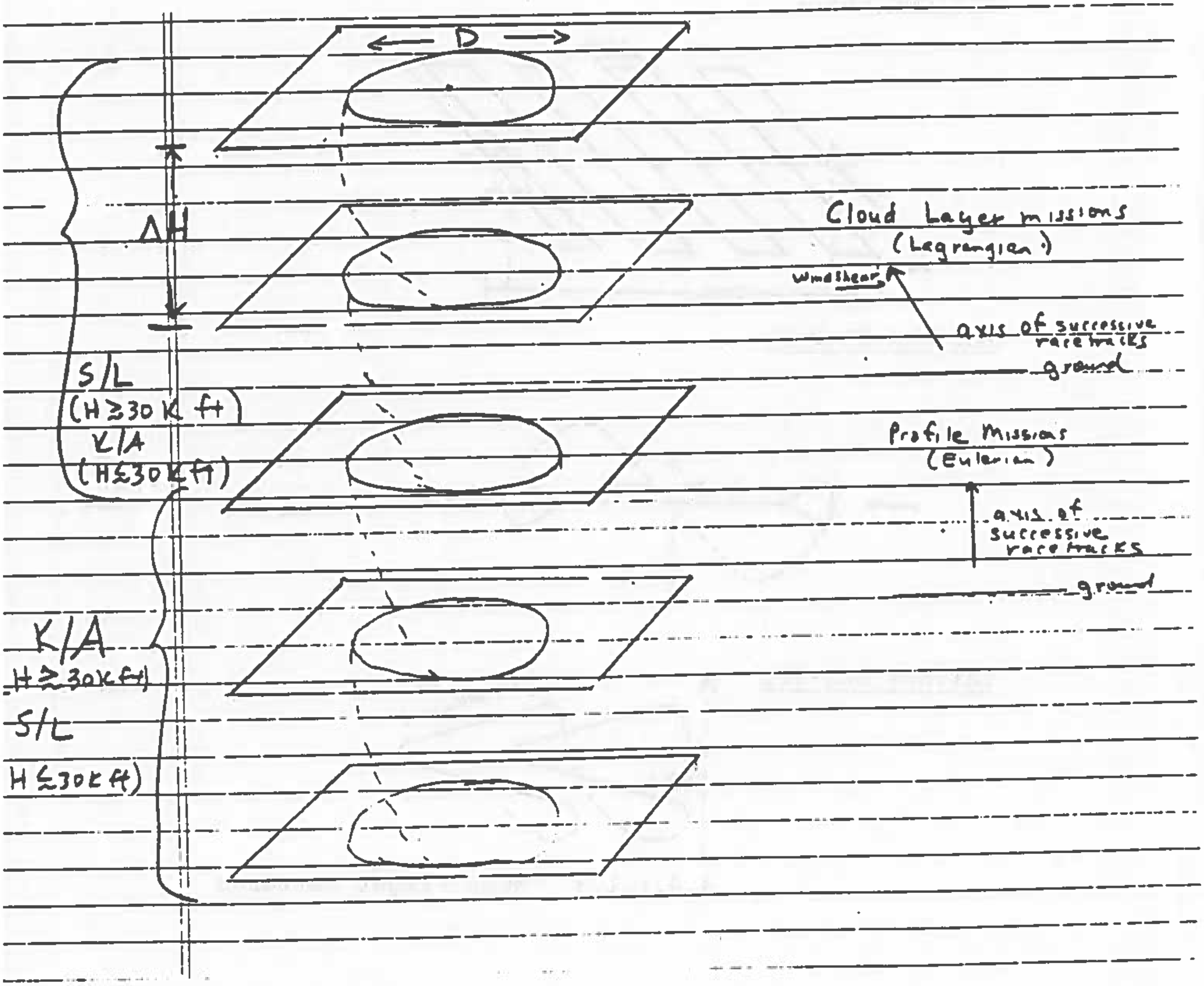
PATTERN ER2-III



4.4.1.1.3 NCAR Flight Patterns

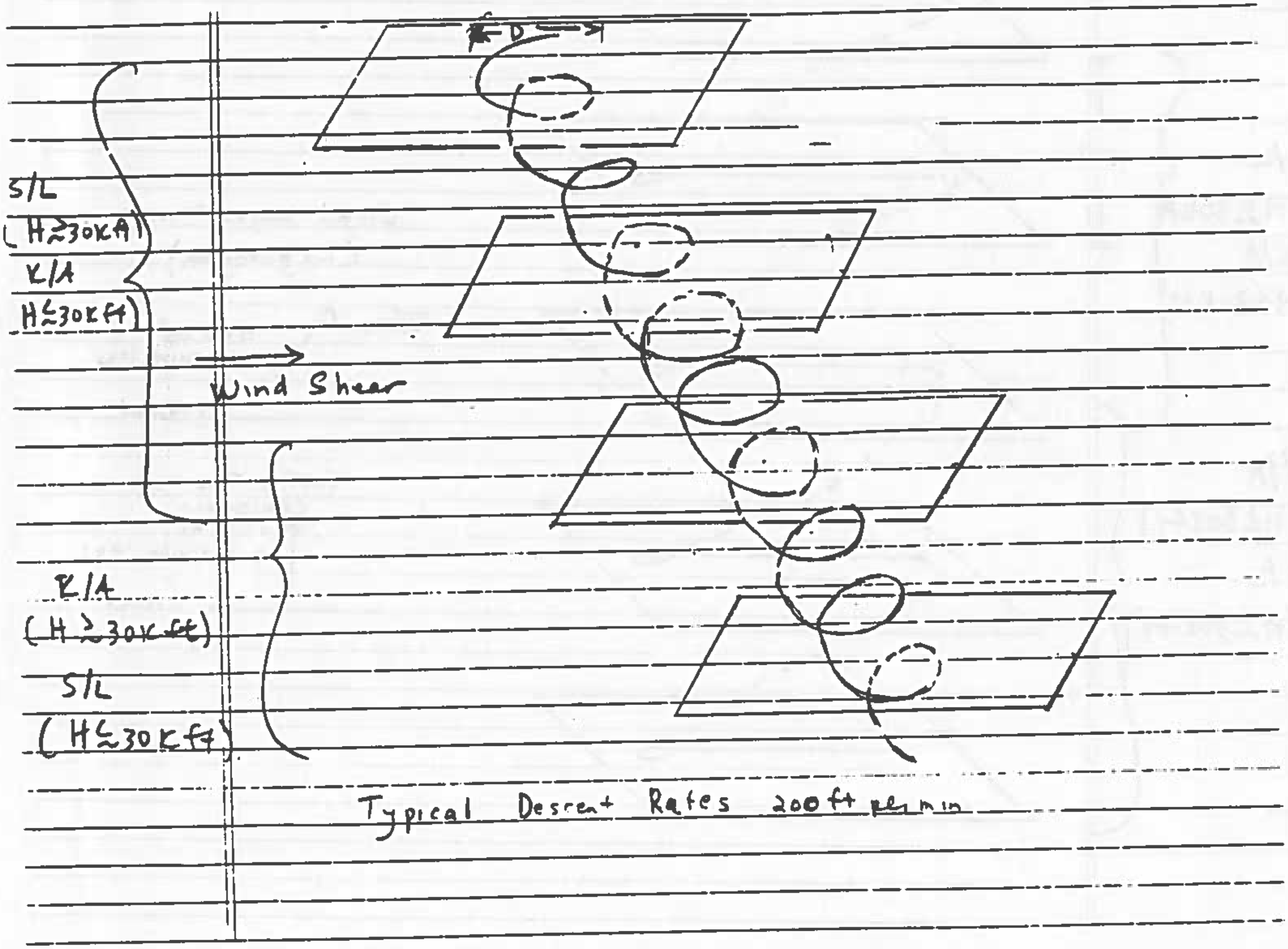
PATTERN NCAR-1

Racetrack Pattern



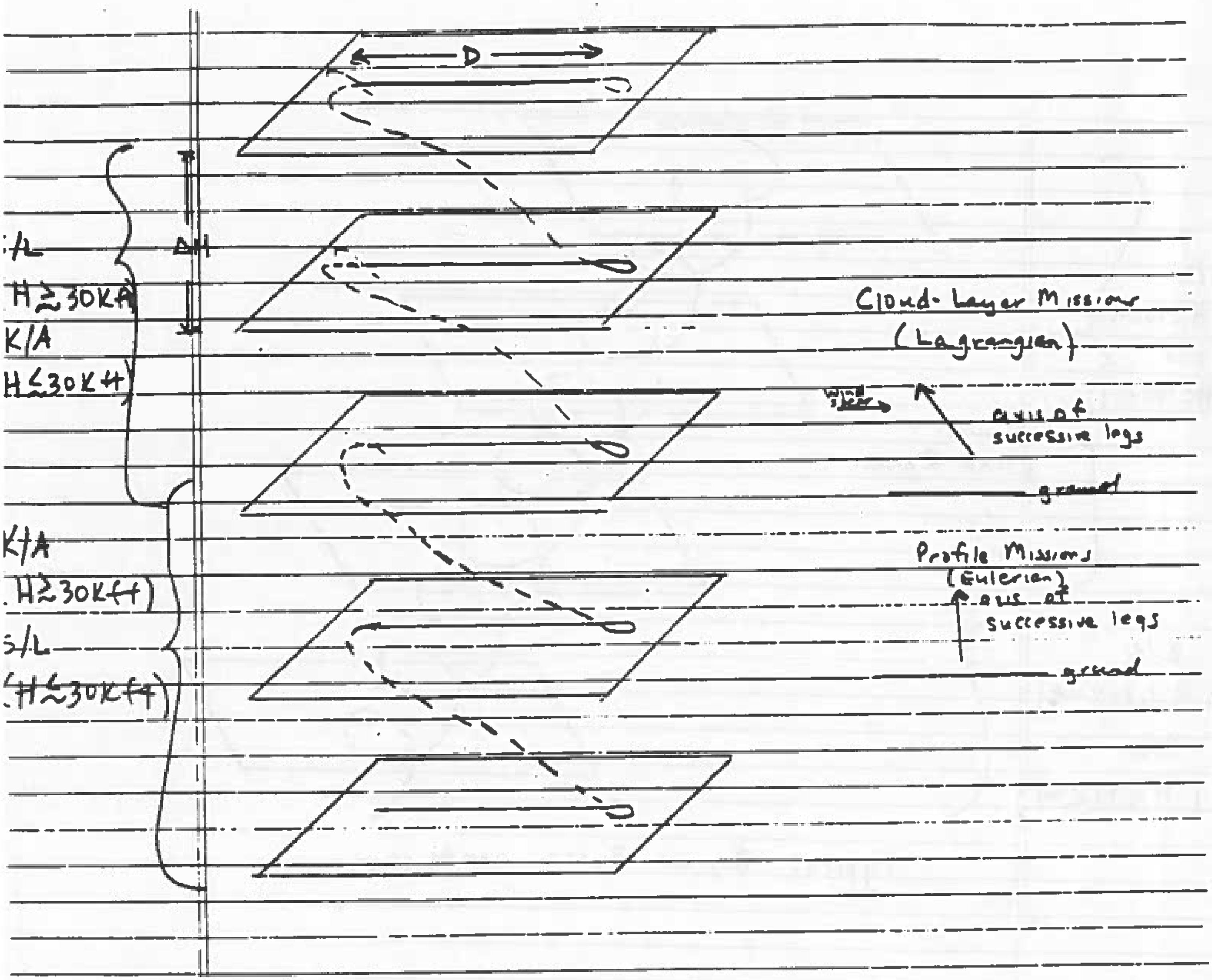
PATTERN NCAR-II

Spiral Descent
(lagrangian only)



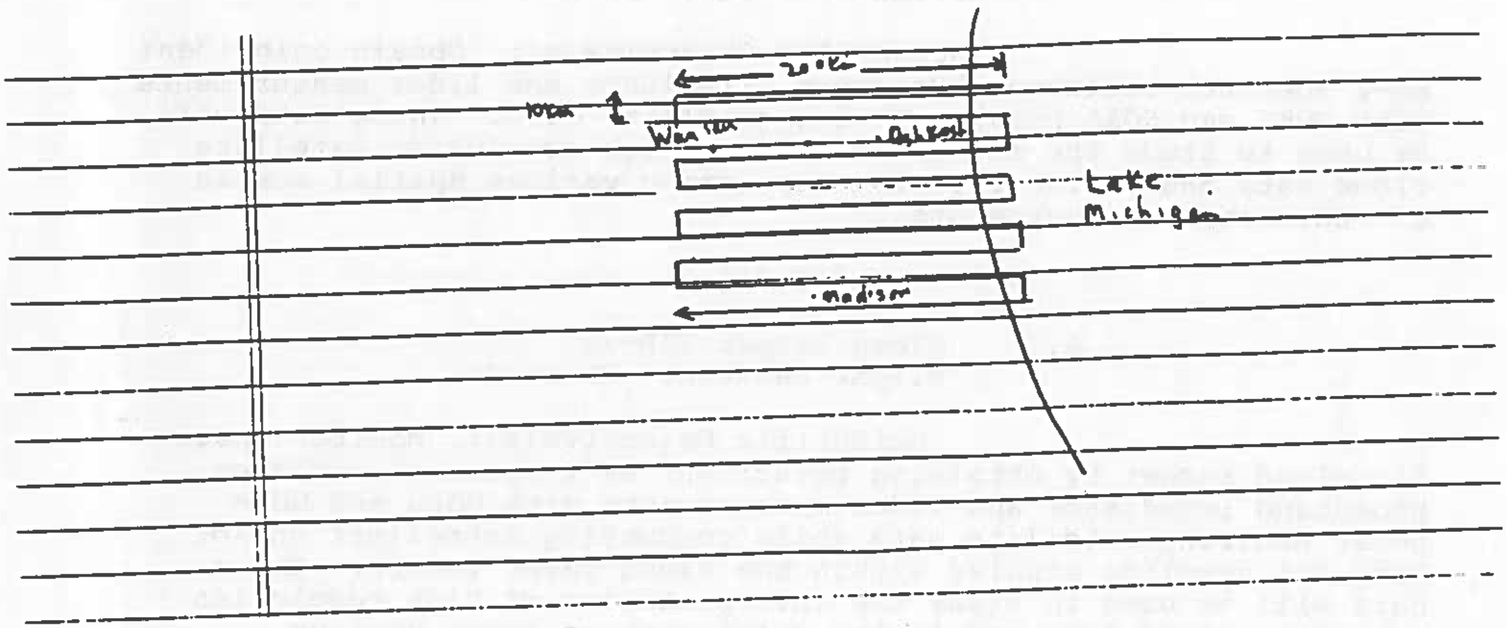
<u>PATTERN NCAR-II</u>

Step-Down



PATTERN NCAR-IV

King Air Mapping Mission
(1000 Ft AGL)



4.4.2

III. MISSION PLANS

4.4.2.1

A. MAPPING MISSIONS

4.4.2.1.1

A.1 Scene overview (ER-2)
Flight Pattern: ER 2-I

Scientific Objective(s): Obtain coincident ER-2 spectral radiance, broadband irradiance and lidar measurements with GOES and NOAA polar orbiting satellite data. These data will be used to study the interpretation of high resolution satellite cloud data and in the relationships among various spatial scales of radiometric measurements.

4.4.2.1.2

A.2 Cloud target (ER-2)
Flight Pattern: ER 2-II

Scientific Objective(s): Monitor specific cloud target by obtaining coincident ER-2 spectral radiance, broadband irradiance and lidar measurements with GOES and NOAA polar orbiting satellite data while conducting Sabreliner and/or King Air sampling studies within the cloud layer itself. These data will be used to study the interpretation of high resolution satellite cloud data and in the relationships among various spatial scales of radiometric measurements.

4.4.2.1.3

A.3 Surface Temperature-Albedo (King Air)
Flight Pattern: NCAR-IV

Scientific Objective(s): Obtain baseline map of surface albedo and surface temperature characteristics in the surface network region (Fort McCoy, Oshkosh, Wausau).

4.4.2.2

B. CLOUD LAYER MISSIONS

The following three cloud layer missions may be flown in any one of three modes: simultaneous, sequential or single aircraft. The simultaneous mode would be utilized when the experiment requires maximum horizontal or vertical resolution of measurements.

The sequential mode would be adopted to study the time variation of the cirrus layer itself. Both microphysical and radiative properties of the cloud layer would be monitored by aircraft. Typically the Sabreliner would perform a single aircraft B.1 type mission followed immediately by the King Air performing a B.1 or B.2 type mission. The combined endurance of the two aircraft would provide sampling for approximately 7.5 hours.

There will be occasions when only one NCAR aircraft is available; on those occasions the aircraft will be flown in the single aircraft mode when it will perform one or a combination of A.3, B.1, B.2, B.3, C.1, C.2 or D.2 missions.

Although the ER-2 will not usually penetrate the cloud layer itself, it will collect valuable data describing the spatial continuity of the cloud layer from its passive and active remote sensors. These data will be integrated with satellite and in-situ Sabreliner and King Air data.

4.4.2.2.1

B.1 Simultaneous - Coordinated (Sabreliner, King Air) (Coordinated with ER 2 A.1 or A.2 mission)

Flight Pattern: NCAR-I, -II or -III; ER 2-I or -II.

Scientific Objective(s): Sample thermodynamic, air motion, microphysical and radiative properties of the cirrus cloud layer. These data will be used to intercompare and develop radiative transfer models, microphysical models and numerical models of cirrus clouds.

The simultaneous mode would be subdivided into categories - low clouds which both the Sabreliner and King Air could reach cloud top and higher clouds for which only the Sabreliner could reach the cloud top height. In the high cloud cases the Sabreliner would typically sample from the top down to approximately 28,000 feet and the King Air would sample from this level down into the subcloud layer. In this overlap mode it is strongly advisable to have at least one altitude level of overlap. For the lower cloud case the two aircraft would each typically sample the entire cloud layer from top to bottom in different air space.

4.4.2.2.2

B.2 Sequential - Coordinated

(Sabreliner and King Air)
(Coordinated with ER 2 A.1 or A.2 mission)

Flight Pattern: NCAR-I, -II or -III

Scientific Objective(s): Sample thermodynamic, air motion, microphysical and radiative properties of the cirrus cloud layer. In the sequential flight mode the cirrus cloud target would be sampled for a period longer than the typical duration of a single aircraft flight. The sequential nature of this type of flight will be used to depict the time evolution of the cirrus cloud layer. These data will also be used to intercompare and develop radiative transfer models, microphysical models and numerical models of cirrus clouds.

4.4.2.2.3

B.3 Single Aircraft (Sabreliner and King Air)
Flight Pattern: NCAR-I, -II or -III

Scientific Objective(s): Sample thermodynamic, air motion, microphysical and radiative properties of the cirrus cloud layer. These data will be used to intercompare and develop radiative transfer models, microphysical models and numerical models of cirrus clouds.

Note: The step down pattern uses approximately 1/2 the time of the race track pattern to complete a descent through a layer, however it provides only 1/2 the horizontal sample size.

4.4.2.3

C. PROFILE MISSIONS (Sabreliner and King Air)
(Coordinated with ER 2 A.1 or A.2 mission)

4.4.2.3.1

C.1 Synchronized with Surface network
Flight Pattern: NCAR-I, -II or -III

Scientific Objective(s): Sample the cirrus cloud layer simultaneously with surface lidar and radiometric measurements and extend this profile to the ground level to define the properties of the intervening layer. These data will be used to relate surface remote sensing data to in-situ sampling of the cirrus cloud as well as to evaluate the ability of existing radiative transfer models to accurately depict the downward radiation components at the surface in the presence of cirrus clouds.

4.4.2.3.2

C.2 Other targets (see 4.4.2.4.3)
Flight Pattern: NCAR-I, -II or -III

Scientific Objective(s): Sample the cirrus layer and underlying atmosphere to provide specification of the entire atmosphere for use in evaluation and development of satellite remote sensing capability.

4.4.2.4

D. INTERCOMPARISON MISSIONS*

4.4.2.4.1

D.1 Sabreliner - King Air
Flight Patterns: All NCAR Flight Patterns

Scientific Objective(s): These data would interrelate thermodynamic, air motion, microphysical and radiation measurements of the Sabreliner and King Air aircraft.

4.4.2.4.2

D.2 A/C - Surface network [Sabreliner and King Air (See 4.4.2.3.1)]
Flight Pattern: NCAR -I, -II or -III

Scientific Objective(s): These data would interrelate the surface radiation measurements and cirrus properties inferred from surface lidar with in-situ aircraft measurements.

4.4.2.3.3

D.3 A/C - Satellite (see A.1, A.2, B.1, B.2, B.3, C.2)

TENTATIVE MISSION ALLOCATION SCHEDULE

MISSION TYPE

	A.1	A.2	A.3	B.1	B.2	B.3	C.1	C.2	D.1	D.2	D.3
ER2	50%	50%							*	*	*
SABRELINER				2	6	5	2	2	1	*	*
KING AIR			1	2	6	4	4		1	*	*

* Virtually all aircraft operations will support the D.() intercomparison objectives; therefore no additional mission allocation was made to these categories.

4.4.3 Rawinsonde Schedule

Seven (7) National Weather Service (NWS/NCAA) rawinsonde sites will participate in the IFO. They are:

Omaha, NE	(OMA)	41° 22'N	96° 01'W	406m
St. Cloud, MN	(STC)	45° 33'N	94° 04'W	312m
International Falls, MN	(INL)	48° 34'N	93° 23'W	361m
Peoria, IL	(PIA)	40° 40'N	89° 41'W	202m
Green Bay, WI	(GRB)	44° 29'N	88° 08'W	214m
Sault Ste. Marie, MI	(SSM)	46° 26'N	84° 22'W	221m
Flint, MI	(FNT)	42° 58'N	83° 44'W	233m

Two additional special rawinsonde sites will also be operated at

Fort McCoy, WI	(FMC)	43° 59'N	90° 43'W
Platteville, WI	(PLA)	42° 44'N	90° 34'W

by NASA LaRC and SUNYA/NCAR (CLASS), respectively a third special site will occasionally be operated in the vicinity of Wausau, WI (AFGL).

On a given day, one of three possible launch schedules will be selected, ie.,

R1. <u>Enhanced Deployment Mode</u> (16 days)

OMA, INL, SSM, FNT,	12Z, 00Z
STC, PIA, GRB	12Z, 18Z, 00Z
FMC, PLA	12Z, 18Z, 00Z

R2. <u>Intensive Deployment Mode</u> (4 days)

OMA, INL, SSM, FNT	12Z, 15Z, 18Z, 21Z, 00Z
STC, PIA, GRB	12Z, 15Z, 18Z, 21Z, 00Z
FMC, PLA	12Z, 15Z, 18Z, 21Z, 00Z

R3. <u>Minimal Deployment Mode</u> (4 days)

OMA, INL, SSM, FNT	12Z, 00Z
STC, PIA, GRB	12Z, 00Z
FMC, PLA	12Z, 00Z*

* FMC may stand down on these days and PLA may also launch at 187. The Enhanced Deployment Mode (RI) is the usual situation.

OF the twenty-four (24) experiment days, four days are targeted for the Intensive Deployment Mode (R2). It is anticipated that situations requiring only the Minimal Deployment Mode (R3) will occur on about four days, e.g., no aircraft operations due to weather conditions or pilot duty cycles. However, if the meteorology proves uncooperative such that the R3 target is likley to be grossly exceeded, then an additional R2 day may be scheduled. Furthermore, on no more than two occasions, the R1 schedule may be modified by substituting a 06Z launch for the usual 18Z launch, i.e., to coincide with nighttime aircraft aperations and the ~ 0230 CST NOAA-9 overpass.

Selection of the launch schedule and motification of the launch sites will occur by 0100Z each evening, i.e., 1900 CST on the preceding day. Confirmation of the selected schedule (GO/NO GO) will be made by 1400Z of the following morning, i.e., 0800 CST. In the event of nighttime operations (R1), the same deadlines will be employed but in reverse order.

4.4.4 Lidar Operating Modes

4.4.4.1 Langley LIDAR Operating Modes

MODE 1
Max. repetition rate: 1 pulse every 2 seconds/Zenith pointing

MODE 2
Low repetition rate: 1 pulse every 30 seconds/Zenith pointing

MODE 3
Intermittent mode: 1 pulse every 15 minute/Zenith pointing

Suffix codes: P - Pointing mode - off-Zenith direction.
S - Scanning mode same as P except lidar is either being continually pointed in different directions or is being stepped to different directions.

Example: Mode 1S implies rep. rate = 1 pulse every 2 sec. in scan mode. Sky is being scanned angularly either by stepping the lidar or by continually rotating the pointing direction.

4.4.4.2 Utah Lidar Operating Modes

MODE 1: Maximum repetition rate: 1 pulse per minute/Zenith pointing

MODE 2: Low repetition rate: 1 pulse per five minutes standby/ surveillance mode

MODE 3: Intermittent mode: 1 pulse per fifteen minutes

Suffix codes: P - pointing mode - off-Zenith direction
S - scanning mode same as P except lidar is either being scanned continually pointed in different directions or is being stepped to different directions.

Example: Mode 1S implies rep. rate = 1 pulse/min. in SCAN mode. Sky is being scanned angularly either by stepping the zenith angle or a more continuous angular rotation of the azimuth angle.

4.4.4.3 NOAA/ERL Lidar Operating Modes

NOTE: In addition to the normal rangefinding and backscattering signal strength lidar measurements this installation has the capability to measure degree of depolarization and the doppler shift of the backscattered signal.

MODE 1: Maximum repetition rate: 1-2 pulse per second/Zenith pointing

MODE 2: Low repetition rate: 1 pulse per five minutes standby surveillance mode

MODE 3: Intermittent mode: 1 pulse per fifteen minutes

Suffix codes: P - pointing mode - off-Zenith direction
S - scanning mode same as P except lidar is either being scanned continually pointed in different directions or is being stepped to different directions.

Example: Mode 1S implies rep. rate = 1 pulse/min. in SCAN mode. SKY is being scanned angularly either by stepping the zenith angle or a more continuous angular rotation of the azimuth angle.

4.5 Experiment Plan Schedule

A baseline experiment plan schedule is given in Table 3. 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 Wisconsin. 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 King Air - NCAR Sabreliner - NASA ER-2

TABLE 3: CIRRUS IFO BASELINE EXPERIMENT PLAN SCHEDULE

Flight No.	Relative Date (day 0 = start of mission)	Experiment	Flight Duration (hours) ER-2	Sabreliner	King Air
T-1	-6	Instrumentation Test Flight (at aircraft home base)	4	3.5	3.5
T-2	-4	Instrumentation Test Flight (at aircraft home base)	4	3.5	3.5
1	-2	Transit to Wisconsin	3.5	3.5	3.5
2	0	TBD	4	3.5	3.5
3	2	TBD	4	7	7
4	4	TBD	5	3.5	3.5
5	6	TBD	5	7	7
6	8	TBD	5	3.5	3.5
7	10	TBD	5	7	7
8	12	TBD	5	3.5	3.5
9	14	TBD	5	7	7
10	16	TBD	5	3.5	3.5
11	18	TBD	5	7	7
12	20	TBD	5	3.5	3.5
13	21	Transit from Wisconsin	3.5	3.5	3.5
		TOTALS	68.0	70.0	70.0

2. Operations Center - NCAR King Air - NCAR Sabreliner - NASA ER-2

3. Surface Radiometric Site 1 (Oshkosh) - NCAR Sabreliner NCAR King Air

4. Surface Radiometric Site 2 (Wausau) - NCAR Sabreliner NCAR King Air

5. Surface Radiometric Site 3 (Fort McCoy) - NCAR Sabreliner NCAR King Air

6. Surface Radiometric Site 4 (U. Wisconsin) - NCAR Sabreliner NCAR King Air

7. Airbase (ER-2) - ER-2

1, 2, and 7. are absolutely essential

Phone Links:

1. Operations Center - Surface Radiometric Site 1 (Oshkosh)

2. Operations Center - Surface Radiometric Site 2 (Wausau)

3. Operations Center - Surface Radiometric Site 3 (Fort McCoy)

4. Operations Center - Surface Radiometric Site 4 (U. Wisconsin)

5. Operations Center - Special Rawinsonde Sites (Fort McCoy and Plattville)

6. Operations Center - NWS Sites (St. Cloud and International Falls, MN; Flint and Sault Ste. Marie, MI; Green Bay, WI; Peoria, IL; and Omaha, NB)

7. Operations Center - Agencies responsible for operations of various satellites, expecially GOES.

8. Operations Center - FAA authorities in Chicago, Minneapolis, and Madison for flight plan approval.

A voice phone link with guaranteed access must be in place in each of the above cases. Special attention will probably be required to assure this is true for link (6). Link (5) will also serve for data transmission.

Table 4 and Figure 4.1 gives the locations, communications network, type equipment, frequencies, transmitted power, and functions for 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

TABLE 4: COMMUNICATIONS NETWORK

Location	Equipment	Frequency	Transmitted Power	Function
Operations Center, Air National Guard, Madison, Wisconsin	1. Motorola "MAXAR" radio & antenna	164.2, 165.6625 Mhz	25 watts	Voice link to aircraft
	2. Telephones (5)	-	-	Voice link to surface sites NWS, and FAA
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 radio	225.000- 399.975 Mhz	25 watts	voice link to ER-2 surface base
NCAR Sabreliner	Aircraft VHF radio	118 - 135.95 Mhz and 165.6625 Mhz	10 watts	voice link to operations center, tower, and other aircraft
NCAR King Air	Aircraft VHF radio	118 - 135.95 Mhz and 165.6625 Mhz	10 watts	voice link to operations center, tower, and other aircraft

TABLE 4: COMMUNICATIONS NETWORK (Cont'd)

Location	Equipment	Frequency	Transmitted Power	Function
Surface Site 1	VHF Radio	165.6625 Mhz	10 Watts	Voice link to aircraft
(Oshkosh)	Telephone		-	Voice link to operations center and surface sites
Surface Site 2 (Wausau)	VHF Radio Telephone	165.6625 Mhz -	10 Watts -	"
Surface Site 3 (Fort McCoy)	VHF Radio Telephone	165.6625 Mhz -	10 Watts -	"
Surface Site 4 (U. Wisconsin)	VHF Radio Telephone	165.6625 Mhz -	10 Watts -	"
Astronautics	Telephone	-	-	"
Radiosonde Site (Plattville)	Telephone	-	-	"
ER-2 Surface Base	UHF Radio	325.000 399.975 Mhz	25 watts	voice link to ER-2

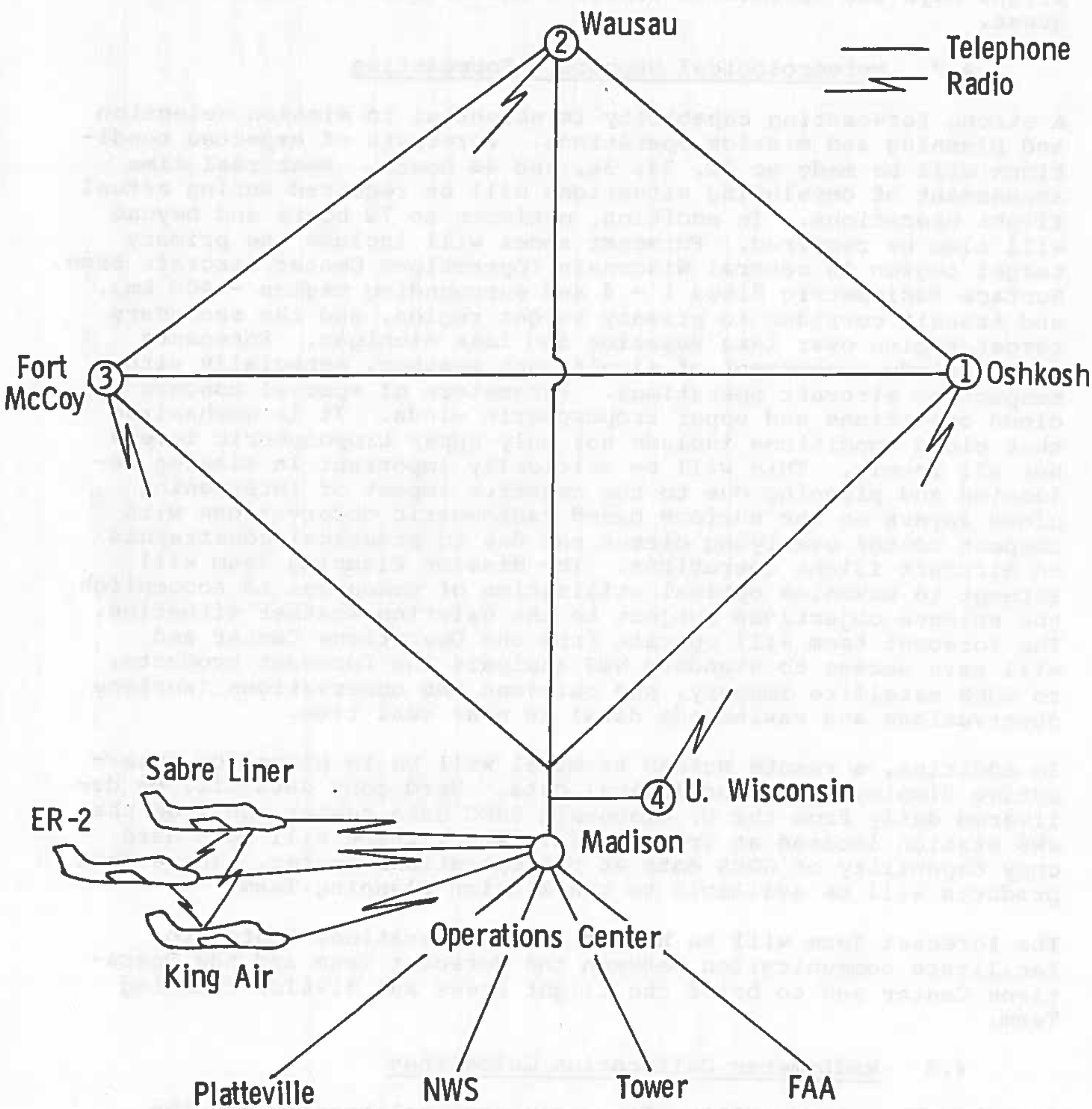


Figure 4.1 Communications Network

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 in central Wisconsin (Operations Center/Aircraft Base, Surface Radiometric Sites 1 - 4 and surrounding region - 400 km), and transit corridor to primary target region, and the secondary target region over Lake Superior and Lake Michigan. Forecasts will include assessment of significant weather, especially with respect to aircraft operations. Parameters of special concern are cloud conditions and upper tropospheric winds. It is emphasized that cloud conditions include not only upper 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 surface based radiometric observations with respect to the overlying cirrus and due to practical constraints on aircraft flight operations. The Mission Planning Team will attempt to maximize optimal utilization of resources to accomplish the science objectives subject to the existing weather situation. The forecast team will operate from the Operations Center and 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.

In addition, a remote McIDAS terminal will be in place for interactive display of meteorological data. Hard copy data will be delivered daily from the U. Wisconsin SSEC data center and from the NWS station located at Truax Field. Also, there will be a hard copy capability of GOES data at the Operations Center. There data products will be available to the Mission Planning Team.

The Forecast Team will be housed at the Operations Center to facilitate communication between the Forecast Team and the Operations Center and to brief the flight crews and Mission Planning Team.

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. 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., Lake Michigan), 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, but the other aircraft should attempt more frequent intercomparisons, at least until the data becomes repetitive.

5.0 SCHEDULES

5.1 1986 Cirrus IFO Major Milestones

See figure 5.1.

5.2 Mission Flight Schedule

See figure 5.2.

5.3 1988 Cirrus IFO

See figure 5.3.

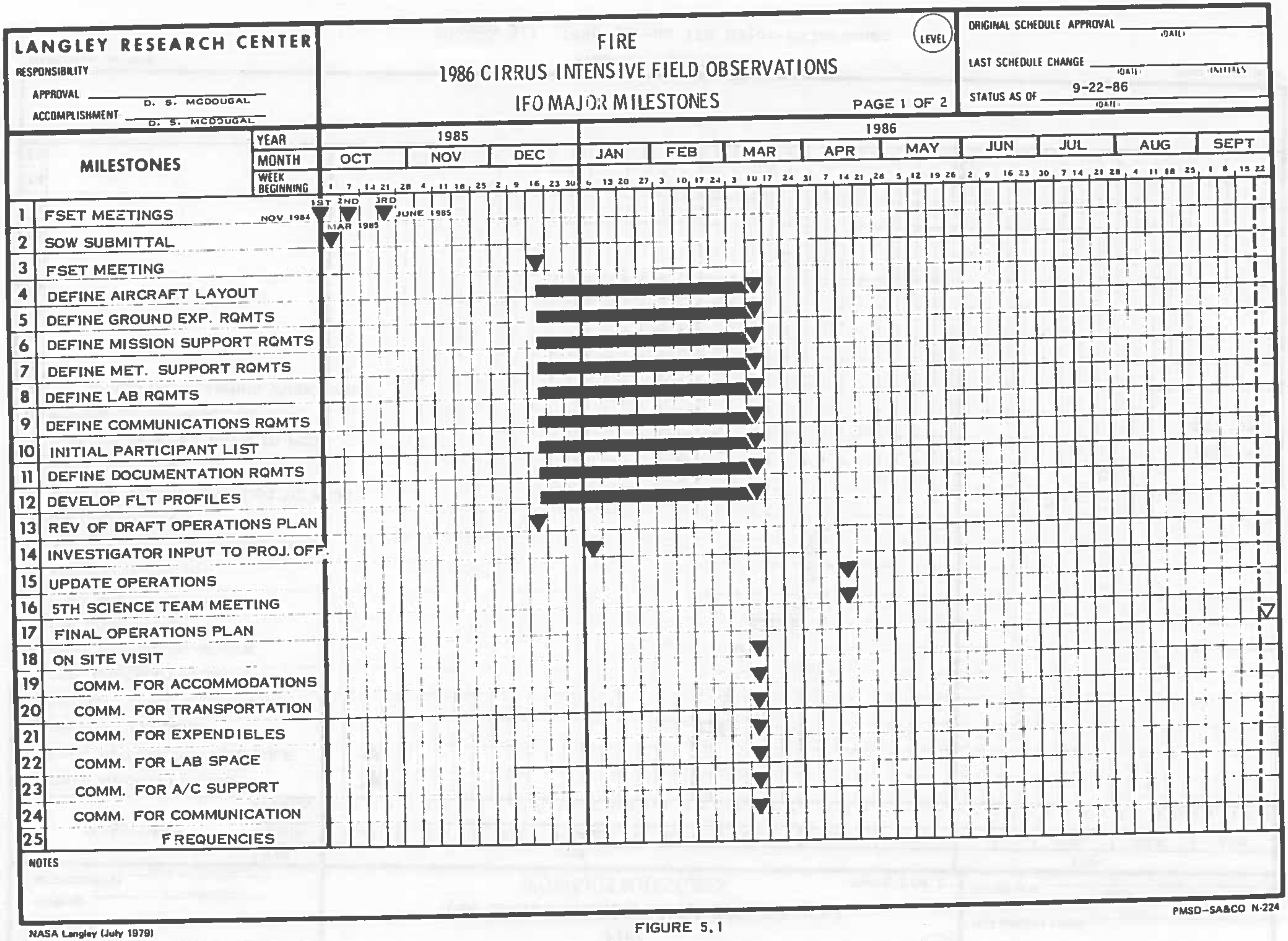


FIGURE 5.1

Figure 5.1 1986 Cirrus IFO Major Milestones

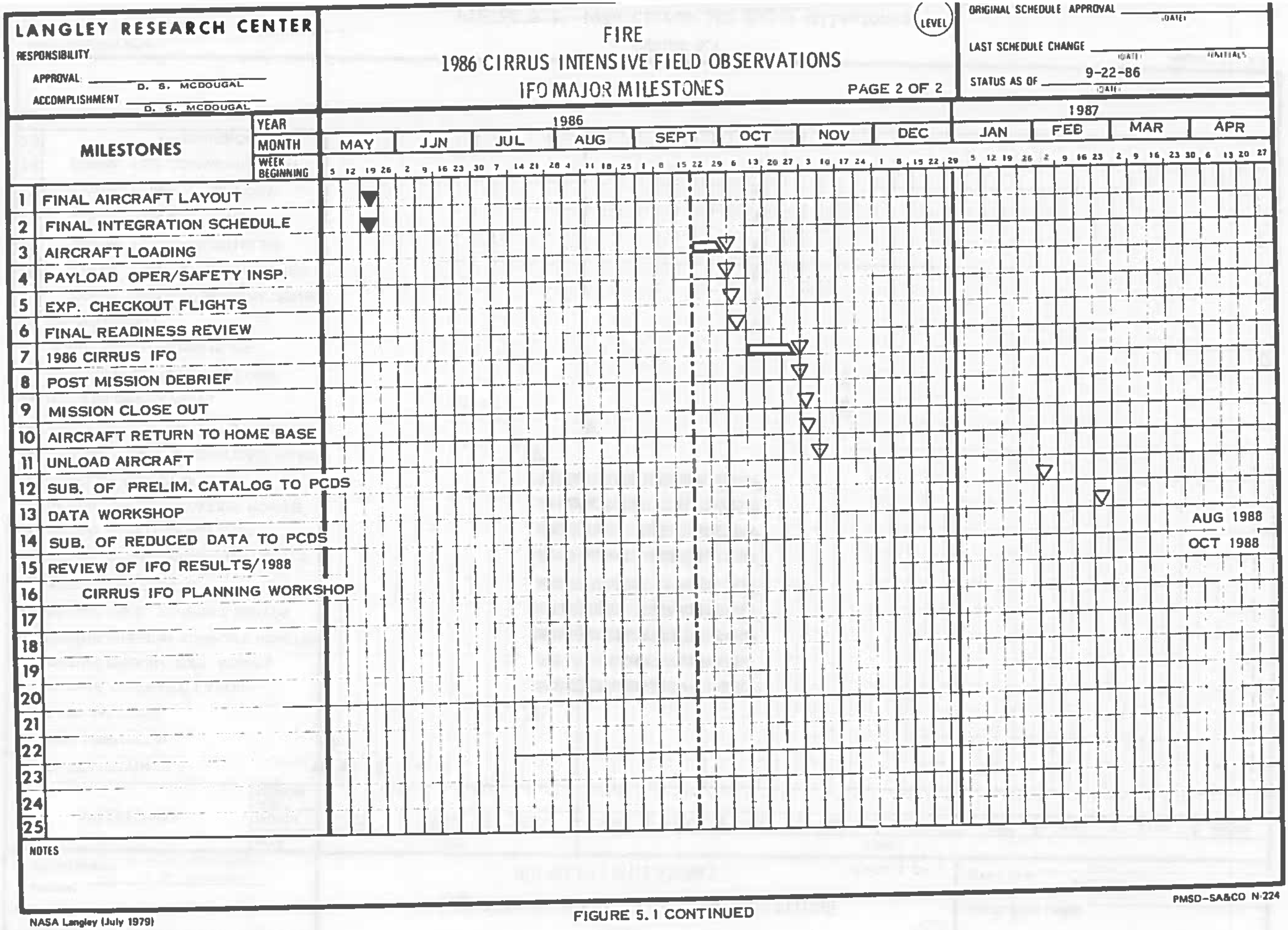


FIGURE 5.1 CONTINUED

Figure 5.1 1986 Cirrus IFO Major Milestones

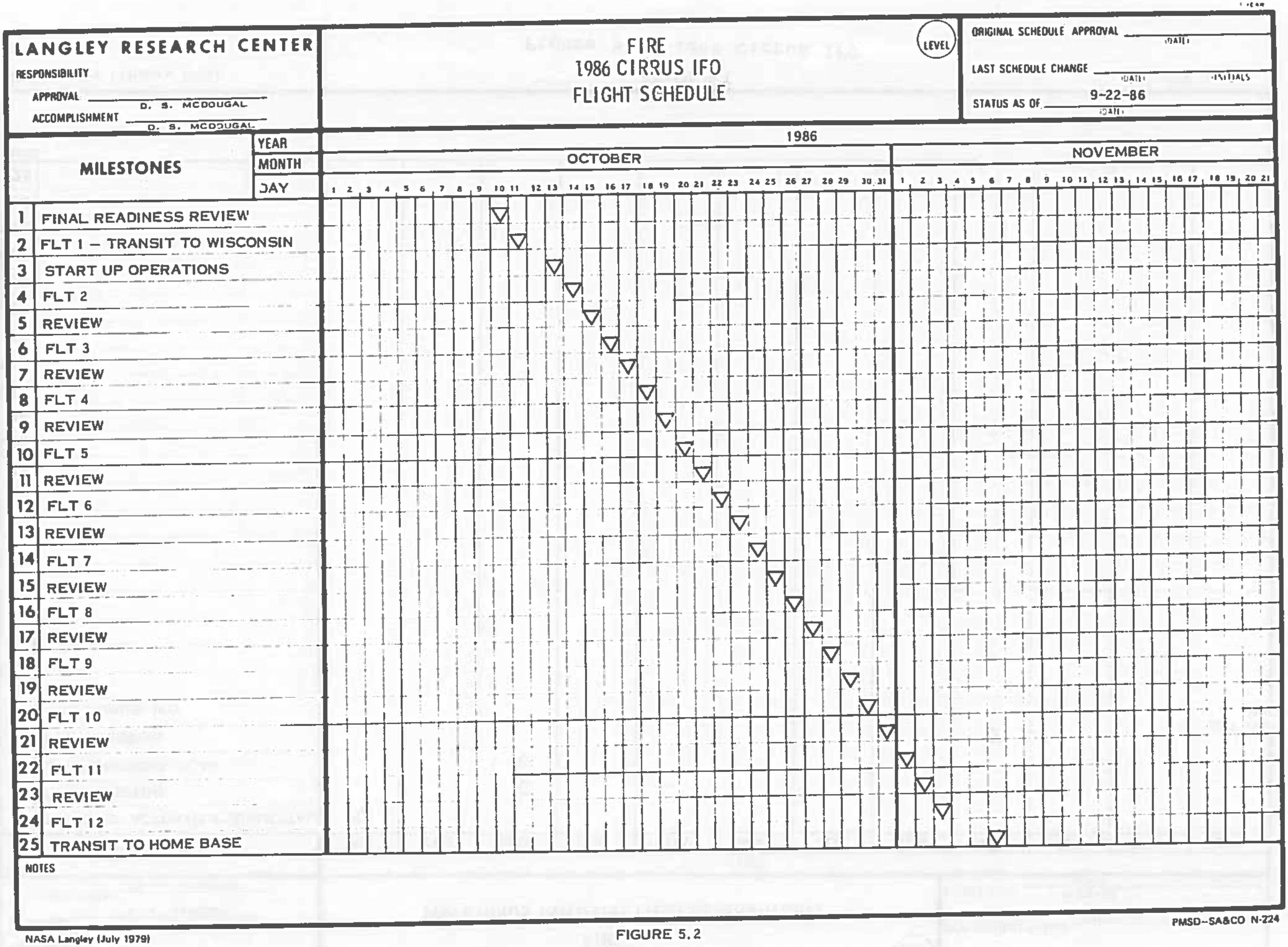


FIGURE 5.2

Figure 5.2 Mission Flight Schedule

LANGLEY RESEARCH CENTER

RESPONSIBILITY:

APPROVAL: D. S. MCDOUGAL

ACCOMPLISHMENT: D. S. MCDOUGAL

FIRE
1988 CIRRUS INTENSIVE FIELD OBSERVATIONS

LEVEL

ORIGINAL SCHEDULE APPROVAL ______ (DATE)

LAST SCHEDULE CHANGE ______ (DATE) (INITIALS)

STATUS AS OF 9-22-86 (DATE)

	MILESTONES	JAN 1987	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	PLANNED ACTIVITIES SUBMITTAL	▽											
2	FSET MEETING			▽									
3	88 OPERATIONS PLAN			▽									
4	FSET MEETING									▽			
5	1988 CIRRUS IFO												OCT 1988 ▽
6													
7													
8													
9													
10													
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21													
22													
23													
24													
25													

NOTES

NASA Langley (January 1980)

FIGURE 5.3

PROJ. DIR. N-382

Figure 5.3 1988 Cirrus IFO

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 Cirrus Working Groups (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 similar to that described for the cirrus component of the ETO operations Plan. Data products are listed below for each instrument in the FIRE Cirrus 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). Data volumes are given based on the sampling strategies outlined in section 3.1 for satellite data and section 4.4 for ground-based data.

6.1.1 Raw Data Products

6.1.1.1 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 6.1.3.

6.1.1.2 Aircraft Data

Raw aircraft data will not be archived by FIRE. Reduced (calibrated, etc.) data and value-added data are described in sections 6.1.3.

6.1.1.3 Surface Data

Ground Based Ruby Lidar (Dual Polarization)

Measurements: Lidar Backscatter (694 nm) vs altitude (every 100 m or less)
Depolarization Ratio vs. altitude (every 100 m or less)
Time of observation (Day/Month/Year, Hr/Min/Sec GMT)
Viewing zenith angle (Degrees, accurate to 0.5 degree)
Viewing azimuth angle (Clockwise relative to North, to 0.5 degree
Minimum altitude range of 1-20 km.

Pyranometers and Pyrheliometers

Measurements: Downward solar radiative flux at 1 minute intervals (W/m) Time of Observation (Day/Month/Yr, Hr/Min GMT).

11 Micron Radiometer Aligned With Lidar

Measurements: Spectral radiance (watts/meter-square/steradian)
Time (Day/Mo/Yr, Hr/Min/Sec GMT)

Sun Photometers

Measurements: Spectral radiance (watts/meter-squared/steradian)
Time (Day/Mo/Yr, Hr/Min/Sec GMT)

Cloud Imaging Cameras

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

CO Doppler Lidar

Measurements: TBD

Supplementary Rawinsonde Launches

Measurements: TBD

Doppler Radar

Measurements: TBD

Microwave Wind Profiler

Measurements: TBD

HIS Spectrometer

Measurements: TBD

6.1.2 Reduced Data Products

6.1.2.1 Satellite Data

Satellite data for the AVHRR-GAC, TOVS, GOES-VAS Imager, GOES-VAS Sounder, DMSP, and ERBE are discussed in section 3.1. Satellite data which is particular to the Cirrus IFO are the AVHRR-HRPT GOES-VAS Imager (1 km visible channel resolution), LANDSAT/5 Thematic Mapper, and SAGE II solar occultation data. Data characteristics for these last four satellites are discussed below.

AVHRR-LAC

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 Cirrus 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 specific sites will vary within plus or minus 1 hour of the nominal 2:30 p.m. crossing 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 VAS Imager

Visible channel data has 0.9 km spatial resolution, infrared channel has 7.2 km spatial resolution (at nadir view). Hourly data from GOES-East and GOES-West (if available), daily for all IFO days and half hourly for flight mission days.

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 cirrus conditions over the IFO sites, several LANDSAT TM scenes may be ordered. These scenes would be ordered only after preliminary examination of surface lidar and cloud image data to verify cirrus 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)

6.1.2.2 <u>Aircraft Data</u>

ER-2

Measurements: Distance to cloud boundary
Depolarization, analyzed to cirrus optical depth
Scattering coefficient
Particle phase
Spectral radiances by view angle and spectral band, analyzed to optical thickness

Sabreliner

Measurements: Particle size distributions
Liquid water content
Temperature
Frost point
Upwelling and downwelling broadband solar and terrestrial irrandiances
Upwelling and downwelling near infrared solar irradiances
Broadband radiation above and below cloud

King Air

Measurements: Ice crystal, droplet, and aerosol size distributions
Liquid water content
Temperature

Dew/frost point
Upwelling and downwelling broadband solar and terrestrial irradiances
Radiometric surface temperature

6.1.2.3 Surface Data

Ground Based Ruby Lidar (Dual Polarization)

Measurements: Cloud Base Altitude (km)
Cloud Top Altitude (km) or Lidar Attenuation altitude
Depolarization Ratio (unitless) profile every 100 meters from cloud base to cloud top.
Backscatter Ratio (unitless) profile every 100 meters from cloud base to cloud top.
Altitude (km) for each level in the profile.
Time of observation (Day/Month/Year, Hr/Min/Sec GMT)
Viewing zenith angle (Degrees, accurate to 0.5 degree) Viewing azimuth angle (Clockwise relative to North, to 0.5 degree)
Minimum altitude range of 1-20 km

Pyranometers and Pyrheliometers

Measurements: Downward solar radiative flux at 1 minute intervals (W/m)
Time of Observation (Day/Month/Yr, Hr/Min GMT)

11 Micron Radiometers Aligned with Lidar

Measurements: Spectral radiance (equivalent blackbody temperature in degrees K)
Time (Day/Mo/Yr, Hr/Min/Sec GMT)

Sun Photometers

Measurements: Spectral radiance (watts/meter-square/steradian)
Time (Day/Mo/Yr, Hr/Min/Sec GMT)

Cloud Imaging Cameras

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

CO Doppler Lidar

Measurements: TBD

Supplementary Rawinsonde Launches

Measurements: TBD

Doppler Radar

Measurements: TBD

Microwave Wind Profiler

Measurements: TBD

HIS Spectrometer

Measurements: TBD

6.1.3 Value-Added Data Products

6.1.3.1 Satellite Data

GOES-VAS Imager/AVHRR/LANDSAT Intercalibration

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

6.1.3.2 Aircraft Data

TBD

6.1.3.3 Surface Data

Ground Based Ruby Lidar (Dual Polarization)

Measurements: Cloud Optical Depth at 694 nm
Cloud Particle Phase (ice, water) vs. altitude for each 100 meter height interval within the cloud.
Cloud ice particle orientation vs. altitude. If the above parameters are not included with reduced lidar data, include time of profile, viewing zenith angle, and viewing azimuth angle

11 Micron Radiometer Aligned With Lidar

Measurements: Cirrus emissivity at 11 micron.
Time of observation

Cloud Imaging Cameras

Measurements: Cloud fraction (%) for the entire camera field of view

Cloud fraction (%) for a 8 km by 8 km area of the cirrus, centered at zenith, for comparison to satellite derived cloud cover.
Cloud type Cloud Height (km)
Time of observation (Day/Mo/Yr, Hr/Min/Sec GMT)

CO Doppler Lidar

Measurements: Ice particle fall spe-.s
Turbulent intensity
Vertical profiles of horizontl divergence/convergence

Doppler Radar

Measurements: TBD

Microwave Wind Profiler

Measurements: TBD

HIS Spectrometer

Measurements: TBD

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 in-estigators 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 concernin- -ata holdings, in the format specified by the central archive 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 a mutually agreed upon 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 FIRE 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 un-reduced observations to facilitate particularly crucial multi-data analyses.

6.2.2 Cirrus Working Group

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, so 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.

(2) To set standards for data quality control, documentation of all data sets, and certification criteria for data products that will be transferred to the permanent FIRE Data Archive.

(3) To select case study data sets for special intensive processing (including re-formatting) 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 18-24 months after acquisition, those data products from the Central Archive that will be transferred to the permanent FIRE Data Archive.

6.2.3 FIRE Central Archive

The Pilot Climate Data Service (PCDS) at Goddard Space Flight Center will serve as the FIRE Central Archive. The PCDS is designed to be an interactive, easy-to-use, on-line, generalized scientific information system. It efficiently 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, and severe storm research (e.g., 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 and archiving data, or for maintaining account records and data inventory. Information on data demands can be used by managers for planning data processing and analysis activities. In addition, academic researchers, who may be working with limited budgets, can obtain quick access to selected portions of larger data sets.

Electronic access to PCDS is fully described in Appendix C. For further information on PCDS, contact Dr. Robert Johnson, FIRE Data Manager, Ms. Mary Reth, PCDS, or Ms. Lola Olsen, PCDS

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 the collection 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 collect 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 collect 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 affordable 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 5) every six months and to disseminate it to FIRE investigators in both hard copy and electronic (on-line dial-up data set) form.

(6) To transfer, on an annual basis, certified FIRE data from the Central Archive to PCDS for permanent archive, called the FIRE Data Archive, and for access by the at-large scientific community.

(7) To provide for archival of all certified FIRE 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.

(8) To publish a FIRE Data Archive Users Manual that describes the contents of the FIRE Data Archive, data formats, data request information, and other pertinent descriptive material.

6.2.4 Project Office

The FIRE data management structure vests the primary data processing function with the individual scientific investigators, the information and arhival 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 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 agencies 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.

6.3 Standard Data Format

There are three types of data acquisition activities in FIRE involving different combinations of observing platforms. There are 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 Cirrus Working Group and Central Archive. The format for the archive is the FIRE Standard Data Format given in Appendix F. 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, it allows for a brief 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 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 to medium length data files.

Transfer of the data from the data archive to the investigators will be done either physically (using 9 track tapes) or electronically, depending on the investigator/data archive requirements.

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 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 Format.

   (c) maintain on line library of catalog information and FIRE data.

6. Care 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 computer system questionnaire

2. PCDS generates and distributes sample catalog and data products.

3. PIs

(a) respond to computer system questionnaire

(b) generate and forward sample catalog and data products to PCDS (with hard copy to DM)

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

(d) generate and forward reduced data products to PCDS (with hard copy to DM)

4. WGs

(a) define reduced data products for all PIs

(b) define case study data sets

(c) certify FIRE data

5. PCDS

(a) assembles certified FIRE data sets

(b) forwards to permanent archive (about PCDS)

6.6 Data Schedule

6.6.1 Post-Experiment Debrief

After each experiment 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 "quick-look" 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. 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 Cirrus 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 format as documented in Appendix C. The Cirrus 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 FIRE Access to Data Archive

Within one month after the reduced data products have been received by PCDS, the data will be available to the FIRE experimentors through electronic access. The normal PCDS capabilities may be utilized, such as data subset, data merge, tape copy, data manipulation, etc.

6.6.6 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 Cirrus 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 Cirrus 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 1986 Cirrus IFO will be used to provide new insight into the planning for the 1988 Cirrus II IFO objectives and field plans.

6.6.7 Open Access to Data Archive

Eighteen to twenty-four months after the IFO, the data archive will be certified and transferred to PCDS for releast 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 scienfitic interpretation of the data obtained from single and ensemble of instruments. The FIRE Working Groups are responsible for the certification of data submitted to a permanent FIRE Data Archive. 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 working groups.

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 between investigators participating in the FIRE Working Groups 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 format 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. The may not release the data of other investigators without consent.

TABLE 5: DATA MANAGEMENT SCHEDULE

IFO

TIME	MILESTONE
-3	Submit sample catalog product to PCDS
-3	Submit sample data product to PCDS
0	IFO
3	Submit preliminary catalog information to PCDS
3	FSET/WG meeting; definition of reduced data products
9	Submit reduced data sets to PCDS
9	Submit updated catalog information to PCDS
12	FSET/WG evaluation of reduced, value-added, and case study data sets
18-24	WG certification of FIRE data for permanent archive

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.

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. Titles, descriptions and lists of researchers of proposed and current investigations 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 expedition 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 Cirrus 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 Cirrus 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 Cirrus IFO will be submitted for publication prior to December 1, 1987.

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 Cirrus IFO is shown in Figure 7.1. Names, addresses, and phone numbers of the incumbents are provided in Appendix D. A brief description of incumbent responsibilities follows:

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

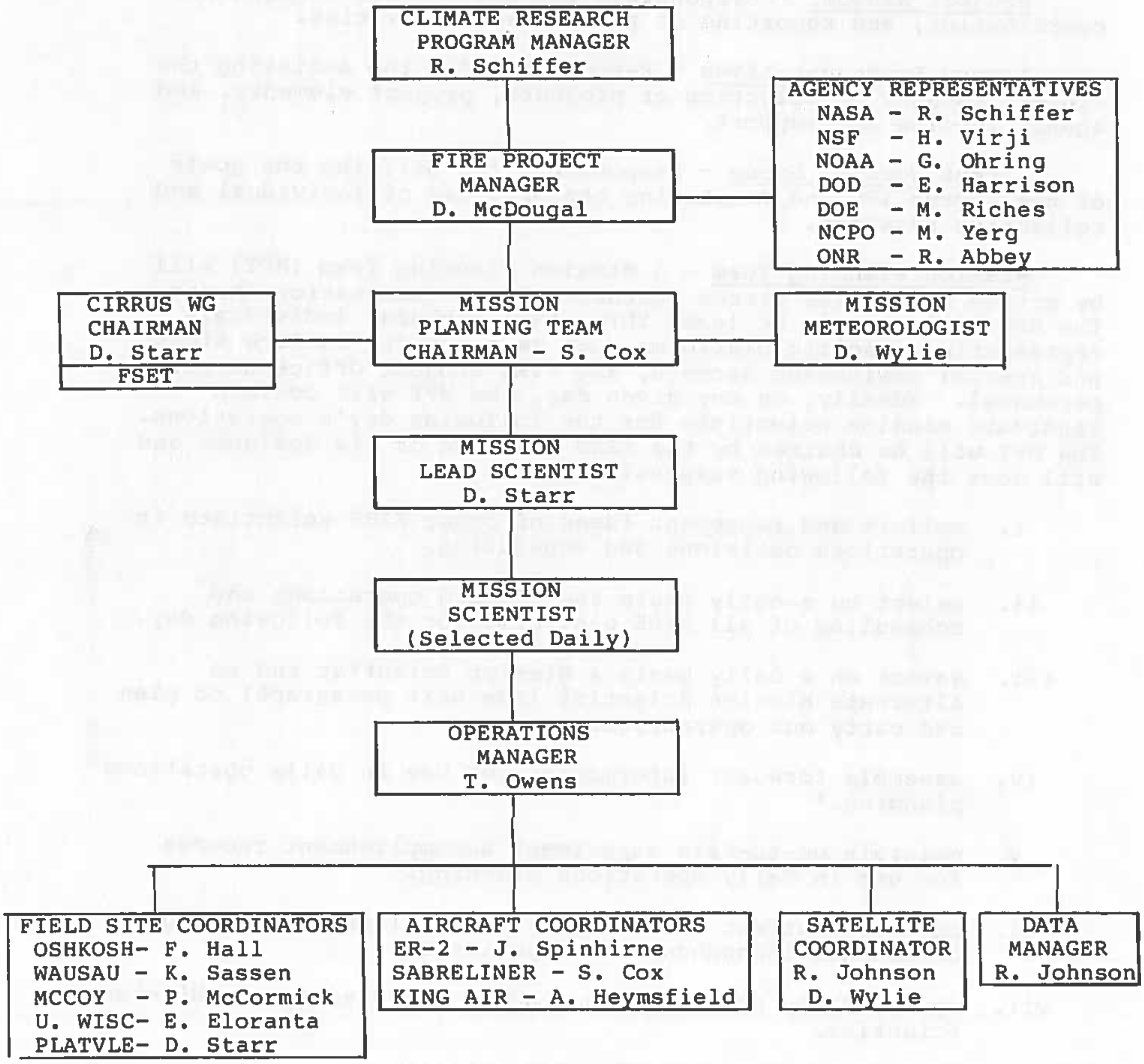

Figure 7.1 - Cirrus IFO Functional Organization

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

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

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

Mission Planning Team - A Mission Planning Team (MPT) will be active during the cirrus 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. Ideally, on any given day, the MPT will contain candidate mission scientists for the following day's operations. The MPT will be chaired by the FSET Chairman or his designee and will have the following responsibilities:

i. solicit and represent ideas of other FIRE scientists in operations decisions and scheduling.

ii. select on a daily basis the planned operations and scheduling of all FIRE platforms for the following day.

iii. select on a daily basis a Mission Scientist and an Alternate Mission Scientist (see next paragraph) to plan and carry out operations.

iv. assemble forecast information for use in daily operations planning.*

v. maintain up-to-date experiment accomplishment records for use in daily operations planning.*

vi. maintain current status reports on all data gathering components throughout the experiment.*

vii. review daily post mission reports prepared by the Mission Scientist.

* assisted by the FIRE project office.

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

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. He will 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 MPT and become a part of the FIRE data archive.

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:

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

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

iii. Maintain log on mission status and activites;

iv. Work with the Aircraft Coordinators to allow proper scheduling of crews for flight operations and aircraft access; and,

v. 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.

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.

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 MST 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 Cirrus IFO area. He is responsible for determining that the appropriate satellite observations are being collected, archived, and made available to the Cirrus 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.

Field Site Coordinators - The Field Site Coordinators will have primary responsibility for coordinating complementary ground measurement activities and overall integration, testing, and operation of experiments of their respective sites.

7.2 Aircraft Integration and Unloading Sites

7.2.1 ER-2

Instrument integration and unloading of the ER-2 will occur at NASA Ames Research Center, Moffett Field, CA.

7.2.2 King Air and Sabreliner

Instrument integration and unloading of the King Air and Sabreliner will occur at NCAR, Boulder, CO.

7.3 Logistics

7.3.1 Pre-Mission Site Inspection

Approximately six months and two weeks prior to the start of the Cirrus IFO an advance party consisting of FIRE Project and Bionetics Corporation employees will arrive in Wisconsin to prepare for arrival of the main group. The advance party will perform the following functions:

i. Establish suitable accomodations and have available on schedule;

ii. Establish Operations/Forecast Center location.

iii. Establish Aircraft Base location.

iv. Check status of advance equipment and supply shipments;

v. Ensure availability of supplies to be obtained in Wisconsin;

vi. Set up support system (e.g., communications, meteorological) if required;

vii. Ensure availability of support lab space;

viii. Ensure transportation available on schedule;

ix. Ensure aircraft support on schedule; and

x. 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 Wisconsin is the responsibility of each principal investigator. To allow for delays, clearances, and "red tape", shipments should be scheduled to arrive in Wisconsin no later than 1 October 1986, if possible.

7.3.3 Personnel Deployment

Arrangements and maintaining budget for the deployment of personnel to and from the field sites in Wisconsin 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 Accommodations

Lodging will be at the Midway Motor Lodge, 3710 E. Washington

Avenue, Madison, Wisconsin 53704 as coordinated by The Bionetics Corporation. See Appendix F for additional relevant information.

7.3.5 Insurance

Please note that insurance for the equipment and personnel is the responsibility of each principal investigator.

7.4 Briefing, Planning, and Coordination Meetings

7.4.1 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:

i. Three FSET members as designated by the MST

ii. Mission Meteorologist

iii. Aircraft Coordinators

iv. Field Site Coordinators

v. Other experiment representatives

vi. Operations Manager

vii. Other project support personnel

7.4.2 Weather Briefing

A weather briefing will be scheduled on each non-flying day (see 7.4.1 Mission Planning Team Meeting A single morning briefing will be held on each flight day (see 7.4.3 Preflight Status Briefing). The briefing will be presented by the Mission Meteorologist.

7.4.3 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:

i. Mission Meteorologist;

ii. Aircraft Coordinators;

iii. Field Site Coordinators;

iv. Operations Manager;

v. Mission Scientist and/or Associate Mission Scientist

7.4.4 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.

7.4.5 Mission Debriefing

After each flight a debriefing will be held to review all aspects of the mission from weather conditions to instrument performance. The following persons are expected to attend:

i. Operation Manager;

ii. Aircraft Coordinators;

iii. Field Site Coordinators;

iv. Mission Scientist;

v. Alternate Mission Scientist;

vi. Experiment Representatives.

7.5 <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 Cirrus IFO Mission with an average work day of 8-10 hours. Baseline flight schedules are shown in Table 3.

7.6 <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 not circumstances will aircraft be left open and unattended.

7.7 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;

ER-2:	Pilots only
King Air:	Pilot Ken Sassen Andy Heymsfield David Starr
Sabreliner:	Pilot Steven Cox Chris Johnson-Pasqua Graduate Research Assistant

7.8 In-Flight Safety Procedures and Operations Requirements for Cirrus IFO

i. No smoking while on-board the aircraft.

ii. No alcoholic beverages on-board aircraft.

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

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

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

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

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

viii. 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.

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

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

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

xii. 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.

xiii. 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.

7.9 Nominal Schedule for Non-Flight Day

Local Time	Event
1300 - 1500	Planning Session
	- Weather briefing
	- Develop prime and backup
	- Flight plans
1500	Inform Surface Sites, NWS
	- Call CSU GOES

7.10 Nominal Schedule for Flight Day

FLIGHT DAY

(Assume 1430 Local Time Polar Orbiter Overflight)

	Local Time	Event
T-3	0800 - 0900	Weather Briefing
		- Surface site input

	Local Time	Event
		- Experiment status
		- 1200Z P'ville & McCoy soundings
		- Go/No Go decision
		- Go/No Go CSU GOES
T-2	0900 - 0930	- File flight plans
		- Inform surface sites
		- Brief flight crews
		- Go/Delay
T-1	1000	- Weather update
		- Call Sassen
T-0	1100	Aircraft Take Off
		- ER-2
		- King Air
T·L	1630	Aircraft Land
		- Experiment debrief
T·L + 1/2	1600 - 1700	Secure Aircraft
T·L + 1	1700 - 1800	- Call to surface sites
		- Experiment summary
		- Next day experiment planning

7.11 Flight Go/No-Go Criteria

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

i. One member of the required flight crew is ill and there is no adequate replacement;

ii. Aircraft malfunction;

iii. Failure of communication system on aircraft (must have two working VHF transceivers and one HF radio);

iv. Failure of either INS or Omega navigation system if operations beyond VORTAC range;

v. Less than two functioning navigation systems for operations over land;

vi. Unsafe equipment or materials on-board aircraft;

vii. Intoxicated technical or aircraft crew member;

viii. Forecast IFR flight conditions in both primary and secondary flight plan areas;

ix. Forecast IFR conditions at field base plus or minus 2 hours of recovery time; and,

x. Non-operational status of critical experiment instrumentation system in accordance with previously established rules governing adequate use of mission resources.

7.12 Mission Abort

The following conditions or circumstances may cause a mission abort:

i. Illness among critical flight crew members;

ii. Aircraft mechanical or electrical malfunction;

iii. Communications or navigation equipment malfunction;

iv. Development of adverse weather;

v. Injury to crew member;

vi. Unruly conduct by crew member;

vii. Attempt to alter experimental equipment power cables;

viii. Changes or attempted changes to any aircraft system;

ix. Interference with any aircraft crew member or failure to follow instruction of aircraft crew members.

x. Non-operational status of critical experiment instrumentation system in accordance with previously established rules governing adequate use of mission resources.

7.13 Medical Considerations

7.13.1 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:

i. Up to date medical history;

ii. List of all medications being used;

iii. List of all allergies;

iv. 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.

7.13.2 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.

7.14 Public Relations

FIRE operations may generate some degree of interest with the local news media. The MPT 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 MPT Chairman and Project Manager before release to local news media.

7.15 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.

7.16 Operations Phase-Out

7.16.1 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.

7.16.2 Post-Mission Calibration

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

7.16.3 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.

7.16.4 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.

APPENDIX A - DESCRIPTION OF INSTRUMENTATION

A.1 Satellite Sensor Characteristics

FIRE will obtain data from six possible satellites carrying eight instruments. They are summarized in Table A.1. Each satellite has the following instruments and characteristics:

A.1.1 GOES

The Geostationary Operational Environmental Satellite (GOES) system operates one to two spacecraft in geostationary orbits. These spacecraft are positioned on the equator at 135°W and 75°W longitude. If only one is operated, as was the situation at the start of FIRE in 1986, then it is positioned from 90° to 100°W.

The GOES carry two instruments of interest to FIRE. The Visual Infrared Spin Scan Radiometer (VISSR) produces images of the full earth every one-half hour. It scans in both the visual (0.6 micron) and infrared window (11 micron) wavelengths simultaneously. The sensor uses the spin of the spacecraft to scan from west to east and a mirror for rastor scanning from north to south. In one west to east scan 8 lines are scanned in the visual image by 8 photomultipliers and one line in the infrared image by a separate photomultiplier. The single field of view resolution is 1 km in diameter for the visible image and 8 km in the infrared image. The infrared image is digitized at every 4 km in the west to east direction so the transmitted pixel has a 4x8 km shape. At the latitudes of the FIRE experiment (30°-42°N), the fields of view of the sensor are approximately 1.4 km in the visible and 11 km in the infrared.

The GOES VISSR normally scans the full earth twice per hour. However, for special operations images can be started at three minute intervals if a limited latitude belt is scanned. This "rapid scan mode" is normally invoked by NOAA for monitoring severe convective activity. The images are reduced in their north-south dimension to approximately 20° of latitude over the continental United States.

The GOES spacecraft carry a second imaging sensor, the VISSR Atmospheric Sounder (VAS) for multispectral imaging. The VAS has 12 channels, 11 in the infrared and 1 in the visible. These channels are primarily in the CO_2 and water vapor absorption regions of the spectrum. Each channel has a response to radiation upwelling from different altitudes in the atmosphere. The multispectral channel data is used for determining vertical profiles of temperature and water vapor, and for cloud top altitude information.

All channels have field of view resolutions nominally of 8 km at nadir which corresponds to approximately 11 km at the FIRE sites. The VAS image starts after the VISSR at 18 and 48 minutes

TABLE A.1 SATELLITE INSTRUMENTS

aracteristics	VISSR	VAS	AVHRR	HIRS	Thematic Mapper	ERBE	SAGE-II	DMSP
tellite	GOES	GOES	NOAA-9	NOAA-9	Lansat	NOAA-9, 10 & ERBE	AEM-2	DMSP
bit	Geostationary at 100°W or 135° and 75°W if two satellites		Polar		Polar	Polar	Polar	Polar
clination	NA	NA	Sun synchronous			55°	55°	
age freq.	1/2 hr	hourly	12 hours			2-3/day		4/day
age times	3 and 33 mins after hour	18 or 48 mins after hour	2 am, pm nominally			2:30 NOAA-9		6:30 am & pm 10:30 am & pm
an characteristics an system	Spacecraft spin with mirror		Spinning mirror				mirror scanning across the sun	
an direction	West to east North to south		Across orbit track					across orbit track
ximum coverage	±55° from subpoint		nearly entire earth		entire earth		55°N to 55°S	
age characteristics ight dth	55°N to 55°S ±55° from subpoint		nearly pole to pole 20°long. at equator		180 km			nearly pole to pole 20° longitude
gle Field of v resolution								
sible	1.4 km		1 km			3 km	0.5x200 km	2 km
rared	11.2 km	11.2 km	1 km	30 km		3 km	0.5x200 km	2 km
annel wavelength (microns)								
.	0.6		0.63	20 channels		0.2–0.25	0.385, 0.45 & 0.6	
ndow IR	1.1	12 channels	10.8 & 12.0			5-50	none	
her		1. 14.73 CO_2 2. 14.48 " 3. 14.01 " 4. 14.01 " 5. 13.33 " 6. 4.52 7. 12.66 window 8. 11.17 9. 7.26 10. 6.72 11. 4.44 12. 3.92	near IR 0.91 IR 3.74	1. 14.97 CO_2 2. 14.72 " 3. 14.47 " 4. 14.21 " 5. 13.96 " 6. 13.65 " 7. 13.36 " 8. 11.14 window 9. 9.73 ozone-H_2O vapor 10. 8.22 " 11. 7.33 " 12. 5.74 H_2O vapor 13. 4.56 14. 4.52 15. 4.46 16. 4.39 17. 4.24 18. 3.98 window IR 19. 3.74 " 20. 0.7 visible		0.2-5.0 broad band	1.0 near IR	

after the hour. Two images per hour are taken under normal operations; however, the latitude extent of each image is limited to 20°. Repeat scans are made on each line because only one channel can be scanned per line at a time. Repeat scans on some channels are also made to reduce noice in the signal. The VAS scans four lines across the earth then leaves four blank lines. This venetian blind scanning mode is used to maximize the latitude extent of each image.

The latitude belt scanned by VAS is normally alternated between the northern and southern parts of the United States. Thus, one location is covered at any hourly frequency.

A.1.2 NOAA (TIROS-N)

NOAA operates one to two polar orbiting satellites of the TIROS design. The satellites are three axis stabilized in sun synchronous orbits. They normally pass once in the morning (approximately 9:00 local time) and once in the afternoon (2:30 local time). However, at the start of FIRE only one spacecraft, NOAA-9, was operating (2:30 local time).

The Advanced Very High Resolution Radiometer (AVHRR) scans across the orbit track producing images at five spectral wavelengths. One channel is in the visible (0.6 micron), two are in the infrared window (10.7 and 12 microns), and two are in the near infrared (0.9 and 3.7 microns). Each image covers approximately 20° of longitude at the equator. Overlapping coverage between orbits is common near the poles.

The AVHRR channels all have fields of view of 1 km in diameter. These high resolution data are transmitted directly as scanned along the orbit track, and are called the High Resolution Picture Transmission (HRPT) format. HRPT imagery is only archived when the satellite is in view of a ground station. Lower resolution data at 4 km field of view are stored on the satellite and offloaded for complete Global Area Coverage (GAC).

The NOAA satellites also carry a package of instruments called the TIROS Operational Verical Sounder (TOVS). Three instruments are in this package: the High Resolution Infrared Sounder number 2 (HIRS-2), the Stratospheric Sounding Unit (SSU) and the Microwave Sounding Unit (MSU). The HIRS has 20 channels, 19 in the infrared and one in the visible. These channels are used for vertical temperature and moisture profiles similar to the GOES VAS. They are in the CO_2, water vapor, and ozone regions of the spectrum (see Table A.1.).

The HIRS is scanned in parallel with the AVHRR, covering nearly the same swath. The field of view diameter of the HIRS varies from 30 km at nadir to 52 km at the edge of the scan. All HIRS data are transmitted from the satellite and archived globally.

A.1.3 LANDSAT

LANDSAT carries an extremely high resolution multispectral instrument called the Thematic Mapper. This sensor has 8 channels in the visible and near infrared wavelengths. Its field of view is extremely small, 100 m, compared to other satellites. However, its images also cover very small areas of 180 km in dimension. The polar orbit of the satellite and small viewing area combine to limit its coverage of a location to once every 18 days.

A.1.4 ERBE

The Earth Radiation Budget Experiment (ERBE) employs a specially designed scanner that makes broad band spectral images for inferring the radiative heat exchanges to and from the earth.

The ERB instrument is scheduled to fly on three satellites, NOAA-9, NOAA-10, and the ERB satellite. At the start of FIRE, only the NOAA-9 and ERB satellites were operating the ERB instrument.

The ERB satellite is in a polar orbit which is not sun synchronous. This orbit is designed to provide complementary coverage to the NOAA satellites which are sun synchronous.

The ERB sensor has three channels. A visible channel (0.2 to 0.25 microns) and infrared channel (5 to 50 microns), and a broad band channel encompassing the other two (0.2 - 50 microns).

A.1.5 SAGE II

The Stratospheric Aerosol and Gas Experiment (SAGE) operates a sensor on the Applications Explorer Mission (AEM 2) satellite. The AEM is in a sun synchronous polar orbit.

The SAGE instrument measures solar radiation passing through the limb of the atmosphere as the satellite views sunrises and sunsets. This instrument in essence scans the atmosphere horizontally, using forward scattered radiation from the sun.

The SAGE instrument has four channels, three of which are visible wavelengths (0.385, 0.45 and 0.6 microns) and one near infrared channel at 1.0 microns. These channels are sensitive to aerosols and clouds in the stratosphere and upper troposphere.

The limb scanning mode of the SAGE sensor has a field of view that is greatly elongated, 0.5 x 200 km. The location of each field of view is highly dependent on the relative angle between the sun and the satellite. Each point on the location earth is scanned at sunrise or sunset for three days in succession in a six-month period.

A.1.6 DMSP

The Defense Meteorological Satellite Program (DMSP) operates a fleet of polar orbiting satellites. These satellites carry scanners for producing images at two wavelengths, one visible and the other in the infrared window. The images are similar to the AVHRR of the NOAA satellites. Field of view resolutions are approximately 2 km in both spectral channels.

The satellite orbits are close to sun synchronous, passing most FIRE sites at 6:30 and 10:00 am and pm. Two satellites were operating at the start of FIRE.

A.2 Aircraft Instrumentation

A.2.1 NASA ER-2

Investigators: Drs. Spinhirne, King and Valero
Instruments:

Cloud Lidar System (CLS) (Spinhirne)
Downward pointing Nd and doubled Nd (0.53 and 1.06 μm) dual polarization lidar with ~7.5m vertical resolution and 50 m horizontal sampling interval.

Multispectral Cloud Radiometer (MCR) (King/Spinhirne)
Cross-track (± 45° off nadir) scanning multispectral (0.754, 0.760, 0.763, 2.644, 2.724, 3,264, 20.070 μm radiometer with a resolution of ~ 100 m at nadir. Accuracy - 4% for solar channels, ± 2K (nominal) for 10 μm channel. Synchronized with the CLS.

Modified Thematic Mapper Simulator (Spinhirne)
Cross-track (complete) scanning multispectral, compatible with AVHRR and Thematic Mapper channels. Resolution of ~ 50 m at nadir. Accuracy ~ ± 5% for solar channels, ± 2 K (nominal) for infrared.

Fixed Pyranometers (Valero)
Upwelling and downwelling broadband shortwave fluxes.

Rotating pyranometers (Valero)
Upwelling, downwelling and net broadband longwave fluxes.

Narrow Field of View Infrared Radiometer (Valero)
Nadir viewing 2-channels (ir window)

Notes: Comprehensive on-board data logging facilities. Data sampling rate of 3.47 Hz.

A.2.2 NCAR King Air

Investigators: Drs. Sassen and Heymsfield
Instruments:

2-D PMS
Measures the ice crystal and hydrometeor size distributions from 25 μm resolution, and 0.1 to 3.2 mm at 0.3 mm resolution.

FSSP
Measures cloud droplet size distributions from 0.5 to 7.5 μm at 0.5 μm resolution.

Rosemount
Measures liquid water content from 0 to 0.1 gm^{-3} with resolution of 0.01 gm^{-3}.

Pyranometers
Upwelling and downwelling broadband longwave fluxes.

Barnes PRT-5
Nadir viewing ir window radiances.

ASASP
Aerosol size distributions from 0.12 to 3.12 μm with resolution of 0.025 μm.

Decelerator
Impactor for studying small ice crystal morphology.

Notes: The above values, together with temperature, dew point and absolute humidity to be sampled once per second. Comprehensive on-board data logging capabilities.

A.2.3 NCAR Sabreliner

Investigator: Professor Cox
Instruments:

2-D PMS
Measures the ice crystal size distributions (50 - 1600 μm) and the hydrometeor size distributions (0.1 - 3.4 mm).

FSSP
Measures cloud droplet size distributions from 0.5 to 50 μm at 0.5 μm resolution.

JW LWC
Measures liquid water content.

Pyranometers
Upwelling and downwelling shortwave fluxes. Two measure total solar, two from 0.7 to 3 μm $\pm 5\ w\ m^{-2}$.

Pyrgeometers
Upwelling and downwelling broadband longwave fluxes. $\pm$ 15 $W\ m^{-2}$.

Barnes PRT-6
Nadir viewing ir window radiances. Sampled at 5 Hz.

CSU Radiometer
Continuously variable filter wheel from 0.3 to 3.5 μm, scanning from nadir to zenith. Discrete filters for longwave radiation. Referenced to an NBS standard detector to $\pm$ 1%. Sampled at 250 Hz

Notes: Except as stated, the sampling rate is 1 Hz. Temperature, frost point and a/c parameters also sampled. Comprehensive on-board data logging capabilities.

A.3 Surface Instrumentation

A.3.1 Site 1 Oshkosh

Investigators: Drs. Sassen, Kukla and Cox
Instruments:

Scanning ruby lidar with dual polarization receiver. (Sassen)
Scanning narrow beam infrared (10-12 μm) radiometer. (Sassen)
Weathermeasure 3040A radiometer, measuring upwelling, downwelling and net total fluxes. (Sassen)
All-sky, 35 mm fisheye camera. (Sassen)
Eppley precision pyranometers (4). (kukla)
Stereo sky camera. (Kukla)
Eppley pyrheliometer. (Kukla/Egan)
Eppley pyrgeometer. (Cox)

Notes: Passive radiometry to operate continuously, Lidar as cloud conditions warrant.

A.3.2 Site 2 Wausau

Investigators: Drs. Hall and Cox
Instruments:

Scanning CO_2 lidar. (Hall)
Eppley pyranometer, Eppley pyrgeometer and mfov radiometer. (Cox)
Passive radiometry to operate continuously, Lidar as cloud conditions warrant.

A.3.3 Site 3 Fort McCoy

Investigators: Drs. McCormick and Cox
Instruments:

Scanning lidar system (details to be determined).
Scanning, narrow beam, visible (0.40 - 0.75 μm) radiometer.
Scanning, narrow beam, near infrared (1.04 - 2.2 μm) radiometer.
Eppley pyranometer, Eppley pyrgeometer and mfov radiometer. (Cox)

Notes: Passive radiometry to operate continuously, Lidar as cloud conditions warrant.

A.3.4 Site 4 Madison

Investigators: Drs. Cox, Davies, Egan and Eloranta
Instruments;
High resolution scanning lidar system (Eloranta)
Broadband Eppley pyrgeometers, upwelling and downwelling. (Davies)
Broadband Kipp and Zonen albedometer. (Davies)
Pyreheliometer. (Davies)
Barnes PRT-4 infrared, narrowbeam radiometers (2). (Davies)
Barnes MMR, 8 Channel (visible, solar infrared and window infrared) narrowbeam radiometer. (Davies)
Spectral photometers and polarimeter. (Egan)
Multiple field of view (mfov) radiometer. (Cox)

Notes: Lidar to be used sparingly depending on cloud conditions.
Pyranometers, pyroheliometer and mfov radiometer to record continuously.
Other instruments to be used depending on cloud conditions and investigator availability.

A.3.5 Site 5 Plattville

Investigator: Dr. David Starr
Instrument:

Portable rawinsonde system (CLASS).

Notes: The intention is to have the rawinsonde over the center of the aircraft operations at cirrus altitude.

APPENDIX B

FIRE Program, Project, and Cirrus IFO Personnel

Program Manager:	Dr. Robert A. Schiffer Code EET National Aeronautics and Space Administration Washington, D.C. 20546 (202) 453-1438 FTS 453-1438
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Satellite Coordinator:	Dr. Robert W. Johnson Mail Stop 483 NASA Langley Research Center Hampton, Virginia 23665 (804) 865-4375 FTS 928-4375

APPENDIX C

PROPOSED STANDARD DATA FORMATS FOR FIRE

The following are proposed data format guidelines for all FIRE data sets submitted to the FIRE Central Archive. The detailed data tape format specifications discussed below are meant to serve as a guide to the FIRE Science Experiment Team (FSET) which will approve the actual data format specifications.

1. Types of data

FIRE will produce several distinct types of data exhibiting very different characteristics: (a) digital satellite image data which are usually large in volume with varied formats and appended information, (b) digital ground and aircraft instrument data which can be either small or large in volume with formats that are nearly unique to the instruments, and (c) photographs (analog data) produced by ground and aircraft observers to document the clouds present. The film data are completely distinct from the digital data. The scientific objectives of FIRE call for the analysis of all these data types together for many cases in order to elucidate cloud and radiation processes and to obtain statistical descriptions of the cloud properties. Some standardization of data formats is required to facilitate this analysis.

2. Data archived

The data collected during FIRE will be held in a distributed archive, PCDS including the individual investigator holdings and the FIRE Central Archive; however, certain subsets of the total data set will be selected by the FSET for special study or identified by the FSET as especially important. All of these data will be submitted to the FIRE Central Archive to facilitate team interaction and later to a permanent FIRE data archive. Only these data must be reformatted into the standard formats outlined here; however, investigators are encouraged to adopt the format described below for their own use or to take advantage of the formatting software developed for this purpose to reformat any data requested by another investigator.

3. Submission of data to archive

Since the format standards described here allow some variations of the format, investigators or other providers of data to FIRE must seek approval of their format by the FSET by submitting a document describing the format along with a sample data tape. The FIRE Central Archive will check the sample data tape to verify that it corresponds to the documentation for the approved format. In addition to the (revised) data 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, and useful software for manipulation of the data (such as tape read, navigation, or remapping programs).

4. Standard format for instrument data

The FIRE data tape format for all non-satellite data is standardized only in terms of certain tape characteristics, file arrangement on the tape, a few file structure and data characteristics, and a few data organization guidelines. In other words, the actual data arrangement within a data file is not standardized except for certain imposed simplifications. This approach compromises between a 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; however, the investigator is required to fix the format and produce a detailed format document. Once data are 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 most common "change of format" that occurs is that produced by missing data. Once a data format is fixed, missing data must be replaced by dummy values to maintain the data structure.

4.1 Data tape characteristics

i. All data tapes shall be computer compatible magnetic tapes at 1600 or 6250 bpi density. The FIRE Central Archive will maintain the capability of supplying versions of the data at either 1600 or 6250 bpi density.

ii. The tapes shall be written entirely in blocks (records) of a single fixed length that is selected for efficient data packing but is not larger than 12000 bytes. The record size is recorded in the tape and file headers.

iii. Tape files may be composed of more than one data type (e.g., character, integer), but each record must be composed entirely of a single data type.

iv. All tapes should be in unlabeled format; i.e., there should be no extra computer-specific records or files that identify a data file to that particular computer system. The computer system and operating system software will be identified in the tape header file.

4.2 Data characteristics

i. Only two data types shall be used: CHARACTER type (ASCII) for labelling and other textual information and INTEGER for all numerical values. The preferred data type is 32-bit INTEGER for all numerical values; however, 8-bit or 16-bit INTEGER may be used for high volume data sets. The number of different INTEGER types used should be one, or at most two, and should not be mixed in one record. The specific data types used will be indicated in the tape and file headers.

ii. All numerical values shall be reported as scaled integers with the scale factors given as numerical values in the same file; in other words, no floating point values should be used.

iii. Bad data, missing data or filling of numerical records should be represented by the integer value corresponding to all 32-bits set to 1. Missing information or filling of character records should be represented by blanks.

4.3 Tape file structure

i. Each data tape shall be constructed of a Volume ID file, a Volume Table of Contents file, a Test Data file, a fixed number of Ancillary Data files, and a variable number of Observation Data files.

ii. The last file on the tape shall be followed by an extra end-of-file mark.

iii. The Volume ID and Table of Contents files are to be written entirely in CHARACTER type data.

iv. All Data files begin with a fixed number of records containing only CHARACTER type data (the header) followed by a variable number of records containing INTEGER type data (the data).

v. A fixed number of the first data records in a file shall contain the "global" numerical values (such as scale factors) described in the header for ease of processing.

4.4 File contents and structure

4.4.1 Volume ID file

This file is always the first file on a data tape and is composed entirely of ASCII character type data, arranged in 80-byte units (card images), representing text describing the tape contents.

The text information is arranged into five segments, each terminated by three 80-byte sequences of character blanks. This file should contain at least the following information.

CARD IMAGE #	CONTENTS
1	FIRE.CCCCC.DDDD.BBBB.NNNNNN.V.YYDDD.YYDDD
	CCCCC - FIRE data collection element (ETO, CIIFO, MSIFO) DDDD = source institution or investigator BBBB = type of data (variable or instrument code) NNNNNN = tape sequence number for that data type which is unique and starts with 000001.
	V = tape version nu~'er starting with 0 YYDDD = year and Julian day of first data YYDDD = year and Julian day of last data
2	Investigator name(s) or contact person
3 - 7	Investigator institution address and code
8	Tape creation date (YYDDD)
9 - 10	Internal input tape numbers used to create tape
11	Tape creation software version number as date of last change (YYDDD)
12	Total number of files on tape
13	Record size on tape
14	Size of INTEGER values in bits (8, 16, 32)
15 - 16	Computer system and operating system software used to generate tape
17 - II	Contents of ancillary data files: variables, units, coverage and resolution
II+1 - JJ	Contents of observation data files: variables, units, coverage and resolution
	SEGMENT 2
JJ+2 - JJJJ	Instrument name(s) and numerical code
JJJJ+1 - KK	number Instrument description(s), including manufacturer, platform, spectral channels, sensitivity, noise level, spectral, time and space resolution
	SEGMENT 3
KK+2 - LL	Description of distribution of observations in time period
LL+1 - MM	Description of observation site or location, navigation information, coordinate system used

CARD IMAGE #	CONTENTS
MM+1 - NN	Calibration information including source, uncertainties, and calibration factors
	SEGMENT 4
NN+2 - III	Bibliography of instrument specifications, calibration, analysis methods, and algorithms
	SEGMENT 5
III+2 - JJJ	Software for data manipulation, such as tape reading, navigation, remapping

4.4.2 Volume Table of Contents file

This file is always the second file on a data tape and is composed entirely of ASCII CHARACTER type data, arranged in 80-byte units (card images), representing text describing the tape contents. The textual information is arranged in the form of a table showing a file by file listing of contents. Information listed for each file should include the following.

Data file sequence number on tape
Data sequence number within data set
Date of first and last observations in file
Time of first and last observations in file
Variables actually present in file
Geographical region covered by data in file
Spatial resolution of data in file
Time resolution of data in file

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 should be highly coded and need only provide an approximate indication of these features of the data.

4.4.3 Data file

The first 10 records in a data file (ancillary or observation) contain descriptive information about the data in that file and are composed entirely ASCII CHARACTER type data arranged in 80-byte sequences. These records are called the ASCII file header.

The next 2 records repeat all numerical factors in the file header, but entirely in INTEGER form for computational convenience. These records are called the numerical file header. These parts of a data file must remain fixed even if the records are mostly full. The information provided in both these parts of a data file should include the following.

ASCII HEADER	NUMERICAL HEADER
File number on tape	*
Data sequence number within data set on tape	*
Size of records	*
Size of INTEGER values in bits	*
Number of records for navigation	*
Number of records for calibration	*
Beginning date	*
Beginning time	*
Geographic location of first data	*
Ending date	*
Ending time	*
Geographic location of last data	*
Time resolution	
Spatial resolution	
Spectral resolution	
Each variable name	
" " code number	*
" " units	
" " source instrument	
" " instrument code	*
" " order within file	
" " observation sequence name	
" " obs. seq. numbers	*
" " scale factors	*
" " variable range	*
Analysis method (brief) description	
Code for data source (from Volume ID)	*

The header information concerning the variables reported in the data file must provide a guide to the actual arrangement of the data within each record of that file; i.e., the specific variables should be identified in the data records by code numbers given in the header and their order of appearance in the file described.

All records within a data file should begin with a series of sequence numbers to prevent loss of synchronization by I/O errors. These sequence numbers are as follows.

Record sequence number within the file
Data type code number (0=CHARACTER, 1=INTEGER)
Data file number on tape

Observation sequence number on tape
Beginning data sequence number within file
Ending data sequence number within file

The data sequence numbers within a file are simply reference numbers indicating the position of the data in that record within the file.

5. Standard format for satellite data

Satellite data will be submitted to the FIRE Central Archive in nearly original format to avoid reprocessing of 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 attempt to supply satellite data to FIRE investigators which have been modified slightly to provide some uniform structure or to prepare complete format documentation, including sample tape-read software. However, certain satellite data sets identified by the FSET, especially for the key case studies, will be reprocessed into the standard format described above to facilitate intensive data comparisons. 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 reformat these data as well.

The key modification of the standard format for large volume satellite data sets is the use of 8-bit or 16-bit INTEGER to represent the radiances rather than 32-bit INTEGER. In this case bad or missing data will be represented by the integer value that corresponds to all bits set to 1. Interleaving of 8-bit and 16-bit INTEGERS may also be necessary, but should be avoided except upon approval of the FSET. All such data should be arranged so that the numerical values are aligned on 32-bit word boundaries. (For example, only four 8-bit values should occur between two 32-bit values.)

6. Guidelines for organization of data

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.

i. Use of file divisions. The arrangement of the data on a single data tape should follow a "natural" sequence, usually time sequences 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 end-of-file 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.

ii. 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.

iii. 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. An example of this would be those multiple variables that are simultaneously measured by multiple instruments on board a common platform, i.e., aircraft. Note that the format of Segment 2 of section 4.4.1 is flexible enough to include the description of scientific instruments.

iv. Data and analysis products. Data (raw or reduced through straightforward processing) should be compiled separately from analysis products and placed 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.

v. The FSET shall decide the data types, analysis product types, and other desired combinations of these that will be produced by all data suppliers.

vi. To allow for future expansion of additional data products, it is encouraged that data formats include additional locations in the data record. These additional locations should be set in the "missing data" flag, as described in 4.2 (iii). This would eliminate the need for replacing all of the previously submitted archive holdings or by labelling the new data format as different data (see 4.0).

The final specification of all data formats will include more detail than given here; however, this detail will be decided by the

FSET in discussion with the individual investigators and representatives of the FIRE Central Archive. Thus, this FIRE standard data tape format document will be superceded by a later document that will show the selected formats and will be provided as part of the FIRE documentation of the data holdings.

7. PCDS Users Access Information

In order to obtain archived data, scientists of their staff will usually access the NSSDC computer systems where PCDS resides and run the PCDS to request specific data. Scientists can gain access to this computer in one of several ways:

- via dial-in directly to the computer using a Bell 212A compatible modem at either 300 or 11200 baud
- via the Space Plasma Analysis Network (SPAN) with DECnet protocol from a number of universities and NASA facilities
- via GTE Telenet by dialing their local access number
- via terminals linked directly to the computer system (mainly those at Goddard)

The NSSDC Computer Facility is usually available for full access weekdays between 07:00 and 20:00 Eastern time. It is also usually available for limited access, requiring no operator intervention (such as for tape access), on weekends and early morning (00:00 to 07:00).

If a scientist cannot access the system himself, he can contact the PCDS User Support Office (phone # to be provided), and request that the data be extracted and sent to him.

Each scientist wishing to access the computer facility should request an account from the PCDS Manager (phone # to be provided). He accesses this account with an account name and a password. He can then run the PCDS and examine the catalog and inventory and request the data that meets his needs. The details of this access are provided in the PCDS User's Guide, NASA TM 86084. The system is menu-driven and provides an extensive help facility. Therefore, even the novice user should have little difficulty in accessing the data. Numerous types of terminals are supported, and users have had success in accessing the system with their personal computers.

PCDS will be providing catalog and inventory capabilities for all archived FIRE data sets. The catalog information will be provided to the PCDS by the investigators, and will contain information about all FIRE data sets of interest to the community. The content and format of this information is provided in the NASA Climate Data Catalog, NASA TM 86085. The inventory will provide more detailed information about FIRE data sets which will actually be available for distribution by the PCDS. PCDS will provide a limited tape copy capability for satellite data sets needed by FIRE and full PCDS support for data sets in the FIRE Standard Format. Full support includes, in addition to the catalog, inventory, and data access capabilities, some data manipulation and graphics capabilities.

APPENDIX D

SATELLITE OVERPASS TIMES
FOR
MADISON, WISCONSIN

D.1 Satellite Overpass Times

The Langley Orbital Sampling Analysis Program has been used to calculate the overpass times and viewing angles of the NOAA-9 spacecraft for Madison, Wisconsin (Table D.1A). The time is GMT and the viewing zenith angle and azimuth angle measured from north are listed which coincide with the satellite AVHRR scanner observations of the ground site. These data are for the closest passage of the satellite to the site. The maximum viewing angle considered is 70 degrees. The printout also includes the relative azimuth angle measured from the solar plane and the solar zenith angle at the site. In addition, the latitude and longitude of the satellite nadir position and the solar time at the subsatellite point are provided for your information. Both ascending (daytime) and descending (nighttime) coincident measurement opportunities are listed. The primary days (days 5 through 10 and 20 through 25) for each month for ET-LA observations are identified by an asterisk.

Table D.1B lists the ERB overpass times for Madison, WI; and Table D.1C lists the SAGE II predicted measurement time and locations.

D.2 LANDSAT Overpass Times

The LANDSAT 5 satellite is in a sun synchronous orbit which views the Wisconsin IFO area at approximately 10 a.m. Central Standard Time. LANDSAT data is collected in 180 km by 170 km target "scenes" along the satellite ground track. Nominal center of each scene is given in the accompaning map (figure D.2) for the 4 scenes which cover the FIRE Cirrus IFO-1 region in Wisconsin, and the 4 scenes which cover Lake Michigan.

The map shows the nominal scene center (large filled circle) and scene coverage (outlined box) for each of the eight scenes pertinent to FIRE. LANDSAT scenes are referenced by path (orbit path number) and row (scene number along an orbit path), as shown on the map. The scene covering the northwest portion of the FIRE IFO is designated as path/row 25/29. The predicted scene centers shown are accurate to within approximately 15 km for any given scene. Nominal navigation accuracy of a selected scene after data processing is 1 km. Using known ground control points, navigation can be improved to 1 pixel (28.5 meters) accuracy. Note that there is a small amount of North/South overlap of the scenes and a large amount of East/West overlap

The following table gives the dates and GMT times (nearest half minute) of data collection for each of the eight LANDSAT scenes shown in the map.

Scene Path/Row:	25/29	25/30	24/29	24/30	23/29	23/30	22/29	22/30
Region Covered:	N.West IFO-1	S.West IFO-1	N.East IFO-1	S.East IFO-1	N.West L.Mich	S.West L. Mich	N.East L.Mich	S.East L.Mich
GMT Time:	1616.5	1617	1610.5	1611	1604.5	1605	1558.5	1559
Date of Overpass:	10/26	10/26	10/19	10/19	10/28	10/28	10/21	10/21

As seen from the table, there are four target days for LANDSAT overpasses during the FIRE IFO-1: October 19, 21, 26, and 28. The GMT times given in the table are correct to $\pm$ 2 minutes; more accurate overpass times will be available at the start of the IFO experiment.

TABLE D.1A: NOAA-9 (AVHRR) OVERPASS TIMES FOR MADISON, WISCONSIN

MADISON, WI
LAT= 43.22 LONG= 270.65

GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	SATELLITE POSITION LONG	SATELLI SOL. TI
85	9	28	19	43	43.46	66.48	149.01	52.21	ASCENDING	45.18	278.71	14.44
85	9	28	21	24	65.20	265.94	23.94	66.29	ASCENDING	41.24	254.66	14.52
85	9	29	9	45	26.67	287.62	142.01	113.57	DEC	44.15	266.21	3.64
85	9	29	19	32	51.95	67.12	147.24	51.47	ASCENDING	45.84	281.18	14.42
85	9	29	21	13	59.44	264.16	24.64	64.92	ASCENDING	41.42	257.33	14.52
85	9	30	9	34	12.73	266.47	141.34	115.63	DEC	43.61	268.74	3.64
85	9	30	19	21	58.65	64.89	146.18	50.80	ASCENDING	46.66	283.57	14.42
85	9	30	21	2	52.31	262.33	25.36	63.60	ASCENDING	41.65	259.98	14.53
85	10	1	9	23	4.35	100.41	34.42	117.62	DEC	43.13	271.29	3.62
85	10	1	19	11	64.02	63.35	144.46	50.24	ASCENDING	47.42	285.98	14.40
85	10	1	20	51	43.35	260.43	26.06	62.33	ASCENDING	41.93	262.61	14.53
85	10	2	9	13	19.73	104.23	40.19	119.64	DEC	42.59	273.82	3.63
85	10	2	19	0	68.44	61.20	143.31	49.79	ASCENDING	48.35	288.31	14.37
85	10	2	20	41	31.93	258.35	26.58	61.16	ASCENDING	42.26	265.22	14.51
85	10	3	9	2	33.47	101.53	39.50	121.64	DEC	42.20	276.41	3.63
85	10	3	10	42	67.93	298.55	143.25	104.32	DEC	48.23	253.28	3.76
85	10	3	20	30	17.86	255.62	26.57	60.01	ASCENDING	42.65	267.81	14.51
85	10	4	8	51	44.58	99.44	39.51	123.60	DEC	41.88	279.02	3.63
85	10	4	10	32	63.39	296.39	143.87	106.43	DEC	47.31	255.62	3.74
85	10	4	20	19	2.29	265.63	39.38	58.92	ASCENDING	43.20	270.33	14.52
85	10	5	8	40	53.32	97.53	39.72	125.49	DEC	41.60	281.65	3.62
85	10	5	10	21	57.69	294.86	143.83	108.52	DEC	46.56	258.03	3.72
85	10	5	20	8	14.61	73.07	150.31	57.90	ASCENDING	43.69	272.88	14.52
85	10	6	8	30	60.25	95.70	40.17	127.39	DEC	41.38	284.30	3.62
85	10	6	10	10	50.98	292.62	144.42	110.66	DEC	45.74	260.43	3.72
85	10	6	19	58	28.34	72.01	148.51	56.98	ASCENDING	44.23	275.40	14.50
85	10	7	8	19	65.65	93.90	40.77	129.25	DEC	41.20	286.97	3.62
85	10	7	10	0	42.24	291.26	144.14	112.74	DEC	45.09	262.90	3.70
85	10	7	19	47	40.06	69.26	148.28	56.12	ASCENDING	44.93	277.86	14.50
85	10	7	21	26	66.93	266.33	25.22	70.14	ASCENDING	41.14	253.75	14.57
85	10	8	9	49	31.17	288.66	145.00	114.85	DEC	44.38	265.35	3.70
85	10	8	19	36	49.23	67.90	146.66	55.36	ASCENDING	45.57	280.34	14.48
85	10	8	21	17	61.57	264.53	25.83	68.77	ASCENDING	41.30	256.43	14.57
85	10	9	9	38	17.62	287.73	144.21	116.90	DEC	43.83	267.87	3.68
85	10	9	19	26	56.51	65.62	145.83	54.66	ASCENDING	46.37	282.74	14.48
85	10	9	21	6	54.96	262.68	26.45	67.45	ASCENDING	41.52	259.08	14.57
85	10	10	9	28	1.64	268.49	161.61	118.99	DEC	43.21	270.37	3.69
85	10	10	19	15	62.28	63.47	144.89	54.08	ASCENDING	47.23	285.12	14.46

TABLE D.1A: NOAA-9 (AVHRR) OVERPASS TIMES FOR MADISON, WISCONSIN

MADISON, WI
LAT= 43.22 LONG= 270.65

GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	SATELLITE POSITION LONG	SATELL SOL. T
85	10	10	20	56	46.64	260.74	27.03	66.18	ASCENDING	41.78	261.71	14.5
86	10	11	9	17	14.65	104.42	36.22	121.05	DEC	42.77	272.94	3.6
85	10	11	19	5	67.00	61.92	143.31	53.59	ASCENDING	48.03	287.51	14.4
86	10	11	20	45	36.08	258.62	27.49	64.97	ASCENDING	42.10	264.33	14.5
85	10	12	9	6	29.18	101.74	35.44	123.05	DEC	42.37	275.52	3.6
85	10	12	10	46	69.31	299.27	146.32	105.44	DEC	48.56	252.48	3.8
85	10	12	20	34	22.96	258.46	29.95	63.81	ASCENDING	42.59	266.88	14.5
85	10	13	8	55	41.00	99.72	35.48	125.08	DEC	42.02	278.13	3.6
86	10	13	10	36	65.06	297.12	146.95	107.56	DEC	47.62	254.80	3.8
86	10	13	20	23	8.12	256.78	30.97	62.71	ASCENDING	43.01	269.46	14.5
86	10	14	8	45	50.48	97.85	35.75	127.07	DEC	41.73	280.75	3.6
86	10	14	10	25	59.92	295.58	146.94	109.67	DEC	46.85	257.21	3.7
85	10	14	20	13	9.09	74.89	148.24	61.71	ASCENDING	43.48	272.01	14.5
85	10	15	8	34	57.99	96.05	36.19	129.04	DEC	41.49	283.40	3.6
85	10	15	10	15	53.57	293.38	147.51	111.83	DEC	46.01	259.60	3.7
85	10	15	20	2	23.66	70.92	149.41	60.75	ASCENDING	44.11	274.50	14.5
85	10	16	8	23	64.02	94.28	36.77	130.97	DEC	41.30	286.06	3.6
85	10	16	10	4	45.49	292.02	147.26	113.93	DEC	45.34	262.06	3.7
85	10	16	19	51	36.40	70.08	147.39	59.87	ASCENDING	44.68	277.01	14.5
85	10	16	21	32	68.55	267.43	27.29	73.77	ASCENDING	41.20	252.79	14.6
85	10	17	8	12	68.96	92.53	37.49	132.86	DEC	41.17	288.74	3.6
86	10	17	9	53	35.36	289.59	147.99	116.07	DEC	44.61	264.50	3.7
85	10	17	19	41	46.28	68.70	145.92	59.09	ASCENDING	45.31	279.50	14.5
85	10	17	21	22	63.53	264.91	27.12	72.40	ASCENDING	41.19	255.52	14.6
86	10	18	9	43	22.47	288.68	147.21	118.15	DEC	44.05	267.01	3.7
85	10	18	19	30	54.21	66.36	145.36	58.39	ASCENDING	46.09	281.91	14.5
86	10	18	21	11	57.39	263.05	27.66	71.07	ASCENDING	41.39	258.18	14.6
85	10	19	9	32	7.44	283.69	150.39	120.27	DEC	43.42	269.50	3.7
86	10	19	19	19	60.41	64.18	144.53	57.75	ASCENDING	46.93	284.30	14.5
86	10	19	21	0	49.72	262.16	29.22	69.79	ASCENDING	41.78	260.77	14.6
85	10	20	9	21	9.87	104.14	31.86	122.33	DEC	42.95	272.06	3.7
86	10	20	19	9	65.47	62.65	143.08	57.22	ASCENDING	47.71	286.70	14.4
86	10	20	20	49	40.02	260.34	29.90	68.56	ASCENDING	42.07	263.40	14.6
85	10	21	9	11	24.27	101.78	31.43	124.41	DEC	42.54	274.64	3.7
86	10	21	18	58	69.66	60.51	142.20	56.79	ASCENDING	48.65	289.02	14.4
86	10	21	20	38	27.89	258.41	30.51	67.39	ASCENDING	42.42	266.00	14.6
85	10	22	9	0	37.11	99.92	31.58	126.48	DEC	42.18	277.24	3.7
86	10	22	10	40	66.62	297.85	149.83	108.68	DEC	47.94	253.99	3.8

TABLE D.1A: NOAA-9 (AVHRR) OVERPASS TIMES FOR MADISON, WISCONSIN

MADISON, WI
LAT= 43.22 LONG= 270.65

GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	SATELLITE POSITION LONG	SATELL SOL. T
85	10	22	20	28	13.57	255.95	30.59	66.31	ASCENDING	42.82	268.58	14.6
85	10	23	8	49	47.43	99.26	33.02	128.53	DEC	41.74	279.81	3.7
85	10	23	10	30	61.82	296.30	149.84	110.80	DEC	47.15	256.39	3.8
85	10	23	20	17	3.29	81.18	141.54	65.26	ASCENDING	43.27	271.14	14.6
85	10	24	8	38	55.58	97.31	33.26	130.54	DEC	41.47	282.45	3.7
85	10	24	10	19	55.95	294.13	150.40	112.97	DEC	46.29	258.76	3.8
85	10	24	20	6	18.78	71.76	148.25	64.28	ASCENDING	43.69	273.64	14.6
85	10	25	8	27	62.07	95.44	33.70	132.53	DEC	41.26	285.10	3.7
85	10	25	10	8	48.50	291.83	151.11	115.08	DEC	45.49	261.17	3.8
85	10	25	19	56	32.31	70.96	146.37	63.40	ASCENDING	44.45	276.16	14.5
85	10	26	8	17	67.35	93.63	34.32	134.49	DEC	41.10	287.77	3.7
85	10	26	9	58	39.19	290.44	150.87	117.19	DEC	44.86	263.65	3.7
85	10	26	19	45	43.08	68.45	146.07	62.56	ASCENDING	45.16	278.61	14.5
85	10	26	21	26	65.39	266.06	29.21	75.75	ASCENDING	41.24	254.56	14.6
85	10	27	9	47	27.17	287.55	152.04	119.34	DEC	44.16	266.11	3.7
85	10	27	19	34	51.67	67.12	144.63	61.83	ASCENDING	45.82	281.08	14.5
85	10	27	21	15	59.68	264.28	29.77	74.40	ASCENDING	41.42	257.23	14.6
85	10	28	9	36	13.12	286.20	151.61	121.48	DEC	43.63	268.64	3.7
85	10	28	19	24	58.41	64.90	143.95	61.15	ASCENDING	46.64	283.47	14.5
85	10	28	21	4	52.60	262.47	30.34	73.10	ASCENDING	41.64	259.87	14.6
85	10	29	9	26	4.12	101.00	24.97	123.56	DEC	43.14	271.19	3.7
85	10	29	19	13	63.63	63.38	142.62	60.59	ASCENDING	47.40	285.89	14.5
85	10	29	20	53	43.70	260.59	30.89	71.86	ASCENDING	41.92	262.50	14.6
85	10	30	9	15	19.15	101.53	27.40	125.67	DEC	42.71	273.76	3.7
85	10	30	19	3	68.29	61.22	141.87	60.10	ASCENDING	48.33	288.22	14.5
85	10	30	20	43	32.46	258.55	31.27	70.70	ASCENDING	42.26	265.11	14.6
85	10	31	9	4	32.97	101.73	29.57	127.77	DEC	42.21	276.30	3.7
85	10	31	10	44	68.08	298.57	152.41	109.77	DEC	48.26	253.19	3.8
85	10	31	20	32	18.49	255.96	31.19	69.56	ASCENDING	42.64	267.70	14.6
85	11	1	8	53	44.16	99.60	29.49	129.85	DEC	41.88	278.92	3.7
85	11	1	10	34	63.59	297.01	152.44	111.89	DEC	47.45	255.57	3.8
85	11	1	20	21	2.62	264.86	42.65	68.48	ASCENDING	43.19	270.23	14.7
85	11	2	8	42	53.02	97.66	29.72	131.91	DEC	41.60	281.55	3.7
85	11	2	10	23	58.13	294.87	153.03	114.01	DEC	46.58	257.94	3.8
85	11	2	20	11	13.88	72.81	146.78	67.47	ASCENDING	43.68	272.78	14.6
85	11	3	8	32	60.02	95.82	30.14	133.94	DEC	41.37	284.20	3.7
85	11	3	10	13	51.27	292.62	153.64	116.18	DEC	45.76	260.33	3.8
85	11	3	20	0	27.87	71.94	145.05	66.56	ASCENDING	44.21	275.30	14.6

TABLE D.1A: NOAA-9 (AVHRR) OVERPASS TIMES FOR MADISON, WISCONSIN

MADISON, WI
LAT= 43.22 LONG= 270.65

GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	LONG	SATELLI SOL. TI
85	10	22	20	28	13.57	255.95	30.59	66.31	ASCENDING	42.82	268.58	14.60
85	10	23	8	49	47.43	99.26	33.02	128.53	DEC	41.74	279.81	3.72
85	10	23	10	30	61.82	296.30	149.84	110.80	DEC	47.15	256.39	3.82
86	10	23	20	17	3.29	81.18	141.54	65.26	ASCENDING	43.27	271.14	14.60
86	10	24	8	38	55.58	97.31	33.26	130.54	DEC	41.47	282.45	3.72
85	10	24	10	19	55.95	294.13	150.40	112.97	DEC	46.29	258.76	3.82
85	10	24	20	6	18.78	71.76	148.25	64.28	ASCENDING	43.89	273.64	14.60
85	10	25	8	27	62.07	95.44	33.70	132.53	DEC	41.26	285.10	3.72
86	10	25	10	8	48.50	291.83	151.11	115.08	DEC	45.49	261.17	3.80
86	10	25	19	56	32.31	70.96	146.37	63.40	ASCENDING	44.45	276.16	14.58
85	10	26	8	17	67.35	93.63	34.32	134.49	DEC	41.10	287.77	3.72
86	10	26	9	58	39.19	290.44	150.87	117.19	DEC	44.86	263.65	3.78
85	10	26	19	45	43.08	68.45	146.07	62.56	ASCENDING	45.16	278.61	14.58
85	10	26	21	26	65.39	266.06	29.21	75.75	ASCENDING	41.24	254.56	14.66
85	10	27	9	47	27.17	287.55	152.04	119.34	DEC	44.16	266.11	3.78
85	10	27	19	34	51.67	67.12	144.63	61.83	ASCENDING	45.82	281.08	14.55
86	10	27	21	15	59.68	264.28	29.77	74.40	ASCENDING	41.42	257.23	14.66
85	10	28	9	36	13.12	286.20	151.61	121.48	DEC	43.63	268.64	3.77
86	10	28	19	24	58.41	64.90	143.95	61.15	ASCENDING	46.64	283.47	14.55
85	10	28	21	4	52.60	262.47	30.34	73.10	ASCENDING	41.64	259.87	14.66
86	10	29	9	26	4.12	101.00	24.97	123.56	DEC	43.14	271.19	3.75
85	10	29	19	13	63.63	63.38	142.62	60.59	ASCENDING	47.40	285.89	14.53
86	10	29	20	53	43.70	260.59	30.89	71.86	ASCENDING	41.92	262.50	14.66
85	10	30	9	15	19.15	101.53	27.40	125.67	DEC	42.71	273.76	3.75
85	10	30	19	3	68.29	61.22	141.87	60.10	ASCENDING	48.33	288.22	14.50
85	10	30	20	43	32.46	258.55	31.27	70.70	ASCENDING	42.26	265.11	14.64
85	10	31	9	4	32.97	101.73	29.57	127.77	DEC	42.21	276.30	3.75
86	10	31	10	44	68.08	298.57	152.41	109.77	DEC	48.26	253.19	3.88
85	10	31	20	32	18.49	255.96	31.19	69.56	ASCENDING	42.64	267.70	14.63
85	11	1	8	53	44.18	99.60	29.49	129.85	DEC	41.88	278.92	3.75
86	11	1	10	34	63.59	297.01	152.44	111.89	DEC	47.45	255.57	3.85
86	11	1	20	21	2.62	264.86	42.65	68.48	ASCENDING	43.19	270.23	14.63
85	11	2	8	42	53.02	97.66	29.72	131.91	DEC	41.60	281.55	3.75
86	11	2	10	23	58.13	294.87	153.03	114.01	DEC	46.58	257.94	3.83
85	11	2	20	11	13.88	72.81	146.78	67.47	ASCENDING	43.68	272.78	14.63
85	11	3	8	32	60.02	95.82	30.14	133.94	DEC	41.37	284.20	3.74
86	11	3	10	13	51.27	292.62	153.64	116.18	DEC	45.76	260.33	3.83
86	11	3	20	0	27.87	71.94	145.05	66.56	ASCENDING	44.21	275.30	14.60

TABLE D.1B: ERBS OVERPASS TIMES FOR MADISON, WISCONSIN

MADISON, WI
LAT= 43.22 LONG= 270.65

GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	SATELLITE POSITION LONG	SATELLIT SOL. TIM
86	10	2	19	46	30.75	39.22	178.60	54.08	DEC	45.42	273.23	14.20
86	10	2	21	26	68.70	236.45	5.23	68.07	DEC	36.96	259.85	15.01
86	10	3	13	12	20.03	320.29	147.71	77.32	ASCENDING	44.59	269.04	7.39
86	10	3	18	17	65.97	25.03	165.44	47.80	DEC	51.58	277.04	13.05
86	10	3	19	58	10.09	227.51	6.54	55.87	DEC	42.62	269.77	14.20
86	10	4	11	44	57.74	127.36	34.47	93.26	ASCENDING	38.64	277.93	6.53
86	10	4	13	24	47.99	324.68	145.91	75.46	ASCENDING	47.41	266.18	7.43
86	10	4	18	29	55.88	31.96	162.55	48.67	DEC	48.81	276.05	13.14
86	10	4	20	10	46.68	229.97	6.07	57.71	DEC	39.88	265.64	14.11
86	10	5	11	56	30.32	132.83	37.58	91.31	ASCENDING	41.25	273.42	6.44
86	10	5	13	37	61.84	331.72	141.51	73.64	ASCENDING	50.25	264.60	7.51
86	10	5	18	41	36.17	39.15	160.27	49.69	DEC	45.95	273.77	13.18
86	10	5	20	22	66.22	235.63	8.93	59.62	DEC	37.42	260.78	14.01
86	10	6	12	8	12.66	319.88	137.74	89.38	ASCENDING	44.06	269.66	6.37
86	10	6	13	49	69.26	337.97	139.00	71.82	ASCENDING	52.85	264.12	7.74
86	10	6	17	13	67.27	23.92	145.36	48.97	DEC	52.05	277.12	12.01
86	10	6	18	53	1.83	209.86	7.68	50.86	DEC	43.08	270.54	13.19
86	10	7	10	40	61.09	126.49	43.73	105.58	ASCENDING	38.17	278.81	5.52
86	10	7	12	20	44.20	323.58	136.46	87.40	ASCENDING	46.88	266.63	6.40
86	10	7	17	25	58.24	30.87	142.55	49.01	DEC	49.32	276.36	12.11
86	10	7	19	5	41.43	229.06	23.32	52.13	DEC	40.37	266.46	13.11
86	10	8	10	52	36.79	131.87	46.68	103.64	ASCENDING	40.75	274.20	5.43
86	10	8	12	32	59.91	330.64	131.84	85.45	ASCENDING	49.77	264.83	6.48
86	10	8	17	37	40.93	37.07	140.46	49.22	DEC	46.48	274.28	12.16
86	10	8	19	17	63.47	234.28	25.13	53.51	DEC	37.91	261.77	13.00
86	10	9	11	4	4.83	321.65	125.94	101.69	ASCENDING	43.54	270.30	5.35
86	10	9	12	45	68.19	336.84	128.13	83.47	ASCENDING	52.40	264.12	6.70
86	10	9	16	8	68.45	22.80	127.22	54.12	DEC	52.51	277.16	10.88
86	10	9	17	49	6.49	46.46	135.14	49.58	DEC	43.60	271.21	12.18
86	10	10	9	35	64.09	125.09	53.39	117.64	ASCENDING	37.76	279.79	4.51
86	10	10	11	16	39.87	322.47	127.55	99.68	ASCENDING	46.35	267.11	5.38
86	10	10	16	20	60.34	29.77	124.09	53.40	DEC	49.84	276.64	11.08
86	10	10	18	1	35.55	228.15	42.62	50.10	DEC	40.87	267.25	12.09
86	10	11	9	47	42.59	130.92	56.52	115.79	ASCENDING	40.25	275.01	4.41
86	10	11	11	28	57.74	328.75	123.67	97.68	ASCENDING	49.20	264.98	5.45
86	10	11	16	33	45.11	35.99	121.68	52.83	DEC	47.09	274.75	11.14
86	10	11	19	13	60.41	233.43	44.05	50.77	DEC	38.25	262.67	11.99
86	10	12	9	59	3.91	130.48	53.44	113.91	ASCENDING	43.02	270.98	4.34

TABLE D.1B: ERBS OVERPASS TIMES FOR MADISON, WISCONSIN

MADISON, WI
LAT= 43.22 LONG= 270.65

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. TI
86	10	12	11	40	67.02	335.72	119.09	95.68	ASCENDING	51.94	264.17	5.56
86	10	12	15	4	69.48	21.67	112.35	62.26	DEC	52.95	277.15	9.84
86	10	12	16	45	14.32	43.31	118.23	52.41	DEC	44.13	271.85	11.16
86	10	13	8	31	66.79	124.27	65.82	128.97	ASCENDING	37.31	280.71	3.50
86	10	13	10	11	34.03	321.36	118.29	111.96	ASCENDING	45.82	267.62	4.36
86	10	13	15	16	62.22	27.02	109.39	60.97	DEC	50.40	276.73	10.05
86	10	13	16	57	29.04	227.26	61.90	52.15	DEC	41.37	268.03	11.08
86	10	14	8	43	47.74	129.10	67.40	127.34	ASCENDING	39.82	275.90	3.40
86	10	14	10	24	55.30	327.66	114.54	109.99	ASCENDING	48.69	265.30	4.42
86	10	14	15	28	48.77	34.90	105.70	59.92	DEC	47.53	275.19	10.12
86	10	14	17	9	34.09	232.57	65.39	52.03	DEC	38.75	263.55	10.99
86	10	15	8	55	12.05	133.51	68.70	125.65	ASCENDING	42.50	271.67	3.32
86	10	15	10	36	65.68	334.61	110.09	108.01	ASCENDING	51.47	264.26	4.52
86	10	15	15	40	21.55	41.68	102.30	58.77	DEC	44.65	272.46	10.14
86	10	16	7	27	69.22	123.45	82.20	138.72	ASCENDING	36.85	281.65	2.55
86	10	16	9	7	29.30	320.22	107.65	123.86	ASCENDING	45.29	268.17	3.33
86	10	16	14	12	63.91	26.83	96.83	70.71	DEC	50.89	276.91	9.02
86	10	16	15	53	21.82	226.41	78.98	57.84	DEC	41.88	268.78	10.13
86	10	17	7	39	52.24	128.29	82.98	137.56	ASCENDING	39.33	276.74	2.39
86	10	17	9	19	52.56	326.57	104.24	122.02	ASCENDING	48.16	265.66	3.38
86	10	17	14	24	51.98	33.91	92.68	69.16	DEC	48.06	275.59	9.09
86	10	17	16	4	53.11	231.72	80.85	57.05	DEC	39.23	264.41	10.03
86	10	18	7	51	20.06	133.24	83.97	136.25	ASCENDING	41.99	272.40	2.30
86	10	18	9	31	64.19	333.51	100.13	120.14	ASCENDING	50.99	264.39	3.48
86	10	18	14	36	28.08	40.36	89.02	67.68	DEC	45.18	273.05	9.12
86	10	18	16	16	69.62	236.61	82.31	56.41	DEC	36.76	259.49	9.86
86	10	19	8	3	22.96	319.04	94.08	134.80	ASCENDING	44.76	268.75	2.31
86	10	19	13	7	65.43	25.72	86.30	81.78	DEC	51.37	277.05	7.98
86	10	19	14	48	14.03	225.71	93.37	66.29	DEC	42.39	269.51	9.12
86	10	20	6	34	56.30	127.46	104.45	145.11	ASCENDING	38.85	277.60	1.37
86	10	20	8	15	49.44	325.49	91.29	133.25	ASCENDING	47.64	266.05	2.35
86	10	20	13	20	54.81	32.71	81.90	79.99	DEC	48.58	275.96	8.06
86	10	20	15	0	48.65	230.88	95.57	65.01	DEC	39.72	265.26	9.02
86	10	21	6	46	27.57	132.56	104.47	144.50	ASCENDING	41.48	273.15	1.28
86	10	21	8	27	62.55	331.69	88.59	131.61	ASCENDING	50.44	264.42	2.44
86	10	21	13	32	33.88	39.15	78.00	78.24	DEC	45.71	273.60	8.10
86	10	21	15	12	67.26	235.78	97.51	63.85	DEC	37.21	260.43	8.85
86	10	22	6	58	15.95	317.71	75.38	143.69	ASCENDING	44.24	269.35	1.28

TABLE D.1B: ERBS OVERPASS TIMES FOR MADISON, WISCONSIN

MADISON, WI
LAT= 43.22 LONG= 270.65

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
86	10	22	8	39	69.67	338.66	85.01	129.86	ASCENDING	53.04	264.19	2.67
86	10	22	12	3	66.77	24.61	77.10	93.69	DEC	51.85	277.15	6.85
86	10	22	13	44	6.36	225.95	106.22	76.54	DEC	42.91	270.21	8.10
86	10	23	5	30	59.84	126.62	131.73	148.00	ASCENDING	38.38	278.48	.42
86	10	23	7	11	45.90	324.42	73.47	142.71	ASCENDING	47.11	266.49	1.32
86	10	23	12	15	57.31	30.78	73.31	91.71	DEC	49.16	276.16	7.03
86	10	23	13	56	43.60	230.06	107.75	74.93	DEC	40.21	266.09	8.01
86	10	24	5	42	34.43	131.75	131.43	148.44	ASCENDING	40.97	273.92	.26
86	10	24	7	23	60.72	330.58	71.89	141.58	ASCENDING	49.94	264.65	1.40
86	10	24	12	27	38.99	37.99	68.45	89.79	DEC	46.24	274.12	7.07
86	10	24	14	8	64.63	234.96	110.01	73.38	DEC	37.67	261.36	7.90
86	10	25	5	54	8.45	315.78	50.33	148.66	ASCENDING	43.71	269.99	.26
86	10	25	7	35	68.65	337.53	69.30	140.30	ASCENDING	52.60	264.18	1.52
86	10	25	10	59	67.98	23.49	68.25	105.94	DEC	52.31	277.21	5.80
86	10	25	12	40	4.63	39.76	69.05	87.91	DEC	43.43	270.89	7.08
86	10	26	4	26	62.04	125.77	159.09	145.12	ASCENDING	37.91	279.38	23.40
86	10	26	6	6	41.82	323.37	48.42	148.67	ASCENDING	46.58	266.95	.21
86	10	26	11	11	59.54	29.71	64.41	103.89	DEC	49.67	276.45	5.99
86	10	26	12	52	37.88	229.29	118.15	86.10	DEC	40.71	266.89	6.99
86	10	27	4	38	40.52	130.90	159.64	146.57	ASCENDING	40.47	274.71	23.31
86	10	27	6	18	58.67	329.49	48.18	148.42	ASCENDING	49.43	264.91	.36
86	10	27	11	23	43.43	35.67	60.76	101.90	DEC	46.83	274.50	6.04
86	10	27	13	3	61.68	234.13	120.63	84.33	DEC	38.13	262.26	6.88
86	10	28	4	50	2.66	178.58	154.72	147.85	ASCENDING	43.19	270.65	23.23
86	10	28	6	31	67.49	336.41	46.89	147.97	ASCENDING	52.15	264.20	.47
86	10	28	9	54	69.07	21.72	59.53	118.24	DEC	52.81	277.05	4.76
86	10	28	11	35	11.61	41.04	57.68	99.92	DEC	43.95	271.54	6.05
86	10	29	3	22	65.73	124.93	179.43	137.76	ASCENDING	37.45	280.29	22.39
86	10	29	5	2	37.12	322.33	18.99	148.97	ASCENDING	46.05	267.45	23.18
86	10	29	10	7	61.53	28.62	55.20	116.21	DEC	50.17	276.69	4.95
86	10	29	11	47	31.47	227.05	126.09	98.00	DEC	41.15	267.75	5.97
86	10	30	3	34	45.82	130.02	177.54	139.79	ASCENDING	39.98	275.52	22.29
86	10	30	5	14	56.38	328.40	18.62	149.92	ASCENDING	48.92	265.21	23.32
86	10	30	10	19	47.33	34.66	51.62	114.21	DEC	47.36	274.95	5.01
86	10	30	11	59	58.38	233.32	130.12	96.10	DEC	38.60	263.16	5.86
86	10	31	3	45	8.93	137.25	173.73	141.74	ASCENDING	42.67	271.34	22.20
86	10	31	5	26	66.21	334.62	18.24	150.63	ASCENDING	51.63	264.11	23.42
86	10	31	10	31	18.92	40.39	48.29	112.21	DEC	44.48	272.16	5.03

TABLE D.1B: ERBS OVERPASS TIMES FOR MADISON, WISCONSIN

MADISON, WI
LAT= 43.22 LONG= 270.65

GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	SATELLITE POSITION LONG	SATELLI[TE] SOL. TI[ME]
86	11	1	2	17	68.25	123.61	164.06	127.97	ASCENDING	37.06	281.29	21.3
86	11	1	3	57	31.75	321.30	6.64	143.61	ASCENDING	45.52	267.98	22.1
86	11	1	9	2	63.29	27.53	44.51	128.34	DEC	50.67	276.89	3.8
86	11	1	10	43	24.39	225.98	135.00	110.25	DEC	41.66	268.51	4.9
86	11	2	2	29	50.54	129.13	160.86	130.29	ASCENDING	39.49	276.36	21.2
86	11	2	4	9	53.73	327.33	8.60	145.41	ASCENDING	48.40	265.55	22.1
86	11	2	9	14	50.75	33.63	41.32	126.39	DEC	47.88	275.36	3.97
86	11	2	10	55	54.67	231.80	138.55	108.30	DEC	39.02	264.10	4.8
86	11	3	2	41	16.79	135.43	156.98	132.50	ASCENDING	42.15	272.05	21.1
86	11	3	4	22	64.81	333.51	10.29	147.11	ASCENDING	51.15	264.24	22.3
86	11	3	9	27	25.69	39.51	38.19	124.45	DEC	45.01	272.76	4.0
86	11	4	2	53	25.70	320.30	25.32	134.71	ASCENDING	44.99	268.55	21.1
86	11	4	7	58	64.83	26.42	30.57	139.60	DEC	51.16	277.05	2.7
86	11	4	9	39	16.78	224.81	144.53	122.53	DEC	42.17	269.25	3.9
86	11	5	1	25	54.72	128.24	148.01	119.48	ASCENDING	39.01	277.21	20.2
86	11	5	3	5	50.72	326.28	28.51	136.92	ASCENDING	47.87	265.93	21.1
86	11	5	8	10	53.75	32.58	28.18	137.90	DEC	48.41	275.74	2.9
86	11	5	9	50	50.50	230.97	148.15	120.60	DEC	39.50	264.95	3.8
86	11	6	1	37	24.46	134.17	144.00	121.93	ASCENDING	41.64	272.79	20.1
86	11	6	3	18	63.25	332.40	31.58	139.12	ASCENDING	50.66	264.40	21.3
86	11	6	8	22	31.76	38.54	25.68	135.16	DEC	45.54	273.32	2.9
86	11	6	10	2	68.22	236.42	151.22	118.66	DEC	37.07	260.02	3.7
86	11	7	1	49	18.97	319.35	39.20	124.16	ASCENDING	44.47	269.14	20.0
86	11	7	6	53	66.23	25.30	10.15	148.86	DEC	51.64	277.17	1.7
86	11	7	8	34	8.99	223.24	155.79	134.41	DEC	42.68	269.96	2.8
86	11	8	0	21	58.43	126.73	137.69	108.34	ASCENDING	38.59	278.15	19.2
86	11	8	2	1	47.30	325.24	42.98	126.52	ASCENDING	47.35	266.35	20.1
86	11	8	7	6	56.40	31.51	9.20	147.74	DEC	48.93	276.08	1.8
86	11	8	8	46	45.79	230.05	159.56	132.61	DEC	39.99	265.78	2.8
86	11	9	0	32	31.56	131.53	134.61	110.68	ASCENDING	41.20	273.63	19.1
86	11	9	2	13	61.51	331.30	46.85	128.86	ASCENDING	50.16	264.60	20.1
86	11	9	7	18	37.13	37.54	8.00	146.48	DEC	46.07	273.85	1.9
86	11	9	8	58	65.70	235.10	161.72	130.77	DEC	37.46	261.01	2.6
86	11	10	0	44	11.77	318.54	50.66	113.01	ASCENDING	43.94	269.76	19.0
86	11	10	2	25	69.06	338.21	51.42	131.22	ASCENDING	52.80	264.24	20.3
86	11	10	5	49	67.50	23.52	19.05	153.79	DEC	52.16	277.09	.67
86	11	10	7	30	3.58	188.64	121.39	145.13	DEC	43.20	270.65	1.8
86	11	10	23	16	61.73	125.90	127.30	97.38	ASCENDING	38.12	279.04	18.1

TABLE D.1C: SAGE II PREDICTED MEASUREMENT TIME AND LOCATIONS

MADISON, WI
STD LATITUDE 43.2
STD LONGITUDE -84.2
RADIUS 500.0

LAT(DEG)	LONG(DEG)	DATE	GMT TIME	DIST(KM)	EVENT
44.95	279.10	4/23/1986	0:12:13.56	327.85	SUNSET
41.46	274.92	4/24/1986	0:24: 9.96	206.59	SUNSET
42.55	278.30	9/16/1986	23:30:32.65	216.57	SUNSET
38.95	274.64	9/17/1986	23:42:29.63	483.11	SUNSET
39.92	279.27	10/11/1986	11:33:10.44	465.86	SUNRISE
43.21	277.25	10/12/1986	11:45:19.33	117.85	SUNRISE
46.01	275.30	10/13/1986	11:57:21.90	315.32	SUNRISE
44.14	275.75	10/31/1986	12:16:41.83	104.49	SUNRISE
40.69	271.35	11/ 1/1986	12:28:57.56	462.24	SUNRISE
41.91	281.48	11/10/1986	21:53:42.87	487.20	SUNSET
44.00	276.95	11/11/1986	22: 5:39.93	129.16	SUNSET
45.71	272.58	11/12/1986	22:17:31.82	378.74	SUNSET
46.24	276.55	11/26/1986	21:47:16.14	343.12	SUNSET
44.75	274.70	11/27/1986	21:59: 5.05	193.42	SUNSET
42.90	273.08	11/28/1986	22:10:59.40	223.57	SUNSET
40.60	271.70	11/29/1986	22:23: .69	446.34	SUNSET
44.64	278.47	1/ 6/1987	13: 7:50.37	267.22	SUNRISE
43.30	274.33	1/ 7/1987	13:19:37.09	120.00	SUNRISE
42.76	279.42	1/22/1987	22:17:25.86	298.86	SUNSET
44.90	275.22	1/23/1987	22:29:23.48	194.99	SUNSET
41.37	276.31	3/ 5/1987	12: 8: 2.18	207.90	SUNRISE
44.51	273.51	3/ 6/1987	12:19:58.12	234.52	SUNRISE

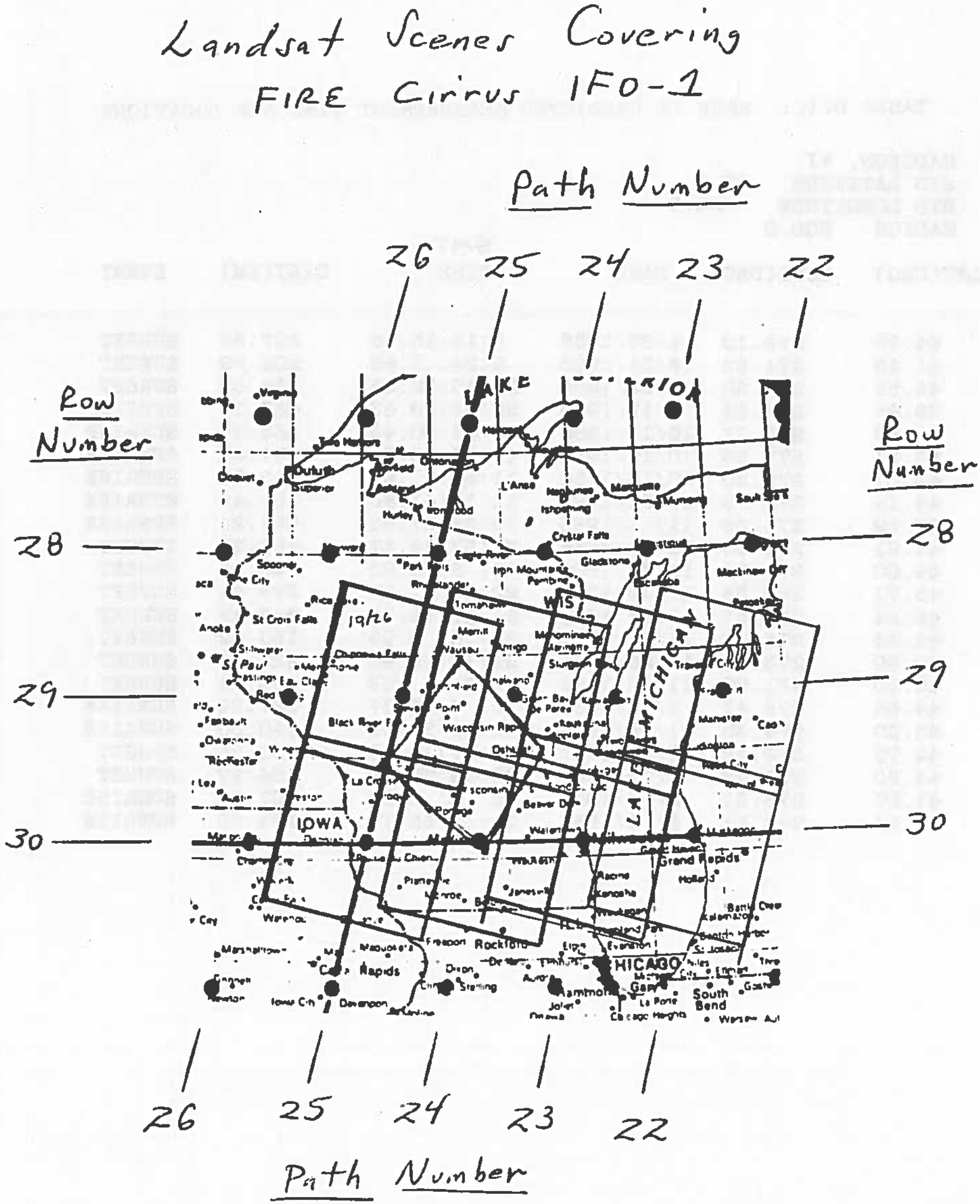

Figure D.2 - LANDSAT Scenes Covering FIRE Cirrus IFO-1

APPENDIX E

EXPERIMENT PLAN
FOR
WISCONSIN SURFACE RADIATION BUDGET DATA SET
DURING
OCTOBER 1986

EXPERIMENT OBJECTIVES

The primary objective is to obtain a pilot study data set for downwelled shortwave irradiance at the surface (SW, 0-5 microns) which meets the Surface Radiation Budget (SRB) Workshop document (Suttles and Ohring, 1986) requirements for accuracy (10 W/m^2) and spatial resolution (10-150 km grid). The data set shall include all satellite as well as ground-based measurements needed to apply and compare various satellite data analysis algorithms for obtaining global downwelled SW irradiance from ISCCP[1] data products. the data set shall include all types of sky, cloud, and solar angle conditions over a 3-week period.

A secondary objective is to obtain a test data set for downwelled longwave irradiance at the surface (LW, greater than 5 microns) which approaches the SRB Workshop document (Suttles and Ohring, 1986) requirements for accurace (10 W/m^2) and spacial resolution (30-250 km grid). For this experiment, expected accuracy of the downwelled LW irradiance will be of the order of 10-20 W/m^2 and spatial resolution will be over a 50-150 km grid system. The data set shall include downwelled surface irradiance, cloud information, rawinsonde data, TOVS[2] and GOES[3] data, as well as ISCCP data products for both day and night conditions over a 3-week period.

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1 International Cloud Climatology Project.
2 TIROS Operational Vertical Sounder.
3 Geostationary Operational Environmental Satellite.

EXPERIMENTAL MEASUREMENTS

Shortwave Data

Ground-Based:

In a cooperative effort with FIRE[1], downswelled SW irradiance will be measured at a total of 18 stations by Kipp and Epply PSP pyranometers located in a grid pattern with spacings ranging form 10 to 150 km (see figure 1). All SW instruments will be intercompared with each other prior to the experiment and most will be calibrated both before and after the experiment period. In addition, some of the instruments will have been calibrated prior to the experiment by both Eppley and NOAA. In general, measurements will be taken every few seconds and averged to obtain minute values which are recorded over the 3-week period.

Sky photographs (35 mm) will be taken every hour from the base of operations at Wisconsin Dells to give qualitative information on cloud conditions. In addition, visible-wavelength optical depths will be taken from the same location every hour with a hand-held photometer on clear-sky days.

Lidar measurements of backscatter profile will be taken once a day from Ft. McCoy near the time of the NOAA-9 satellite overpass (approximately 2:00 PM) under all sky conditions. When cirrus clouds exist, near-simultaneous lidar and optical depth measurements will be made at Ft. McCoy.

Satellite:

One-km resolution visible and 8-km resolution infrared images will be obtained from GOES every 3-hours over the 3-week data period. That satellite data will be calibrated to obtain radiance from counts by NOAA U-2 experiments over White Sands during October and/ or by vicarious calculation using the technique of Frouin and Gautier, 1985. These results will be compared with ISCCP normalization values in order to obtain a recommended data reduction procedure for SRB algorithm investigators, In addition, the ISCCP cloud fraction and optical depth algorithms will be obtained and made available to SRB investigators as part of the satellite data package.

Hige-resolution TOVS data products will also be obtained by NOAA using special procedures over the 3-week data period. These data will be 4 times a day as per the NOAA polar orbiter schedule.

[1] First ISCCP Regional Experiment.

Longwave Data

Ground-based:

In a cooperative effort with FIRE, downwelled LW irradiance will be measured with Eppley PIR instruments at a total of 8 stations located in a grid pattern with spacings ranging from 50 to 150 km (see figure 2). All LW instruments will be calibrated before the experiment and will be intercompared with each other just prior to field measurements. Each instrument contains both dome and body thermistors from which dome temperature difference corrections will be made. The corrections will be based on coefficients determined from controlled laboratory and field-shading measurements at actual experimental body temperatures. Five of the stations will also have continuous recording of surface air temperature and relative humidity.

Sky photographs (35 mm) will be taken every hour from Wisconsin Dells to give qualitative infromation on cloud conditions. In addition, visible-wavelength optical depths will be taken every hour at the same location with a hand-held photometer on clear-sky days.

Lidar measurements of backscatter profile will be taken once a day from Ft. McCoy near the time of the NOAA-9 satellite overpass (approximately 2:00 PM) under all sky conditions. When cirrus clouds exist, near-simultaneous lidar and optical depth measurements will be make at Ft. McCoy. A limited number of lidar soundings will also be make at night or in the early morning coincident with rawinsonde launchings under NOAA-7 and NOAA-9 TOVS. The purpose is to provide cloud bottom altitude such that cloud bottom temperature may be deduced from rawinsonde data.

Rawinsonde balloon data will be taken from Ft McCoy near the time of NOAA-9 afternoon overpasses under all sky conditions. As discussed above, a limited number of Ft. McCoy rawinsonde soundings will be taken from Platteville and Green Bay, Wisconsin at 7:00 AM and 7:00 PM under all sky conditions near the overpass times of NOAA-7. Soundings from these latter two stations should be useful in validating high-resolution TOVS data products.

Satellite:

Both GOES and TOVS data will be obtained as discussed under the SW data section.

OPERATIONAL SCHEDULE

Surface-based irradiance instruments will be calibrated in an absolute sense and tested with their data logging systems during the Summer of 1986 by their respective organizations (NASA Langley, Colorado State University, Purdue University, Columbia University, and the University of British Columbia). The instruments will intercompared with each other during the period October 8-13, 1986 in Madison, WI. On October 13, each instrument will be deployed at its respective site, and the experiment period will continue until November 1, 1986. All instruments shall be recalibrated in an absolute sense after the experiment.

Arrangements for NOAA and/or Scripps-type calibration of the GOES visible channel will be completed during the Summer of 1986. Also procedures for obtaining the high resolution TOVS data product must be established in this same time period.

TOVS satellite data should be obtained within a few weeks after the experiment. GOES satellite data will not be obtained until 4 to 6 months after the experiment. It is expected that calibrations and ISCCP products should be available in this time period.

Surface irradiance data should be available with final calibrations and dome temperature corrections within 6 months after the experiment. Rawinsonde, lidar backscatter, optical depth, and general meteorology data should also be synthesized within this same time period.

DATA DISTRIBUTION

It is planned that SW pilot study satellite data will be official ly distributed to SRB algorithm investigators during the Summer of 1987. The SW surface irradiance data as will as lidar and rawinsonde results will make available as "truth and error assessment" data later at the time of actual SW algorithm intercomparison. (The data for Cirrus and clear-sky conditions only will be distributed to FIRE early as per their requirements.)

The LW test data set will be carefull assessed for accuracy considering known limitations in the LW measurement state of art. Portions of the data will be distributed to SRB algorithm developers in an imformal manner. (The data for Cirrus and clear-sky conditions only will be distributed early to FIRE as per their requirements.) Depending on accuracy results and weather conditions, portions of the LW data set may be reserved as part of a future LW pilot data set.

REFERENCES

Frouin, R., and Gautier, C.: Calibration of GOES-5 and GOES-6 VISSR/VAS Shortwave Channels. Presented at the ESA 3rd International Colloquium on the Spectral Signatures of Objects in Remote Sensing, December 16-20, 1985, Les Arcs, France.

Suttles, J. T., and Ohring, G.: Surface Radiation Budget for Climate Applications. WCP-115, 1986 (Also NASA RP-1169).

REFERENCES

[illegible]

[illegible]

APPENDIX F

General Information of Local Area

The Bionetics Corporation has reserved a block of rooms in available motels located in the area of each of the IFO sites. Information on the lodging request form will provide the accommodation requirements you desire during your participation in the Cirrus IFO Mission. While the responsibility to obtain lodging will be yours, reservations assistance will be available prior to September 1, 1986. All unreserved rooms will be cancelled after that date.

MADISON

Midway Motor Lodge 608-244-2424
3710 East Washington Avenue, Madison, WI 53704
Single: $32.00 + 12% tax; Total $35.84
Double: $36.00 + 12% tax; Total $40.32

WAUSAU

Holiday Inn 715-845-4341
201 North 17th Avenue, Wausau, WI 54401
Single: $36.00 + 10% tax; Total $39.60
Double: $41.00 + 10% tax; Total $45.10

FT. McCOY

Heritage Hotel 608-269-6991
Highway 16 & 27, Sparta, WI
Single: $23.00 + 5% tax; Total $24.15

Janes Motel 608-269-3066
Highway 16, Sparta, WI
Single: $23.10 (includes tax)
Three beds (One bedroom) Completely furnished apartment: $44.10
Four beds (Two bedrooms) Completely furnished apartment: $56.00

PLATTEVILLE

Gov. Dodge Motel/Best Western 608-348-2301
Highway 151, Platteville, WI 53818
Single: $37.00 + 5% tax; Total $38.85
Double: $47.00 + 5% tax; Total $49.35

Mound View Motel 608-348-9518
Platteville, WI
Single: $22.00 + 5% tax; Total $23.10
Double: $30.00 + 5% tax; Total $31.50 (one bed)
Double: $35.00 + 5% tax; Total $36.75 (two beds)

OSHKOSH

Holiday Inn 414-233-1511
500 South Koeller, Oshkosh, WI 54901
Single: $38.00 + 10% tax; Total $41.80

Howard Johnson Motor Lodge 414-233-1200
US 41 & Wisconsin 21, Oshkosh, WI 54901
Single: $27.00 + 10% tax; Total $29.70
Double: $33.00 + 10% tax; Total $36.30

Tiffany Inn Bed & Breakfast 414-426-1000
206 Algoma Boulevard, Oshkosh, WI 54901
Carriage House: $40-$65.00 + 10% tax; Total $44-$71.50
Main House: $70-$80.00 + 10% tax; Total $77-$88