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NATURAL ENVIRONMENT SUPPORT GUIDELINES FOR SPACE SHUTTLE TESTS AND OPERATIONS

By E. A. Carter and S. C. Prown
Space Sciences Laboratory

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16. ABSTRACT

This report outlines Space Shuttle activities that will require natural environment support and suggests some concepts and procedures to provide that support. All Space Shuttle events from launch through SRB recovery and orbiter landing are considered.

While the philosophy used to establish the natural environment design criteria should insure a low-risk operation there will certainly be some atmospheric constraints established. For example, the vehicle will probably be constrained from flight through a thunderstorm. This constraint then may dictate the establishment of a procedure to identify, monitor, and predict thunderstorm activity in the Space Shuttle flight path. Similar reasoning may be applied to any natural environmental hazard or possible vehicle constraint.

At this point in time it appears that the activities most likely to require advanced detection and monitoring techniques are those from deorbit decision to Orbiter landing. The inflexible flight plan may require the (perhaps real-time) transmission of wind profile information below 24 km (80K ft) and warnings of thunderstorms or turbulence in the Orbiter flight path. This activity may also require extensive aerial reconnaissance and communication facilities and procedures to permit immediate transmission of aircraft reports to the mission control authority and to the Orbiter.

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Contribution to this report were made by an ad hoc team appointed by NASA and Air Force Project Management and included representatives of MSFC, JSC, KSC, SAMSO, and SAMTEC.

PREFACE

The Space Shuttle has as one of its design goals the requirement that it have a minimum operational constraint due to natural environment conditions. This includes not only terrestrial weather activity but also orbital space environment influences. The natural environment criteria requirements on the Space Shuttle design have been developed with this objective in mind. However, it is not practical to design the Space Shuttle such that it can operate satisfactorily in any and all natural environments. Even those environments for which the design is intended to insure maximum operational capability (for example, triggered lightning discharges, maximum dynamic pressure level extreme winds, and high levels of solar radiation) may cause problems. Avoiding unnecessary encounters with these conditions through the use of prelaunch observations, predictions, and real-time monitorship during operation is obviously a prudent precaution.

The objective of this report is to focus attention on these Space Shuttle test and operational events that may need natural environment support based on the Space Shuttle system as described in the NASA Space Shuttle Program (Level II) JSC 07700 documents. By doing so, efforts can be made early in the facilities planning, mission operations network development, and ground mission operations control center establishment to accommodate an adequate degree of natural environment support. It appears that most, if not all, envisioned natural environment support requirements can be met from either existing support capabilities or technology which should easily be operational in this decade. Probably the single most important requirement will be near-real-time communications of natural environment observations and predictions so that warnings and alternate options can be implemented. Another need will be to organize the available natural environment operational support information for the Space Shuttle such that it can be made available where and when it is needed with optimum use of existing resources. This may seem to be an obvious requirement, but only early planning will enable it to be accomplished in a purposeful and coordinated manner. The only alternative is a fractured operational support situation hurriedly put together in the final few weeks or months before the Space Shuttle test or operational program activities.

This document revises and updates the initial report, NASA CR-61346, completed in 1971. While the earlier report addressed general requirements and initial concepts, this report becomes more specific and is directed to the current Space Shuttle concepts, tests, operational plans and flight schedules. Thus, the natural environment support requirements are phased in with the currently planned timetables.

The Space Shuttle Natural Environment inputs can be found in Appendix 10.10 "Natural Environment Design Requirements," Volume X Space Shuttle Level II Program Definition and Requirements (JSC Document #07700).

It is necessary that during tests and operations the Space Shuttle Mission Control Authority be presented a single coordinated version of the natural environment as it affects the mission. To insure this type of support a focal point is needed through which each phase of the natural environment support is funneled. The focal point, at a single senior organization level would establish the procedure that each source would follow in providing his portion of the natural environment support package. For example, one source might have the responsibility for predicting in-flight winds, another might have the status of alternates, and a third the formation and location of thunderstorms/severe weather. These predictions would all flow through the focal point where they would be integrated into a complete picture of the natural environment. In this way, the Test/Mission Control Authority could receive one official input from which to make a decision.

This report is divided into two chapters to separate discussions from listing and work sheets.

Chapter I entitled "Interfaces Between Tests/Operations and Natural Environment" is comprised of discussion type material, while Chapter II entitled "Detailed Natural Environment Support Requirements" lists the natural environment support required for each Space Shuttle activity.

It is strongly recommended that Chapter I be read in full before proceeding to the work sheets of Chapter II.

William W. Vaughan
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LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

Organizations and Locations

AWS	Air Weather Service, U. S. Air Force, Scott AFB, Ill.
AFGWC	Air Force Global Weather Central, Offutt AFB, Neb.
AFSCF	Air Force Satellite Control Facility, Sunnyvale, Calif.
CKAFS	Cape Kennedy Air Force Station, Florida.
EAFB	Edwards Air Force Base, Calif.
FAA	Federal Aviation Administration, Headquarters, Washington, D.C.
FLOP	Flight Operations Planning Group, JSC, Houston, Tex.
JSC	Johnson Space Center (NASA), Houston, Tex.
KSC	Kennedy Space Center (NASA), Fla.
MSFC	Marshall Space Flight Center (NASA), Huntsville, Ala.
MTF	Mississippi Test Facility, Bay Saint Louis, Miss.
NASA	National Aeronautics and Space Administration, Headquarters, Washington, D.C.
NHC	National Hurricane Center (NOAA), Miami, Fla.
NMC	National Meteorological Center (NOAA), Washington, D.C.
NOAA	National Oceanic and Atmospheric Administration, Headquarters, Washington, D.C.
NSSFC	National Severe Storms Forecast Center (NOAA), Kansas City, Mo.
NWS	National Weather Service (NOAA), Washington, D.C. (formerly United States Weather Bureau)

LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS (Continued)

SAMSO	Space and Missile Systems Organization (Air Force), Los Angeles, Calif.
SAMTEC	Space and Missile Test Center, Vandenberg AFB, Calif.
USAF	United States Air Force, Headquarters, Washington, D.C.
VAFB	Vandenberg Air Force Base, Calif.
WMO	World Meteorological Organization, Geneva, Switzerland

Equipment and Programs

AFT	Atmospheric Flight Tests (Orbiter) (includes approach and landing tests)
AN/ANQ-9	Flight radiosonde unit used with AN/GMD-( ) to transmit data to determine pressure, temperature, humidity, and winds aloft
PWN-()	Flight equipment used with Super Loki rocket and AN/GMD-( )
AN/FPS-16	C-Band, high precision, monopulse tracking radar
AN/GMD-( )	Telemetry and tracking equipment for rawinsonde and certain rocketsonde observations
AN/TMQ-5	Meteorological recording unit used with AN/GMD-( )
APT	Automatic Picture Transmission Capability from satellites
AWARS	Airborne Weather Reconnaissance System
DMSP	Defense Meteorological Satellite Program
D/RADEX	Digitized/Radar Experiment
ET	External Tank used with Space Shuttle Orbiter

LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS (Continued)

GOES	Geostationary Operational Environmental Satellite
ITOS	Improved TIROS Operational Satellite
MLS	Microwave Landing System
NEXAIR	Next Generation Upper Air Sounding System
PIBAL	Pilot Balloon Upper Wind Observation
rawinsonde	A method of evaluation of the wind speed and direction, temperature, pressure, and relative humidity aloft by tracking a rising balloon-borne instrument
SRB	Solid rocket booster
SRM	Solid rocket motor
SSME	Space Shuttle main engine
STS-1	Stratospheric temperature sonde used with AN/GMD-()
TAEM	Terminal Aera Energy Management
TIROS	Television Infrared Observation Satellite
VAB	Vehicle Assembly Building
VFT	Vertical Flight Tests (Orbiter)

<u>Other</u>

CT	Critical turbulence
EVA	Extravehicular Activity outside the Space Shuttle Orbiter
IFR	Instrument Flight Rules

LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS (Concluded)

Mev	Million electron volts
RTLS	Return to Launch Site

FOREWORD

This document was prepared to satisfy a requirement of Task Agreement 986-25-21-368, "Systems Requirements and Synthesis-Aerospace Environment" between the Johnson Space Center Space Shuttle Program Manager and the Marshall Space Flight Center Project Manager. The specific task assignment directs the MSFC Aerospace Environment Division to "Assess the needs for test and operational flight program support relative to natural environment measurements and predictions."

The results of the assessment, which comprise the contents of this report, are presented as guidelines rather than directives. However, it is clear that the authority directing the assessment will require that this material be used when implementing natural environment support procedures and as justification for service and equipment systems.

Also, by virtue of its role as a guidelines document, the report is not intended to contain the detail required to implement natural environment support procedures. That task is the prerogative of those organizations responsible for conducting the Space Shuttle test and operational flight programs. But alerting those organizations now may help to insure that adequate support services will be ready when needed. The Aerospace Environment Division of Marshall Space Flight Center is available, as part of its overall Shuttle System assignment, to assist in developing the appropriate details and procedures to implement the requirements.

While the philosophy used to establish the natural environment design criteria should insure a low risk operation, there will undoubtedly be some atmospheric constraints established. For example, the vehicle will, in all probability, be constrained from flight through a thunderstorm. This constraint then will dictate the establishment of a procedure to identify, monitor, and predict thunderstorm activity in the Space Shuttle flight path. Similar reasoning might be applied to any natural environment hazard or possible vehicle constraint. Consequently, it would seem prudent for those organizations charged with atmospheric support responsibilities to begin developing concepts and establishing procedures to insure avoidance of natural environment hazards during Space Shuttle tests and operations.

At this point in time it appears that the activities most likely to require advanced detection and monitoring procedures are those from deorbit decision to Orbiter landing. Some areas needing special consideration are listed in the following paragraphs:

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1. Communications — It may be necessary to establish procedures for rapid (in some cases real-time) transmission of natural environment observations and measurements to the Space Shuttle operations control authority. For example:

a. Winds in the TAEM region for deorbit decision and descent guidance.

b. Severe weather such as thunderstorms and turbulence in the Orbiter flight path for deorbit decision.

2. Flight Following (Meteorological Watch) — These interchangeable terms refer to the very important function of keeping track of the weather during the course of the mission. Effective flight following requires that the atmospheric specialist be a part of the operations team. He must know the in-flight and terminal conditions for all possible landing sites at all times during the mission. Of course this requires close cooperation with the control authority. It is proposed that flight following as described in Section IVB be instituted.

3. Aerial Reconnaissance — Provide for aerial monitoring of icing and turbulence of the Orbiter flight path from jet aircraft altitudes to landing. Establish communication facilities and procedures to permit immediate transmission of aircraft reconnaissance reports to mission control authority (and perhaps to Orbiter).

SUMMARY CHART

The following chart, a condensation of Chapter II, is for the use of those persons who do not need the detail provided by the entire report. The abbreviated list of Shuttle activities carries a letter code that indicates when each of the natural environment observations/predictions is needed. In the letter code R = required, D = desired, and NR = not required.

The chart indicates, for example, that both winds aloft observations and forecasts are required for ground tests. While winds aloft are not needed for all phases of ground tests, they are required for far-field acoustics and solid rocket booster (SRB) exhaust cloud monitoring and predictions.

SUMMARY CHART — NATURAL ENVIRONMENT REQUIREMENTS

NOTES: This chart is designed to provide an overview of natural environment observations and predictions versus certain critical events or activities. The chart shows, in a gross sense, when during the Shuttle Test or operational period each observation/prediction is needed. (See text of report for details.)

R = Required, D = Desired, NR = Not Required

	Space Shuttle Event or Activity[a]									
	Ground Tests	Carrier Orbiter Tests	Prelaunch	Decision to Launch	Orbit	Decision to Deorbit	Landing	Ferry	SRB Recovery	Remarks
Ground Winds	R R	R R	R R	R R	NR NR	R R	R NR	R R	NR D	Wind Measurements to top of vehicle needed
Winds Aloft	R } to 6 R } km	R R	NR NR	R R	NR NR	R R	NR NR	R R	NR D	
Temperature	R1,2 R1,2	R1,2 R1,2	R1 R'	R1,2 R1,2	NR NR	D1 D1	D1 NR	R1 R1	NR NR	1. Ground/Runway 2. Profile/Aloft
Humidity	R R	R R	R R	D D	NR NR	NR NR	D NR	R R	NR NR	
Hydrometeors	R R	R R	R R	R R	NR NR	R R	R NR	R R	NR NR	
Clouds	R R	R R	R R	R R	NR NR	R R	R NR	R R	NR NR	May require aerial reconnaissance
Visibility	R R	R R	D D	R R	NR NR	R R	R NR	R R	D D	
Flight Following	NR NR	R R	NR NR	R[b] R[b]	R R	R[b] R[b]	NR NR	R R	NR NR	Status of alternates, see foreword and Section IIG
Sea State	NR NR	NR NR	NR NR	D D	NR NR	NR NR	NR NR	NR NR	R R	
Solar Activity	NR NR	NR NR	NR NR	R R	R R	NR NR	NR NR	NR NR	NR NR	
Radiation	NR NR	NR NR	NR NR	R R	R R	NR NR	NR NR	NR NR	NR NR	
Air Frame Icing	NR NR	R R	NR NR	R R	NR NR	R R	NR NR	R R	NR NR	May require aerial reconnaissance
Turbulence	NR NR	R R	NR NR	R R	NR NR	R R	NR NR	R R	NR NR	May require aerial reconnaissance
Lightning	R R	R R	R R	R R	NR NR	R R	NR NR	R R	D D	

a. The first row in each column is for observation, the second is for prediction.

CHAPTER I. INTERFACES BETWEEN TESTS/OPERATIONS AND NATURAL ENVIRONMENT

SECTION I. INTRODUCTION

NASA CR-61346, entitled "Natural Environment Support for Space Shuttle Tests and Operations," was written in 1971 to initiate the planning for the natural environment support requirements for Space Shuttle tests and operations through the 1980's. The earlier document, now superseded by this document, was written in general requirements and based on early Space Shuttle concepts. Some of the concepts have changed and plans have developed so that it is now necessary to reevaluate the natural environment support requirements, start the planning for specific hardware items and techniques, define operational constraints based on design achievements, and develop concepts and procedures to assure that operational constraints, when established, will not be exceeded, while optimizing efficiency and safety for the assigned missions.

The purpose of this report is to identify all Space Shuttle activities or events that need natural environment support and to suggest the type and degree of support needed. This material is not directive but is presented as guidelines for use by those persons charged with planning for and implementing natural environment support procedures for Space Shuttle Tests and Operations.

As the Space Shuttle is being developed, it appears that natural environment support requirements will be more demanding than those for previous large scale space vehicle projects. Thus, it is necessary to optimize current capabilities, identify where new facilities and techniques are required, and implement procedures for timely completion of all preparations coincident with Space Shuttle development.

The numerous volumes of the Space Shuttle program requirements, directives, procedures, etc., controlled by the NASA Space Shuttle Program Manager (Level II), JSC 07700 were used extensively to determine Space Shuttle events which will interface with the natural environment. Operational data and information in this report are based on those documents and are subject to change as these primary reference documents are revised. Appendix 10-10, "Natural Environment Design Requirements," of the Space Shuttle Level II Program Definition and Requirements Volume X (JSC 07700) contains a detailed description of the design requirements.

The entire Space Shuttle tests and operations have again been reviewed, and the degree of involvement of events that interface with the natural environment have been determined. This document will follow the same format as the earlier document with two new sections, one devoted to development tests

(Section III) and one devoted to ferry flights (Section VIII). Also the solid rocket booster (SRB) flight and recovery (Section V,C) has a new operational concept. The primary Space Shuttle launch and recovery sites have been designated as Kennedy Space Center (KSC), Florida, and Vandenberg Air Force Base (VAFB), California. The first launches from VAFB may land at Edwards Air Force Base (EAFB). Thus, the natural environment support for launch and recovery can now be tailored to specific operational locations. Chapter I contains a discussion of the interface between operation/test events and the natural environment. Chapter II specifies the detailed natural environment support requirements for each event within the various phases. Because it is expected that certain trade-offs may be necessary, each event is identified as to the importance of natural environment support to that event (inconvenience, caution or safety) and the support is identified as "required" or "desirable." This identification of events and support is based on the best judgment of those contributing to the preparation of this document.

Section II, Chapter I, describes the natural environment support facilities and capabilities available and programmed to be available to support Space Shuttle operations. This section, with details in an associated Section II, Chapter II, specifies the facilities needed at the operating locations. While requirements may be established in other sections, or in support of other documents, these sections recap existing and programmed facilities. Figures 1 and 2 are diagrams of the proposed KSC and VAFB Space Shuttle launch complexes.

For purposes of this document, Space Shuttle operations are divided into 4 phases:

Phase I — Preliminary and Prelaunch Events.

Phase II — Launch to Orbit Events.

Phase III — Orbit Maneuvers and Operations Events.

Phase IV — Deorbit, Entry and Landing Events.

Each phase is discussed in a separate section (IV through VII) in Chapter I. Events with a natural environment interface within each phase are identified and the support required to minimize adverse effects of the natural environment are specified in corresponding Sections IV through VII in Chapter II.

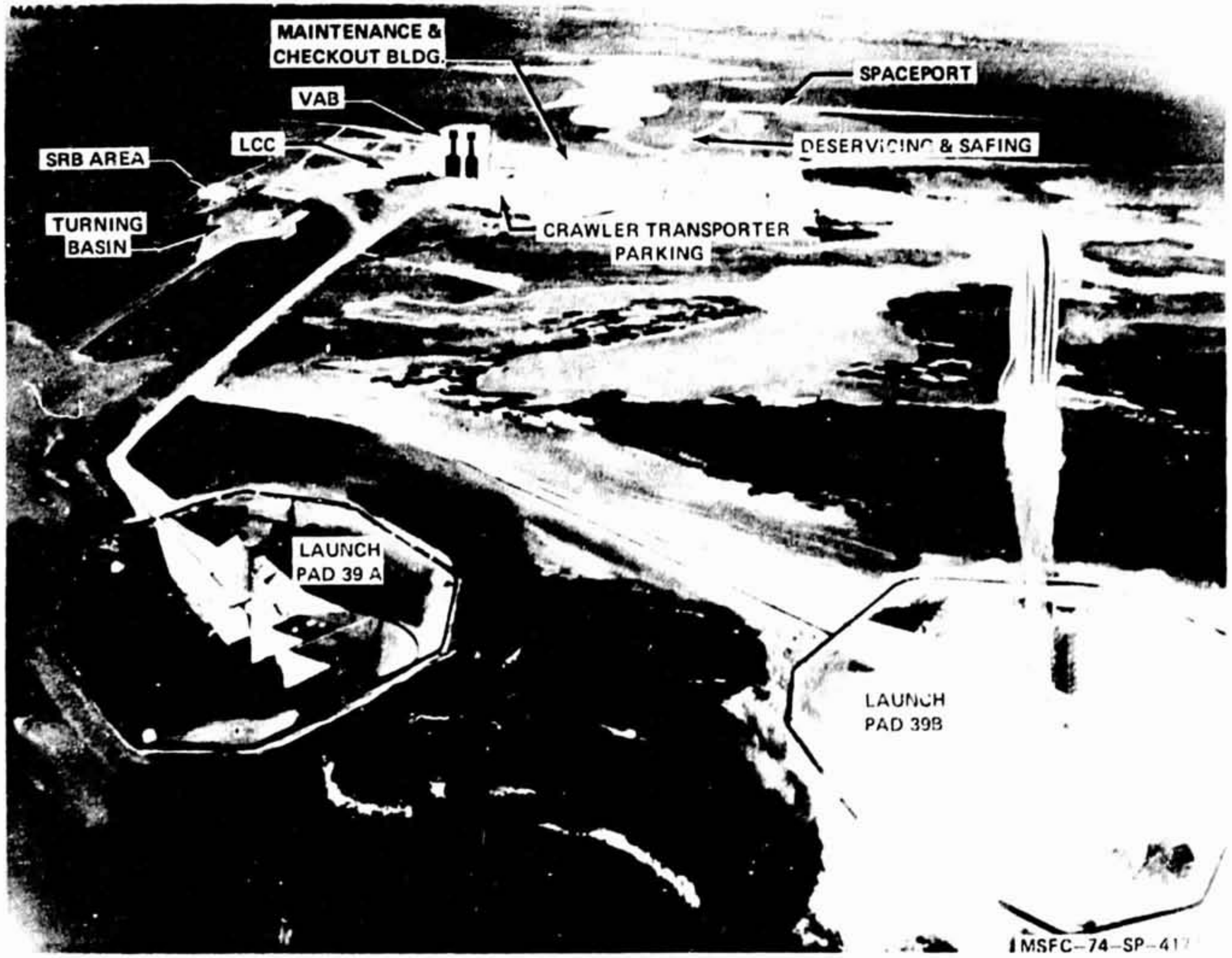


Figure 1. A proposed concept for the KSC Space Shuttle launch complex.

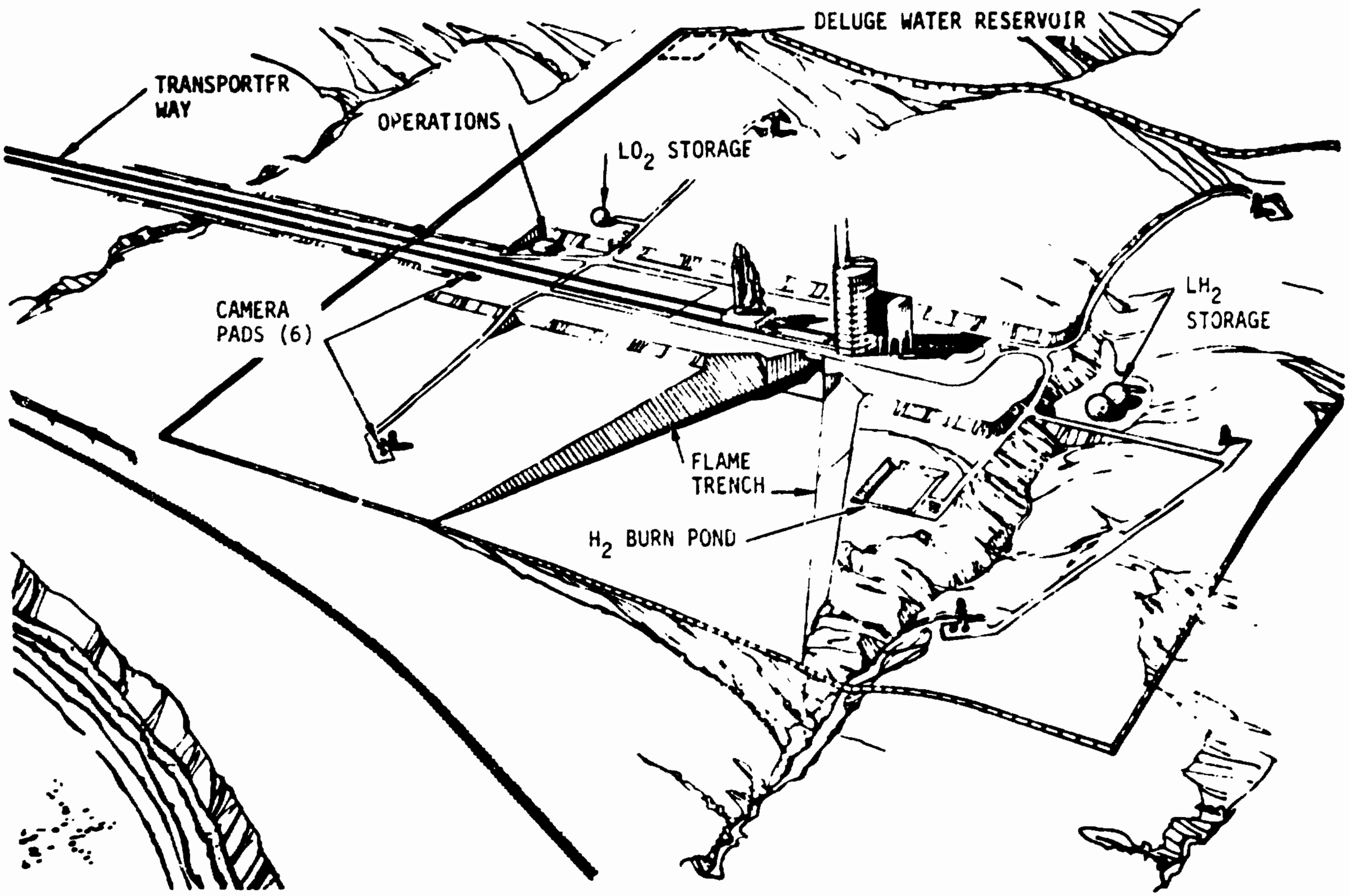


Figure 2. A proposed concept for the VAFB Space Shuttle launch complex.

This document contains a unique, comprehensive Table of Contents with Chapter I and Chapter II page references in columns for easy reference. This also eliminates lists in each chapter, which reduces repetition and, therefore, simplifies revisions. There are other innovations in this document designed to minimize the work in keeping items in the document current. Amendments will generally be page changes or reissue of the document, whichever facilitates easy maintenance of a current document.

The Space Shuttle consists of an Orbiter with a large expendable external fuel tank (ET) which is mated with two recoverable solid rocket boosters (SRBs). Figure 3 is a diagram of the Shuttle flight vehicle configuration. After launch the two boosters will be released at about 41 km altitude (136 000 ft), ascend to apogee at about 64 km (210 000 ft), and descend by parachute for water impact, recovery, refurbishment, and reuse. Ascent max q will be at about 11.25 km (36 900 ft) and SRB descent max q will be at about 17 km (56 000 ft). The disposable ET will be released from about 116 km altitude (380 000 ft) for free-fall and water impact, with descent max q at about 50.6 km (166 000 ft). The Orbiter will continue with a capability of up to 42 man-days in space with various types of missions. After mission completion the Orbiter will enter the atmosphere for glide and landing at the specified terminal. An artist's conception of a typical Space Shuttle mission as presently envisioned is shown in Figure 4. Figure 5 depicts a typical entry trajectory. Table 1 lists the Space Shuttle Program Traffic Schedule.

The present time schedule is that development and operational tests will be conducted through 1977; test vehicles will be utilized in the period 1977 to 1980, and the program will become operational in 1980. Section III, Chapter I, considers the requirements for natural environment support for all tests. This is more inclusive than the earlier document which considered only the tests which would also apply to operational flights, while this document includes all known development tests which have a significant natural environment interface. Of course, experience during tests will be a valuable source of information to use as a basis to modify and improve support for operational flights. Section III, Chapter II provides the detailed natural environment support requirements for development tests.

Ferry flights of the Orbiter vehicle are discussed in Section VIII, Chapter I, with natural environment support requirements for the special ferry flights detailed in Section VIII, Chapter II.

The events and support described in this document are expected to change as the Space Shuttle program evolves. Known changes are solicited to help keep this document current.

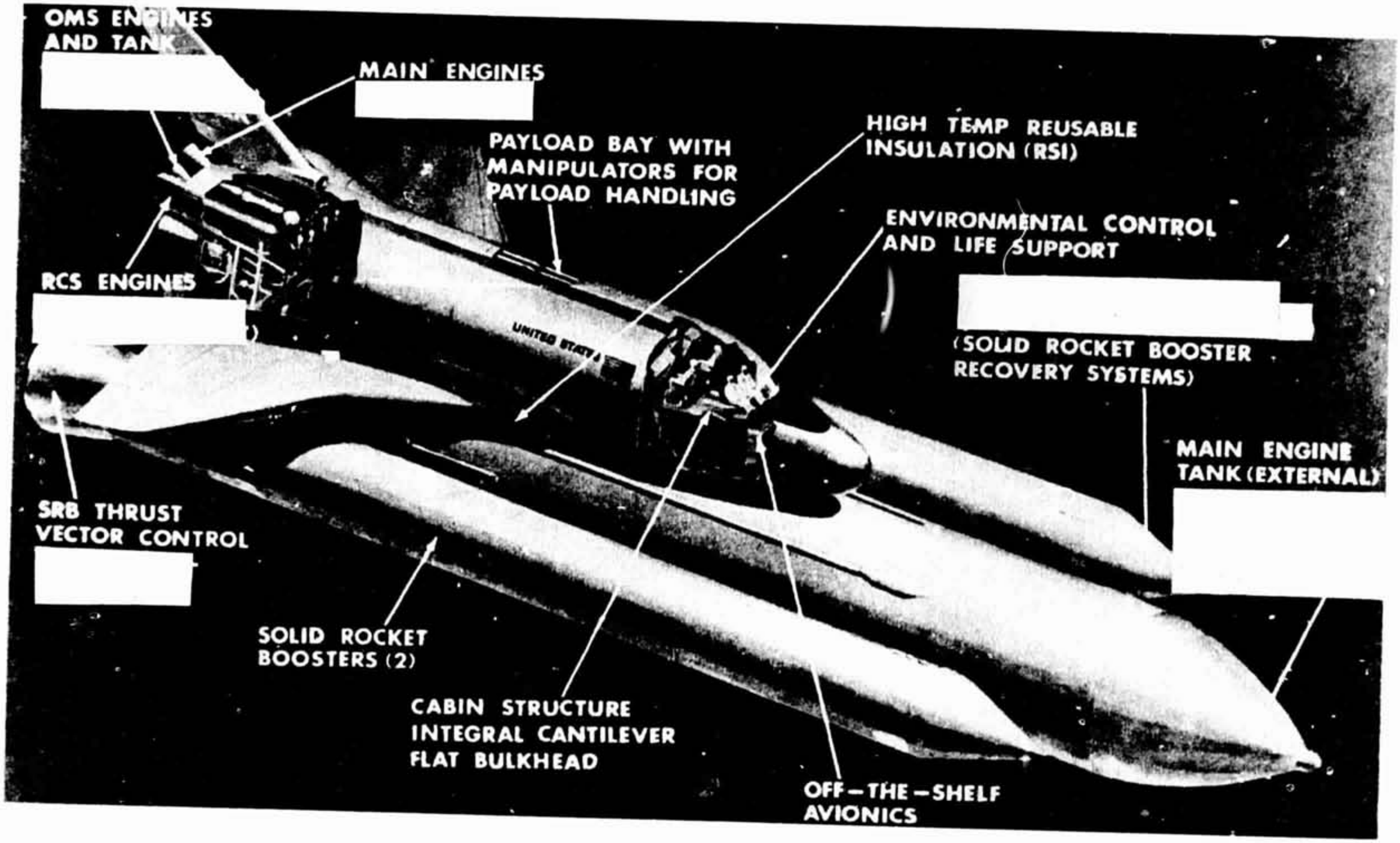


Figure 3. Space Shuttle vehicle.

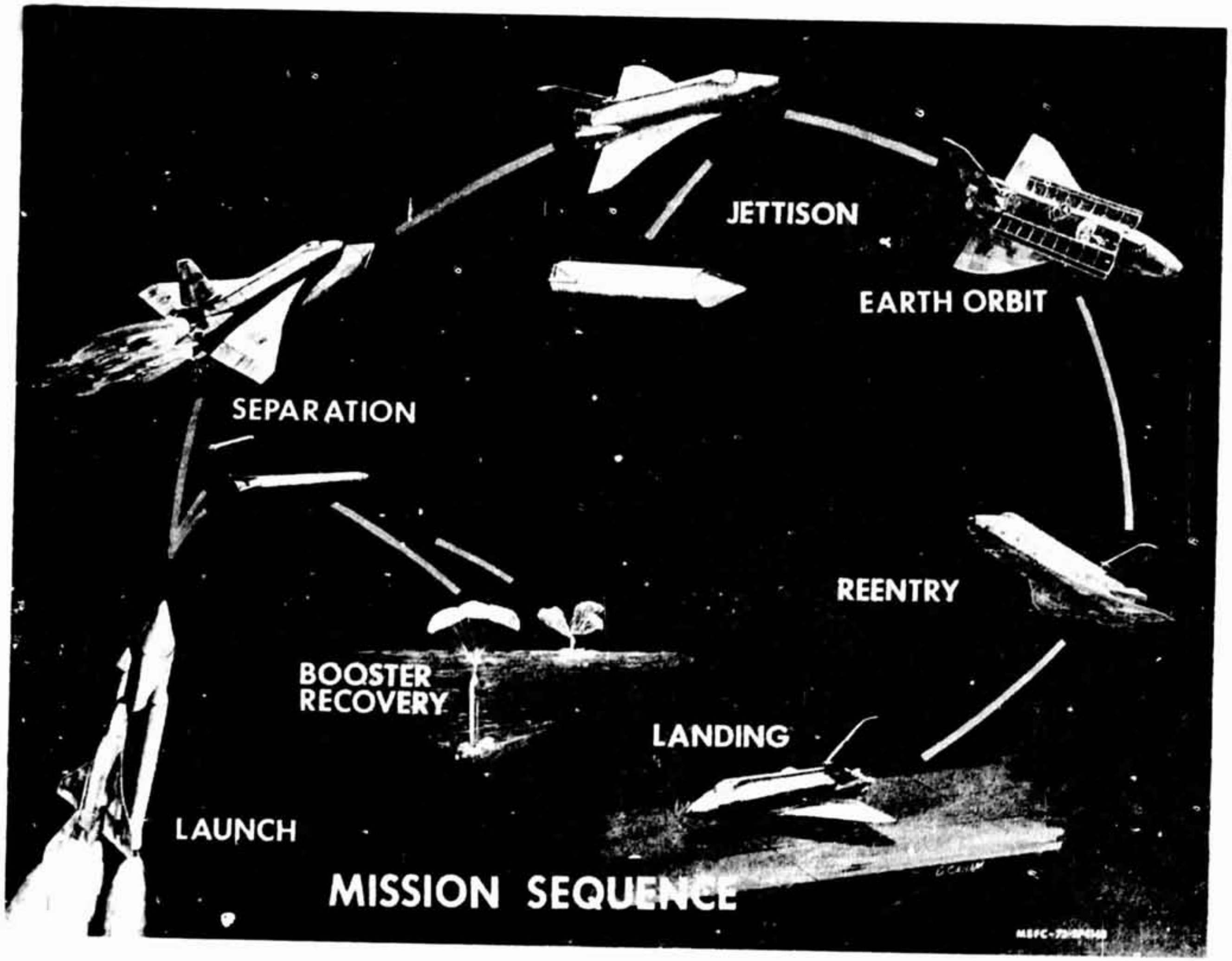


Figure 4. Space Shuttle mission sequence.

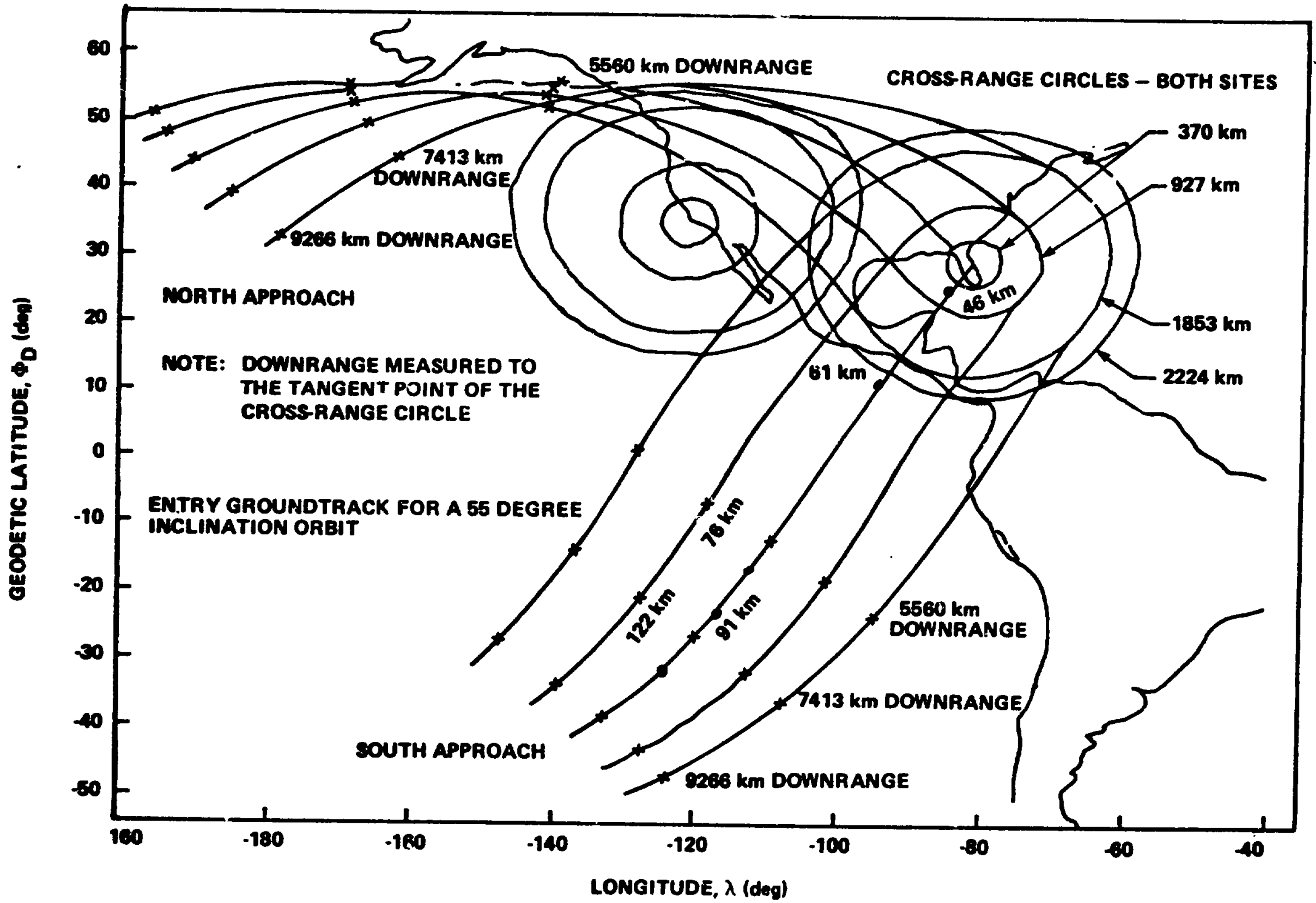


Figure 5. Typical entry ground tracks.

TABLE 1. SHUTTLE PROGRAM TRAFFIC MODEL[a]

3.2.1.1.1 Traffic Model. Program scheduling, operations planning, flight hardware, ground system requirements, and costs shall be based on the Shuttle Program traffic model described in Table 3.2.1.1.1. Launches are assumed to be equally spaced in each year. However, a more rapid second launch shall not be precluded by vehicle or ground system design.

SOURCE:

	Fiscal Year										
	9	80	81	82	83	84	85	86	87	88	89
Total Shuttle Flights/Year	6	15	24	32	40	60	60	60	60	60	28
Flights/Year From KSC	6	15	20	22	26	40	40	40	40	40	18
Flights/Year From VAFB	-	-	4	10	14	20	20	20	20	20	10

a. Taken from JSC 07700, Volume X.

Reliability values given in this document can be considered as root mean square (RMS) deviations about a mean value, which is the best estimate of the measure of the quantity.

SECTION II. NATURAL ENVIRONMENT SUPPORT FACILITIES AVAILABLE AND PROGRAMMED TO BE AVAILABLE TO SUPPORT SPACE SHUTTLE TESTS AND OPERATIONS

The types of natural environment support available to meet Space Shuttle requirements are introduced in this section. Although the information is as complete as possible, a specialist in the specific support required should be consulted for optimum use of resources [1-5]. The Federal Plan for Meteorological Services and Supporting Research, FY 74 [4] has been used extensively as an authoritative reference for descriptions of present and programmed weather service.

Support services for civilian requirements are generally available from the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) and for military requirements from the Department of Defense, Air Force Air Weather Service (AWS), from the U.S. Army (who provide their own weather service for research and development), and from the U.S. Navy (who have a weather service to meet their requirements). Other Government agencies such as the U.S. Coast Guard, the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), and others have the capability to meet their own specialized requirements when the service is not otherwise available. Numerous private companies also provide specialized weather service, studies, and research and development to meet new requirements. Most foreign countries also have a central weather service. Information about foreign weather services is available through the World Meteorological Organization (WMO).

A. Surface Observations

Development of new technology to improve surface weather observations is primarily in two areas:

1. Improvement in automatic sensing and measuring of atmospheric parameters to reduce manpower requirements and secure information from remote and previously inaccessible areas.

2. Improve the automatic collection and initial processing of weather observations.

Both of these will greatly improve the weather information available for Space Shuttle support and specific requirements are identified throughout this document.

1. Wind Observations Near the Surface. Wind measurements near the surface or on towers are usually recorded with wind vanes and cup or impeller anemometers. Standard instruments are reliable to 3 degrees direction and 1.0 m/sec in the usual wind values. Instruments used for range support will provide frequency response up to 2 Hz and 80 percent amplitude resolution. Special low mass anemometers measure three components of the winds at very low wind speeds. Hot wire anemometers are quite accurate, but they are delicate and their use is generally limited to wind tunnels and laboratories. Sonic anemometers have been developed for special uses but the additional cost must be considered for the additional accuracy gained. The near-surface wind

requirements are usually met with vertical and horizontal arrays of standard wind equipment. The wind data may be transmitted immediately to control centers and recorded on magnetic tape. There is also a completely mechanical device which will record the "maximum wind" during a given time period. The FAA is investigating the use of an acoustic and a laser Doppler sounder for low level remote wind measurements to improve measurements of the variability of the wind in areas such as around airports.

The available and programmed surface wind equipment for the Space Shuttle launch and landing is listed in Section II, Chapter II. Wind observations for landing and recovery of the boosters are specified in Events II-9, -10 and -11, Section V, Chapter II.

2. Temperature and Humidity. Temperature and humidity are usually considered together because humidity is quite meaningless without temperature. Both are easily obtained with standard equipment. Relative humidity and absolute humidity are often confused. Relative humidity is the most easily obtained and is popularly referred to as "humidity." It is expressed in percent and represents the percent of water vapor in the air compared to how much water vapor the air could hold, with 100 percent being the saturation point. Absolute humidity is the ratio of the mass of water vapor present to the volume occupied by the moist air mixture, that is, the density of the water vapor component. Absolute humidity is usually expressed in grams of water vapor per cubic meter or, in engineering practice, in grains per cubic foot. When temperature and pressure are known, either type of humidity can be computed from the other. When effects on equipment are considered, the absolute humidity is a more reliable indicator of the amount of water vapor that is available to react with metals or other chemicals.

Temperature and humidity can be determined by a psychrometer — wet- and dry-bulb thermometers — which, when they are properly ventilated, indicate the thermodynamic wet- and dry-bulb temperatures of the atmosphere from which relative or absolute humidity can be determined. Temperature measurements are reliable to about 0.3° C and relative humidity to about 3 percent.

Several temperature and dewpoint measuring sets are on the market which will give continuous readings of temperature from a thermocouple or a resistor and of dewpoint from a chemical solution or from a cooling module and a sensing mirror to measure when condensate forms. These temperature reliabilities are about 0.5° C for temperature and 1° C for dewpoint. These readings can be "remoted," transmitted to a control center and recorded on magnetic tape. A hygrothermograph consists of a strip chart on a drum, usually timed for 8 days, with a temperature pen arm operated by a bimetallic strip or a bourdon tube and a humidity pen arm operated by a hair hygrometer. These readings are not considered accurate, however, unless they are frequently calibrated.

Temperature and humidity equipment for routine observations are adequate for Space Shuttle launch and landing operations. Climatic temperature and humidity data are necessary for vehicle development and to relate development tests to actual operations. Also, temperature and humidity data are needed to evaluate equipment lifetime.

Temperature and humidity data are needed hourly at en route Orbiter ferry sites to compute air density which may be critical for heavy aerospace vehicle operations and also to avoid excessive compartment temperatures if the vehicle is left in the sun where extreme temperatures may reach 88° C (190° F), see Reference 6.

3. Visibility. Visibility has traditionally been a measure of the distance that objects can be distinguished in daylight or lights can be seen at night. A transmissometer has been developed which measures the transmissivity of light, usually in the range of 100 m to 3 km. This transmissivity has been empirically equated to visibility. Reliability is within approximately 10 percent for visibilities up to 5 times the length of the baseline. The system is unreliable for visibilities greater than 5 times the baseline. The "slant-range visibility," a value of direct relation to aircraft landings, is not easily observed. Some attempts have been made to calculate slant-range visibility from surface visibility and cloud heights but these have not been successful. Types of precipitation and condition of the windshield may be significant in making visual contact with the runway. Transmissometer readings may be remoted, recorded, and retransmitted.

Minimum visibilities will be established for safety and to meet mission objectives for launch, landing, and recovery of the boosters. This may vary depending on the mission. Standard visibility observations and predictions will interface with operation events as required in Chapter II.

4. Cloud Heights. Cloud heights are most frequently estimated by a trained observer. Certain mechanical and electronic aids have been developed. A cloud ceiling is defined as the height at which 6/10 or more of the sky is obscured. Both ceiling height and visibility equipment must be supplemented with visual observations to be completely reliable. Equipment to assist in measuring cloud height consists of constantly rising balloons (5 ms^{-1}) for day time use and a ceiling light beam with a theodolite or clinometer for night use

to measure the angle of inclination of the light spot on the cloud base, from which the cloud heights are easily computed. These methods are reliable up to 1 km altitude. Several types of cloud height sets are in use which have a visible or infrared beam and a detector to measure the light spot on the cloud and to compute cloud heights automatically. Readings can be as frequent as every 3 sec. Readings are provided either day or night and reliability is within 10 percent up to six times the baseline (usually 122 m). A vertical pointing radar may be used to detect clouds; it can frequently provide bases and tops of up to three layers of clouds. The measurements of cloud heights can be remoted and transmitted to a control center and recorded on magnetic tape.

Launch of the Space Shuttle vehicle may be through clouds with some limitations and the returning Orbiter may fly through clouds and possibly light rain but these criteria are yet to be determined. Expert predictions, flight following, observations, and possibly reconnaissance will be required. Requirements for cloud information for each operations event are specified in Chapter II.

5. Radar Storm Detectors. Radar storm detectors operating at wavelengths of about 3.2, 5.3, or 10.3 cm can detect clouds to a maximum range of 400 km, depending on the moisture content of the clouds and type of radar used. With this equipment, buildup, movement, and dissipation of fronts, squall lines, and isolated rain showers and thunderstorms can all be detected. The complete data are stored on video tape.

The Basic Weather Radar Network comprises specific NWS and Defense radars. The FAA Air Traffic Control radars are also used in this Network to provide limited data in the mountainous areas of the western United States. NASA and USAF radars will also be available as part of the network for Space Shuttle support operations.

Radar is one of the principal sources of weather information used in preparing vital weather warnings and observations that protect life and property, particularly for control and safety of aircraft in flight.

The Federal Plan for Weather Radars and Remote Displays [7], currently under revision, will provide basic guidance and access for optimum use of the Radar Network. NWS is supporting a Digitized/Radar Experiment (D/RADEX) to complete a three-dimensional digitized radar capability in FY 1974.

6. Remote Automatic Weather Observing Stations. Remote automatic weather observing stations (land and ocean buoy) are available and encompass all of the items of equipment used in taking and recording the surface observations. They operate unattended for up to 2 weeks, or longer with a reliable power source.

Automatic meteorological observing stations have been designed to perform such duties as reading basic meteorological instruments and transmitting data. A comparable system for remote unattended sites is under development. Systems are also being developed to collect data from remote stations by satellite, as well as the satellite capability to observe and report some parameters in remote areas. To get critical sea level information from data-sparse, storm-prone areas, NWS is testing and evaluating three data-gathering buoys. These have proven quite useful and will soon be available for operational programs and scientific investigations. Requirements for these automatic, remote capabilities for collection of data are specified in Chapter II.

7. Electrostatic Potential. Electrostatic potential is measured by a radioactive device to determine the electric field intensity at a point on the earth. The principle of operation of the radioactive device assumes that the ionization of the air close to the conductor is partly carried away by the field or is returned to the sensor, depending upon polarity, until an equilibrium current flow is established.

Another instrument used in measuring potential gradient is the field mill. This instrument operates by allowing a fixed plate to be alternately charged and discharged by the atmospheric potential gradient. Because of the difficulty of calibrating a radioactive device, the field mill is used for more precise measurements of atmospheric potential [5, 8-10].

B. Upper Air Observations

The following improvements are being made in the measurement of upper air parameters:

1. The Next Generation Upper Air Sounding System (NEXAIR) is the use of on-site minicomputers for automatic processing of upper air data from balloon-borne instruments.

2. Experiments have shown that the long-range radar with a digitizer/processor can quantitatively determine severe weather echoes and track them, providing better information on their expected movement.

3. The Airborne Weather Reconnaissance System (AWARS), now under development by the Department of Defense, is a completely integrated system of airborne sensors, with computer-generated display and data processing sub-systems. AWARS is compatible with existing weather collection and data transmission systems and will provide an improved capability to meet requirements for meteorological data collection, processing, and transmission from reconnaissance aircraft.

4. New families of satellites will continue to provide more useful atmospheric data by (a) determining vertical soundings of atmospheric thermodynamic data, (b) providing more and better information from data-sparse areas, and (c) providing better detection and tracking of storms. Also, the observations will be processed for real-time weather support.

5. Remote sensing of atmospheric parameters shows much promise with equipment under development. There is considerable potential for measuring the temperature, humidity, wind, and turbulence in the low levels of the atmosphere with much more detail and reliability than was possible heretofore, and these should be applied to Space Shuttle operations when they become operational.

1. Wind Observations Above the Surface Layer. Winds above the surface layer are observed by noting the motion of objects in the atmosphere as accurately as possible. The use of rising balloons which are tracked by one or two theodolites when they are visible and by radar or radio direction finding equipment is the most widely used method. A radiosonde suspended from a balloon transmits frequencies that are converted to pressure, temperature, and humidity versus altitude and time. The complete observation from the surface until the balloons burst, frequently about 30 km, is called a rawinsonde observation. A radar reflective balloon, which is tracked with a precision radar, provides the most precise wind profile to about 18 km. A roughened balloon is used to prevent or control vortex shedding, with resultant decrease in aerodynamic motion. A widely used sensor is a super pressure-roughened radar reflective balloon about 2 m in diameter, called a "jimsphere." Balloons designed to float at constant altitude can be placed in the atmosphere and tracked for several days.

The resultant wind drift of an aircraft over some distance is used to compute the resultant wind speed and direction at flight altitude. Meteorological rockets launched to altitudes of 65 to 100 km may eject radar chaff, falling spheres, or a sounding instrument. The most common rocketsonde provides information from which winds, temperature, pressure and density are computed from about 65 km to 25 or 30 km at which points the data are compared with radiosonde data. Special sensors are used in the upper atmosphere (see Section IIC5). Many special high-atmosphere and near-earth probes have provided some wind data in this region. Exploration, equipment, and data are expected to become routine above the 65 to 70 km altitude currently achieved and to increase our knowledge of the upper atmosphere greatly in the next few years.

2. Temperature and Humidity. Temperature and humidity in the upper atmosphere are reported routinely by radiosonde observations (the thermodynamic data from the rawinsonde). Moisture decreases below the threshold of routine detection at about 12 km. Special observations have measured moisture above this level but the amount has not been determined as significant for Space Shuttle operational support requirements. Temperature, however, can be measured or computed from nearly all probes discussed under wind observations. Temperature and humidity can be measured from a tethered balloon which is allowed to ascend to about 300 m and is then recovered. Temperature and humidity are also frequently available from aircraft observations. Some specially equipped reconnaissance aircraft may drop sensors known as dropsondes from which profiles of temperature, humidity, and pressure are computed from flight level to the surface from radio signals transmitted to the aircraft.

3. Pressure. Pressure in the upper atmosphere is measured with an aneroid cell and an arm which is activated by the aneroid to sweep across electrical contacts, causing signal transmissions that can be interpreted as pressure. Data are reliable to about 0.2 to 1.0 percent, depending on height, up to 10 mb. Above 10 mb a hypsometer uses the principle of the variation with altitude of the boiling point of a liquid (carbon disulfide) to measure atmospheric pressure. The barometer or hypsometer is part of the sounding equipment described previously.

4. Airborne Radar Storm Detection Equipment. Radar storm detection equipment, specially designed for airborne operation, is often carried aboard aircraft. These observations or scope readings are usually available only to the flight crew and little use is made of them after their immediate use. Special reconnaissance aircraft may photographically record scope pictures of major storms or hurricanes and the AWARS System is designed to make this information available for use along with other weather data.

5. Weather Satellite Observations. Weather satellite observations have provided global cloud cover photographs about 12 years. The program has not yet achieved its full operational capability, but a large amount of useful

data has been collected. Present satellites transmit data directly to ground receiving sites and store the information on magnetic tape for subsequent transmission on demand. Future satellites will rely on scanning radiometers for earth-cloud imagery in both visual and infrared wavelengths.

The environmental satellite program will enter a new phase in 1974 with the launch of two Synchronous Meteorological Satellites, NASA's prototypes for the Geostationary Operational Environmental Satellite (GOES). The GOES system will provide nearly continuous observations of cloud cover, hurricanes, and severe storms and will collect and relay data from observing platforms and remote stations. Both NOAA and the Department of Defense are readying ground facilities for use with the GOES system. NOAA is establishing Satellite Field Service Stations at Miami, Washington D.C., Kansas City, San Francisco, and Honolulu to provide around-the-clock analysis and interpretation of the satellite data for weather analysis and forecasts, storm warnings, and oceanographic forecasts. The Air Force is establishing a similar facility at its Global Weather Central (GWC), Offutt Air Force Base.

The current polar-orbiting NOAA series of operational satellites will be maintained, with new launches scheduled as needed. The ITOS-D, now NOAA 2, was launched in October 1972 and ITOS-E, now NOAA 3, in 1973. Satellites in this series provide day and night images of the earth, its cloud cover and oceans, as well as vertical profiles of temperature and moisture in the atmosphere. Additional information is contained in Reference 11.

C. Space Environment Observing Equipment

1. Earth's Magnetic Field. The earth's magnetic field is measured by a magnetometer network which measures geomagnetic variation. Variations of the geomagnetic data furnished by the network are related to temperature and density variations at the altitudes of low earth satellites. A large solar flare can cause immediate disruption of communications systems due to emission of ultraviolet and X-ray energy. This activity is followed, in 30 to 60 min, by high energy protons, called cosmic rays. About 2 days later the solar protons and electrons emitted from the flare reach the earth's atmosphere, causing magnetic and ionospheric storms. The magnetometer readings provide a quantitative indication of atmospheric and electron density changes to be expected a few hours after the onset of the magnetic storm [2].

2. Ionospheric Soundings. Ionospheric soundings (ionograms) up to the F_2 layer (about 300 km) provide indications of disturbed conditions caused by solar flares or magnetic storms and information concerning the propagation of HF radio communications systems in the region sampled. The ionospheric sounder consists basically of a pulse transmitter, a wide-band receiver, a

readout and a power supply. The equipment determines, as a function of frequency, the virtual heights and electron densities of reflecting layers in the ionosphere up to the layer of maximum electron density (F_2 layer) [2].

3. Cosmic Radio Noise. The relative intensity of cosmic radio noise received at the earth's surface is measured by an instrument called a riometer. The cosmic radio noise is absorbed or attenuated as it passes through the ionosphere and the amount of attenuation depends upon the density of charged particles in the ionosphere. These measurements are useful for detecting solar flare activity and related changes in ionospheric density and for predicting long-range communications conditions [2].

4. Neutron Monitor. A neutron monitor is an equipment system which uniquely detects those secondary neutrons and protons which are produced as a result of collisions of high energy protons with air molecules in the earth's upper atmosphere. The high energy protons, which are emitted from solar flares, have energies greater than 400 Mev. Information concerning the occurrence of high energy protons is useful for providing warnings to manned space activities and for predicting subsequent variations in the density, electron density, and magnetic field strength. The equipment consists of a series of Geiger tubes surrounded by lead and polyethylene. An alarm system is activated when the counting rate exceeds a predetermined level [2].

5. Rocketsonde and Upper Atmosphere Rocket Probes. Rocketsonde and upper atmosphere rocket probes are made on an experimental and test basis. Winds, temperature, pressure, and density are measured quite frequently from rawinsonde altitudes (30 km) to about 65 km. With slightly larger rockets the data can be extended from 65 km to about 90 km. Above 90 km, different techniques must be used and, with larger rockets, the costs increase rapidly. Rocket probes with mass spectrometers to detect the composition of the upper atmosphere have been used experimentally. Data are gathered by these techniques from about 120 km to about 155 km with some measurements as high as 320 km [12]. Special cryogenically cooled instruments may provide atmospheric composition measurements much lower than 120 km.

6. Densities of Satellite Altitudes. Densities at satellite altitudes (140 km and above) are most often computed from orbit trajectories. A drag coefficient of the satellite is computed or assumed, and the orbital decay is a function of the density. Densities at these altitudes are also measured by satellite-borne accelerometers and mass spectrometers.

7. Solar Activity. Solar activity is observed by a solar optical telescope system to maintain continuous visual and photographic surveillance of the solar atmosphere. Also a radio telescope can be used, consisting basically of an antenna and a receiver. The unit of measurement for radio frequencies associated with solar flares is antenna temperature in degrees Kelvin. The radio frequency emission from the sun may increase by several orders of magnitude during a large solar flare. The receiver amplifies only those signals in a certain band of frequencies.

D. Prediction Capabilities of the Natural Environment

Because prediction capabilities have many variables and prediction results are controversial, they are discussed here only in generalities. In addition to the natural environment variables, such variables as the time interval involved, the lead time, the detail desired, the information available and the options available influence a successful prediction capability. There is some capability, however limited, to predict all of the natural environment items discussed herein. Tradeoffs have successfully been reached in the past between observing, engineering and predicting. This document is the initial step to explore ways to again successfully achieve this balance and to identify the actions to follow in the intervening years for support of the Space Shuttle Program.

Nearly all prediction methods require that past occurrences be extensively investigated. Some patterns become apparent (such as seasonal weather conditions and the solar activity cycle), but as more and more detail is required about the future, the more chance there is that some unknown factor will modify the pattern. In the upper atmosphere, data are just becoming available so that as these data are analyzed and more data are gathered, it is reasonable to expect that upper atmosphere predictions will improve more rapidly than those for the lower atmosphere. Also, additional papers on upper atmosphere and space predictions are becoming available [13].

In the lower atmosphere, environmental data have been gathered for many years and the records are available to provide a complete description of past occurrences, so there is now available a nearly complete description of atmospheric phenomena which may be expected to occur in the future, as well as a close estimate of the frequency of expectation of certain criteria. To assure that operations are within the design capability of equipment, the chances of a phenomenon occurring must be traded off against the cost and feasibility of designing for that criterion. Secondly, a capability must be developed to assure that, operationally, the established Space Shuttle design criteria and operational constraints are not exceeded [14]. This is accomplished by (1) carefully measuring the phenomenon, (2) communicating data to control authority along with adequate prediction and warning that the operation is on a collision course with the environment, and (3) directing alternate options that are available.

Progress of prediction capabilities is described in Reference 4 and supporting documents. Special prediction requirements to support events in the Space Shuttle operations are established in Chapter II.

E. Existing and Programmed Facilities for Kennedy Space Center (KSC) and Cape Kennedy Air Force Station (CKAFS), Florida

The existing facilities available for environmental support for the Space Shuttle at KSC and CKAFS are described in detail in Reference 15. A summary of the primary facilities required is listed in this document Chapter II, Section II, which also contains a map of the Wind System Network in the KSC and CKAFS areas.

F. Existing and Programmed Facilities for Vandenberg Air Force Base (VAFB), California

The existing capabilities in support of Space Shuttle Tests and operations at VAFB are described in detail in Reference 16. A summary of primary facilities required is listed in this document, Chapter II, Section II. A map and description of the Weather Information Network and Display System is presented in Chapter II.

G. Natural Environment Support Concepts

This document describes Space Shuttle natural environment service requirements and capabilities to meet known requirements. Although in some cases certain organizations are recommended to meet these requirements, these are intended only to specify possible solutions to begin a systematic procedure to designate support organizations at an early date. It is recommended that a Space Shuttle natural environment support agreement be negotiated between NASA, NOAA, USAF, Navy, and other participants at an early date.

NASA (NOAA) and USAF have weather facilities available to support the Space Shuttle activities at KSC. The MSFC Aerospace Environment Division can provide natural environment support studies for design, mission analysis, diffusion, and other special activities. Normally, JSC controls manned vehicles from lift-off to deorbit. The control for final approach and landing for the Orbiter has not been established.

The forecast facility at VAFB is capable of providing the natural environment support for prelaunch, launch to orbit, and deorbit to landing operations at VAFB and EAFB, California. Normally, AFSCS controls Air Force missions from booster separation to mission completion. Final approach and landing control has not been established.

Initially, natural environment information to and from the Orbiter will be provided through JSC, AFSCS, or other communications center. After some experience, other direct contacts with the Orbiter are being considered for certain information not yet specified.

"Flight Following" should be used for all flights. This consists of a team of atmospheric specialists who analyze every detail of the atmosphere to be encountered in the proposed flight path and continually update their information and analysis as the mission progresses. Additional information continually becomes available and the progress of the mission itself verifies and assists in projecting information for the remainder of the mission.

Worldwide monitoring and forecasting for abort locations is necessary. Several organizations may have this capability. Global Weather Central, Offutt AFB, Nebraska, probably accomplishes this on a routine basis. Coordination is necessary to designate an organization for this function.

SECTION III. DISCUSSION OF NATURAL ENVIRONMENT SUPPORT SERVICE FOR SPACE SHUTTLE DEVELOPMENT TESTS

The Space Shuttle vehicle and support equipment will undergo extensive testing. Some of the tests will require natural environment support specifically for and unique to the tests or series of tests. Other tests will require support similar to that required for future operations. In both cases, the experience gained from the tests will be used in establishing the final operational requirements.

The nature of testing is such that changes are usually required and, while this document will make every attempt to anticipate requirements and specify facilities needed to measure and predict the natural environment expected to be encountered, revisions and improvements are expected during the course of preparation and testing.

Section III, Chapter II describes each test and series of tests with a known natural environment interface and specifies the support required for successful test completion.

The Space Shuttle Program schedule as it is currently known is shown in Table 2.

For all tests in which the natural environment is a significant factor, one must consider not only the environment at the test site but also the environment in which the equipment will operate. For example, a test site in the desert may be adequate and desirable for tests, but subsequent operations at Cape Kennedy may invalidate the tests if "sea air" causes the equipment to deteriorate. When stated, this appears so obvious as to be redundant, but numerous cases have occurred when this was overlooked and extensive modifications were required at the operating location. Also, all changes in the environment with location are not as apparent; therefore, tests must relate to the natural environment at all operating locations. Pertinent NASA documents define the natural environment for all operating locations and the design criteria for space vehicle development [6, 8, 17, 18].

Organizations capable of providing required natural environment support at the test sites are as follows:

1. Edwards AFB — USAF Air Weather Service Detachment.

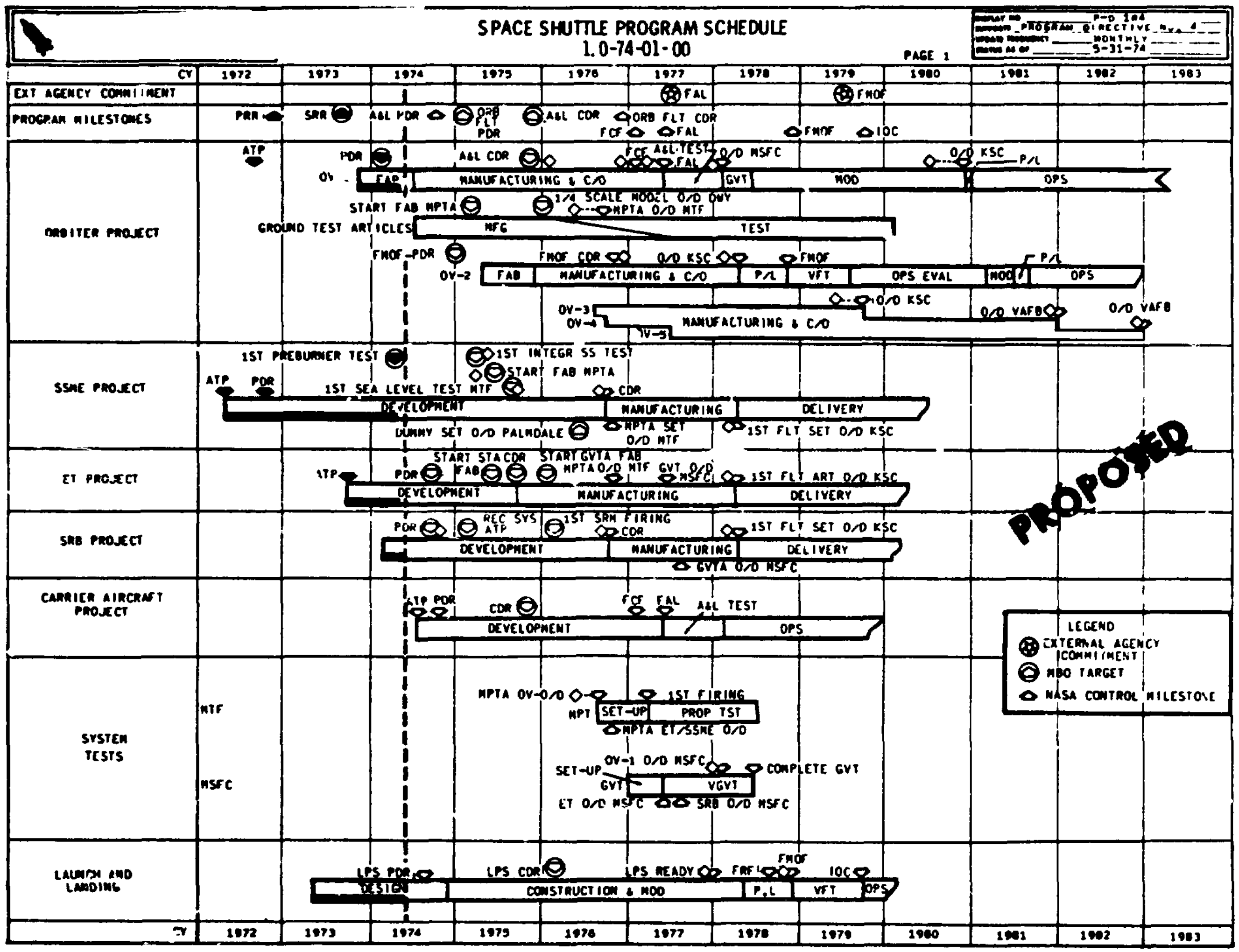
2. Mississippi Test Facility — Assigned technical support contractor and MSFC participation if needed.

3. Kennedy Space Center — NOAA and USAF personnel and facilities are available at Cape Kennedy.

4. Marshall Space Flight Center — NASA personnel and facilities are available at the test area.

Natural environment support for tests at Canoga Park, Santa Susana, and Palmdale, California, should be provided by the organization responsible for the tests. Specific natural environment test support requirements should be coordinated with support personnel well in advance of the requirement. In some cases special data may be required for postanalyses.

TABLE 2. SPACE SHUTTLE PROGRAM SCHEDULE



SECTION IV. DISCUSSION OF NATURAL ENVIRONMENT SUPPORT SERVICE FOR PHASE I EVENTS – PRELIMINARIES AND PRELAUNCH

Preliminaries for the first flights will include considerable developmental testing. The preliminary events for which a standardized natural environment support service appears desirable are included here. Since the Orbiter is reusable, all events which occur after a landing from a previous mission are included in the preliminaries and prelaunch phase for the next mission, except ferry flights which are considered in Section IX. All listed events may not occur during each sequence but the support must be available. The preliminaries are considered as events which take place before the booster and Orbiter are erected for mission launch. There are no firm lines between events and service for any one event may be available from service provided for other events, but for each mission sequence there must be a conscious effort to provide for service required so that lead times are properly anticipated and milestones are successfully achieved. Events may range from a decision to proceed or to alter or cancel the mission because of a condition of extreme emergency. By meeting the requirements for each event, the natural environment service support is expected to develop into a smooth-flowing, available, service operation which can be applied as needed for the success of the mission.

The Phase I events for which natural environment service is specified are listed in the Table of Contents and are discussed in Section IV, Chapter II. Events 1 through 3 are generally considered in preliminary events but some of them must also be considered in prelaunch. Events 4 through 9 are milestones in the prelaunch countdown. Generally this support is patterned after experience gained from Saturn V-Apollo missions [19] and is expected to be revised as the Space Shuttle is developed and tested.

A. Preliminaries

The preliminaries are considered as events which may take place at any place in the world, although generally within the 50 states.

The surface extremes which must be considered are described in References 6 and 17. References 20 and 21 describe the toxic fuel hazards. Section II and References 6 and 17 provide the background necessary to meet the support requirements in Events 1 through 3.

B. Prelaunch

The prelaunch events 4 through 8 are a series of countdown events in which a hazardous environment might cause delays or serious damage. Event 7 requires an advance prediction for the entire mission.

Events 4 through 8 are based on experiences which were encountered in Saturn and other countdowns. However, the environment service is expected to be more exacting for the Spacc Shuttle mated vehicle. The operational vehicles are expected to be on the launch pad only a few days, but test vehicles may be on the pad for several months. The unique support requirements to be considered during this period are as follows:

1. The wind profile from the surface to about 91 m is required. Observations for this profile are required from a meteorological tower near the launch complex. Also on-pad measurements near the top and base of the vehicle are minimum requirements. Predictions must be made for the entire preparation period. The extreme conditions expected are available from climatological records. Continuous predictions up to 72 hours must be made so that precautions can be taken if certain limits are expected.

2. The temperature profile from the surface to about 91 m is required. The basic profile from sensors on a meteorological tower are required, and additional measurements are needed from the surface of the vehicle to compute vehicle bending (due to thermal stresses); and temperatures are needed from inside the vehicle for compartment and equipment temperatures.

3. Measurements must also be made of humidity and other impurities which may cause deterioration of equipment used repeatedly.

4. Items associated with storms must also be monitored and predicted. Storm radar is required for short-term predictions (up to 3 hours) for storms. Specific items to monitor and predict for storms are winds, hail, electrical potential, precipitation, and cloud cover. Data obtained via satellite are required to help interpret storm movement and intensity.

5. Operational sea state or wave energy forecasts for the SRB recovery areas are made routinely by the Fleet Numerical Weather Central at Monterey. These forecasts should be available from approximately 36 hours before launch until the solid rocket boosters are recovered.

In Event 7, decisions to launch are made continually, based partially on the complete spectrum of environmental information for which this document establishes the requirement. There will be certain milestones throughout the mission when this decision will be reviewed. At that time all items in this document for which some foresight is available should be presented. Particular emphasis must be placed on all items which will be critical prior to the next review period. Some decisions will irrevocably commit certain events. The predictions for these events must be carefully prepared and clearly presented. Although the Space Shuttle is planned to become a routine operation, the decisions to proceed with each phase must guard against apathy and such checks should be included in the standardization procedures. Automatic warnings and safeguards must be built into the system to prevent proceeding until all natural environment items have been considered.

The natural environment requirements for mission abort, Event 8, must be satisfied before the decision to launch is made. For the once-around and return to launch site (RTLS) aborts, the landing requirements are the same as those listed in Section VII. Since emergency landings at other locations might be considered, for example at EAFB, it would be necessary to know the status of those airfields prior to launch.

SECTION V. DISCUSSION OF NATURAL ENVIRONMENT SUPPORT SERVICE FOR PHASE II EVENTS – LAUNCH TO ORBIT

The natural environment for the launch-to-orbit phase must be well understood when the final decision to launch is made. The operations events which interface with the natural environment and the means of providing the required service are detailed in Chapter II of this document but they are summarized here. The four groups of events are listed in the Table of Contents. Events 1 through 3 involve the lift-off and lower atmosphere flight. Events 4 through 6 involve the transition portion of the flight (above 7 km). Events 7 through 11 involve the booster flight and recovery. Events 12 through 14 involve the Orbiter flight into earth orbit and disposal of the external tank (ET). The service requirement is based on Saturn V-Apollo experience and it is expected that much more knowledge will be gained during Space Shuttle development tests.

A. Lift-Off and Low Atmosphere Flight

Events 1 through 3 require observation, analysis, and prediction of the lower atmosphere (up to 7 km) as it involves the Space Shuttle. In addition to routine data, the following unique support requirements must be considered:

1. The detailed wind, temperature, and humidity profiles from the surface to approximately 91 m are required and will be measured from sensors on a meteorological tower located in the launch complex. In addition, it is necessary to have wind sensors on the launch tower to monitor the effect of the wind on the vehicle and the booster exhaust cloud.

2. The wind and temperature profile from the surface to about 27 km, obtained from weather charts and from rawinsonde and FPS-16 radar/jimsphere observations, are required. Winds up to 3 km are required for pollution control and up to 6 km for acoustic propagation.

3. Special equipment is required to obtain information of the electrostatic potential between the earth and the atmosphere.

4. Aerial reconnaissance of cloud conditions should be available and used as necessary. Very high level reconnaissance from U-2 type aircraft, AWARS, satellites, or other means with sensors telemetering data and transmitting pictures to the control center may be desirable.

5. Since the MSFC multilayer diffusion model will be used for exhaust cloud predictions, the capability to acquire all input parameters is required. Generally, detailed information is needed on winds, temperature, humidity, and rain in and surrounding the launch area.

B. Transition Flight

Events 4 through 6 require detailed analysis of the atmosphere for the transition portion of the flight. The following unique support requirements must be considered:

1. Winds, specifically from near the surface to about 18 km, are required in as much detail as possible to predict the effects of maximum dynamic pressure, transonic flight, and any wind shears over the length of the vehicle. The FPS-16/jimsphere is recognized as the required system to obtain detailed wind information in this region.

2. Although the ascent vehicle reaches maximum dynamic pressure (max q) near 11.25 km, it is within 10 percent of max q from about 5.8 km (19 000 ft) to 16.5 km (54 000 ft) altitude. It is expected to be quite sensitive to wind direction and speed in this region but the criteria limits have yet to be determined.

3. Booster and Orbiter separation (about 41 km) may demand wind/wind shear requirements for test flights. Details are not yet known.

C. Booster Trajectory, Descent and Recovery

Events 7 through 11 require as much information as possible about the atmosphere from separation to booster apogee and to the surface. The return trajectory and impact location must be determined prior to launch. In addition to routine data there are unique support requirements to consider:

1. The booster recovery vessel is expected to be on recovery station about 6 hours prior to launch. During the prelaunch period complete marine weather surface observations including sea state and mast height wind speed and direction are desired each hour. The ship should have a capability to take upper air wind observations (PIBALS) to 3000 m (10 000 ft), or to cloud base height, and take at least one PIBAL observation prior to launch if requested by launch-support officials.

2. Aerial reconnaissance should be available for use in marginal situations, for determining wind drift, severe weather, clouds, sea state and atmospheric turbulence, to augment other sources if necessary.

3. The horizontal drift of the boosters on impact may be critical. The limits of horizontal drift speed and, in turn, the maximum wind in the lower 150 m of the atmosphere are yet to be determined. Wind may be determined either from sea state observed from satellites or from weather buoys positioned in the area which will transmit meteorological and sea state conditions.

4. Meteorological and sea state observations from satellites, buoys, or radar-scanning[1] on a test basis should be started as soon as possible. The

1. The Skywave radar-scanning technique is being developed by NOAA's Wave Propagation Laboratory.

early start will not only provide information to begin a climatic history of expected conditions but also determine the optimum procedure for collecting the data for record and real-time purposes.

5. While the present concept is that a Space Shuttle launch will not be delayed because of unfavorable conditions in the booster impact area, the observations are required for safety of the recovery operations. Recovery capability is for sea state 4 maximum.

D. Orbiter Flight and Orbit

Events 12 through 14 need space environment information. Because this is a new activity with only limited manned space travel for experience, all possible support requirements must be considered carefully:

1. Natural environment data needed for aborts must be available prior to launch (see Section IVB).

2. After transition to space flight, needed information might include: density at altitudes of low earth satellites, variations of geomagnetic data from a magnetometer network, electron densities in the ionosphere, high energy protons and secondary neutrons and protons, and solar optical and solar radio telescope data for measurements of solar activity. It is anticipated that space observations will provide much improved space data over those presently available from ground stations.

SECTION VI. DISCUSSION OF NATURAL ENVIRONMENT SUPPORT SERVICE FOR PHASE III EVENTS – ORBIT MANEUVERS AND OPERATIONS

The natural environment for space operations for low earth orbit satellites must be continually monitored for known hazards such as effects of solar activity, meteors and meteorites and also because of lack of experience for any unknown, unforeseen or unanticipated hostile environment. The events are listed in the contents. The NOAA operated Space Environment facility at Boulder, Colorado, in coordination with the AWS Aerospace Environment Support Center at Offutt AFB, Nebraska, is available to provide Natural Environment support for Space Shuttle space operations

Planning for the natural environment support for mission payloads and experiments is a responsibility of payload managers as Space Shuttle missions are conceived. It is recommended that payload managers specify and coordinate special mission requirements with the natural environment support personnel.

The Flight Operations Planning Group (FLOP) at JSC plans to publish a handbook for mission payload managers for guidance in planning mission payload support. Support for military missions may be coordinated through the Air Force Satellite Control Facility (AFSCF) at Sunnyvale, California. For joint missions, coordination and agreement for necessary support as far in advance as possible is advisable.

A known situation that must be considered for those payloads that will be left in orbit and retrieved several months later is that the payload must be in a retrievable orbit when scheduled for pickup. The orbital decay must be predicted with sufficient accuracy so that pickup may be accomplished in conjunction with other scheduled missions.

A most unique requirement of the orbital environment dictates "a continuous watch for the unusual." Admittedly, experience in orbital environment cannot be gained until more of it has been encountered. Therefore, continued vigilance for harbingers for the unusual may avert serious situations. Some harbingers that may fall into this category are:

1. The solar activity and its effects on the space environment must be monitored by solar and radio telescopes both on earth and from manned or unmanned satellites.

2. Activity in the ionosphere can be monitored with a vertical-incidence ionospheric sounder to determine, as a function of frequency, the virtual heights and electron densities of reflecting layers in the ionosphere up to the layer of maximum electron density (F_2 layer).

3. Solar particles can be detected with a neutron monitor to detect high-energy solar protons (about 400 Mev) and secondary neutrons and protons. A riometer can be used to detect slower moving low-energy particles (50 Mev) which arrive about 4 hours after the high-energy protons.

4. Measurements of variations in geomagnetic data from satellite data or from a magnetometer network.

5. Density variations at orbital altitudes.

6. Any increase in radiation from natural or man-made sources may be hazardous and require immediate return to earth.

Various activities in the orbital environment might require different criteria for each of the above items but each of them must be monitored and predicted for each event and limiting criteria must be established.

Additional discussion of the near-earth space environment and its effects on space operations is included in Reference 22.

SECTION VII. DISCUSSION OF NATURAL ENVIRONMENT SUPPORT SERVICE FOR PHASE IV EVENTS – DEORBIT, ENTRY, AND LANDING

Under the present mode of operation the Orbiter is committed to a specific landing site (and perhaps even a specific runway) upon the decision to deorbit. Furthermore, it is constrained from flight through thunderstorms, icing, and perhaps rain of moderate or heavy intensity. While no ceiling/visibility constraints have been specified, it is unlikely that landings during Instrument Flight Rules (IFR) conditions will be permitted for the first few test flights. Also, it appears that wind profile information below 24 km (80K ft) will be required.

Considering these atmospheric constraints, the inflexible flight plan, and the time interval between Orbiter landing and deorbit decision, it is apparent that extensive, current natural environment data will be vital to the decision to deorbit. A hypersonic glide profile reentry is described in Reference 22, pages 30 and 31, and meteorological measurement requirements are proposed there.

A. Deorbit to 122 km (400 000 ft), Events IV-1 and IV-2

The decision to deorbit requires a guaranteed suitable landing site. Other atmospheric data such as density along the entry path should be provided as posible using available density models (i.e. 4D Global Reference Atmosphere) with appropriate solar activity inputs.

B. Entry Events IV-3 and IV-4, 122 km (400 000 ft) to 24 km (80 000 ft)

This includes communications blackout which ends between 46 km (150 000 ft) and 27 km (90 000 ft). Current planning indicates that in exceptional situations a landing runway change could be made at blackout end.

From 80 km (260 000 ft) to 60 km (195 000 ft) altitude the vehicle will experience maximum heating due to atmospheric density and density gradients. Entry from high inclination missions may require long duration flight at near-constant altitude and at high latitude. The large horizontal density gradients sometimes found in these regions may present Orbiter heating and trajectory problems. While there are insufficient data for current analyses from infrequent and widely spaced rocketsonde observations a realistic global atmospheric model for simulations is available. Special rocketsonde observations might be desirable in some cases for the Shuttle flight test program.

C. Entry Event IV-5, TAEM, 24 km (80 000 ft) to 3.6 km (12 000 ft)

The wind profile for this phase may be determined from special rawinsonde observations taken as near deorbit time as data evaluation and communications permit. It may be necessary to install special communications facilities to insure immediate transmission of the wind data to the Orbiter.

Aerial reconnaissance and weather radar information to detect and report severe weather, critical turbulence, rain, and icing may be necessary. While the means of observing these phenomena are available, the speedy collection, evaluation, and dissemination to the user may require special communication facilities.

D. Entry Event IV-6, Autoland, 3.6 km (12 000 ft) to Landing

While it is still necessary to avoid certain atmospheric hazards (see constraints listed above), it is not possible to make major changes in the flight plan during this event. Ground-based weather radar and visual observations might be used to avoid hazards in emergency situations. Terminal weather conditions such as ceiling height, visibility, wind direction and speed, altimeter setting, etc., are required information for all landings.

Microwave Landing Systems (MLSs) are planned for KSC, EAFB, VAFB, Hickam AFB, Hawaii, and Anderson AFB, Guam.

SECTION VIII. NATURAL ENVIRONMENT SUPPORT SERVICE FOR ORBITER FERRY FLIGHTS

Orbiter ferry flight events are listed in the contents* and, while execution of each flight will be similar to an aircraft flight, the preparations and associated support will be more critical. Flight criteria are yet to be determined but are expected to be more restrictive than aircraft flights. One organization, such as the Air Weather Service Global Weather Centeral (GWC), should be charged with natural environment forecast and flight-following support for all Orbiter ferry flights. En route support facilities are expected to be military air bases which will follow procedures according to GWC instructions.

The first event encompasses all preliminary planning up to the first flight, which includes the climatology study requirements in selection of the best en route locations (some of which have already been done), and other preparations, up to the in-flight forecast. The climatological studies are being performed by Marshall Space Flight Center. Criteria for ferry flights are not known but it is expected that any degree of icing or turbulence will be avoided.

The flight support required is listed in Events 2 through 4. Flight following as described in Section IIG should be used for all ferry flights. Event 5, vortex predictions and life history, is unique. The process is under study by the FAA although it is well understood now for individual cases. The vortex life history for single flights is predictable so that other aircraft can be advised of the wake drift and it may be avoided for the 3 to 5 min lifetime. The formation strength of the wake vortex is a function of aircraft weight (lift) and speed while the life history is a function of atmospheric conditions. Wake vortices from the complex carrier-Orbiter configuration have not been studied. Wake avoidance is easily accomplished with proper precautions. Wake vortex predictions for all take-offs and landings are required, following FAA accepted procedures.

Event 6 is a general requirement for ground precautions and may be accomplished in conjunction with ground security, but there must be natural environment considerations in ground security precautions.

CHAPTER II. DETAILED NATURAL ENVIRONMENT SUPPORT REQUIREMENTS

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SECTION I. INTRODUCTION

Chapter II lists and describes each test and operational event of Space Shuttle development and operations that has been identified as requiring natural environment support. Each event is identified as to the importance of natural environment support to the success of that event (inconvenience, caution, or safety). Types of natural environment support or methods of providing it are suggested and this support is identified as "required" or "desirable."

Natural environment support is such that measurements and predictions often meet several requirements. However, the natural environment product must be communicated and interfaced with each requirement. Each event is identified separately to assure adequate planning to meet each requirement. Judgments can often be made safely to forego some detailed support but these judgments must always be made consciously based on other supplementary information. The support described herein is designed to obtain optimum information for marginal situations.

Section II lists existing and programmed natural environment support facilities for KSC, Florida, and VAFB, California.

Section III lists events for development tests, while Sections IV through VII list events for the four operational phases of a complete Space Shuttle mission.

Section VIII describes the natural environment support requirements for Orbiter ferry flights.

In this chapter specific environmental parameters are identified for observation and/or prediction, as a function of various test and operation phases, to meet the Shuttle natural environment requirements currently identified. No statement of requirements for accuracy is given. A statement of accuracy is premature at this state of the operational support development cycle. In each case it now appears that currently available "state-of-the-art" capabilities in observations and predictions will be adequate to meet the Space Shuttle system support requirements. In no case is it expected that a new environmental measurement system or prediction procedure/technique development for dedicated Shuttle support will be required. Rather, it is a matter of bringing together into a properly designed environmental support program, with the appropriate communications system, the available "state-of-the-art" technology. As a rule the more demanding requirements on accuracy or representativeness of environmental support exists for those items identified with safety and noted as being required. The least demand is on those identified with inconvenience and noted as desired.

SECTION II. EXISTING AND PROGRAMMED NATURAL ENVIRONMENT SUPPORT REQUIRED

A. Support Required for Kennedy Space Center, Florida

Type of Facility[a]	Installed or Programmed Date[b]	Requirement Phase[c]	Remarks[d]
Weather Surveillance Radar FPS-77	Inst. [370 km (200 mi) range]	I,II,IV FF	
C-Band Tracking Radar, AN/FPS-16	Inst.	II,IV	Jimsphere Upper Air Wind System.
Meteorological Measurement Equipment.			
Wind Measurements		DT,I,II,IV,FF	
Surface	Inst.		
Tower	Inst.		150 m Tower Inst.
Upper Air Wind System	Inst.		Rawinsonde and Jimsphere/FPS-16
Network	Inst.	DT,I,II	See Figure 6
Ceilometer	Inst	DT,II,IV,FF	
Cloud Height Set GMR 13A	Inst.	DT,I,II	
Transmissometer	Not Programmed	DT,II,IV,FF	Other instruments may be substituted.
Barometer	Inst.	DT,II,IV,FF	
Thermometers			
Standard	Inst.	DT,I,II	
Runway	Unknown	IV,FF	The runway for Space Shuttle operations is under construction and the status of runway instrumentation is not available.
Rocketsonde	Inst.	DT	
Electric Field Measuring System	Inst.	DT,I,II,IV	
Weather Satellite Readout	Inst	DT,I,II,III,IV,FF	Required as input for synoptic weather assessment

a. For additional facilities see Reference 15.

b. Inst. – Installed.

c. DT – Development Test, I – Prelaunch, II – Launch, III – On Orbit, IV – Landing, FF – Ferry Flights.

d. Level II Program Definition and Requirements, Vol. IX, Ground Operations Requirements. JSC 07700, NASA, JSC, Houston, Texas (not published).

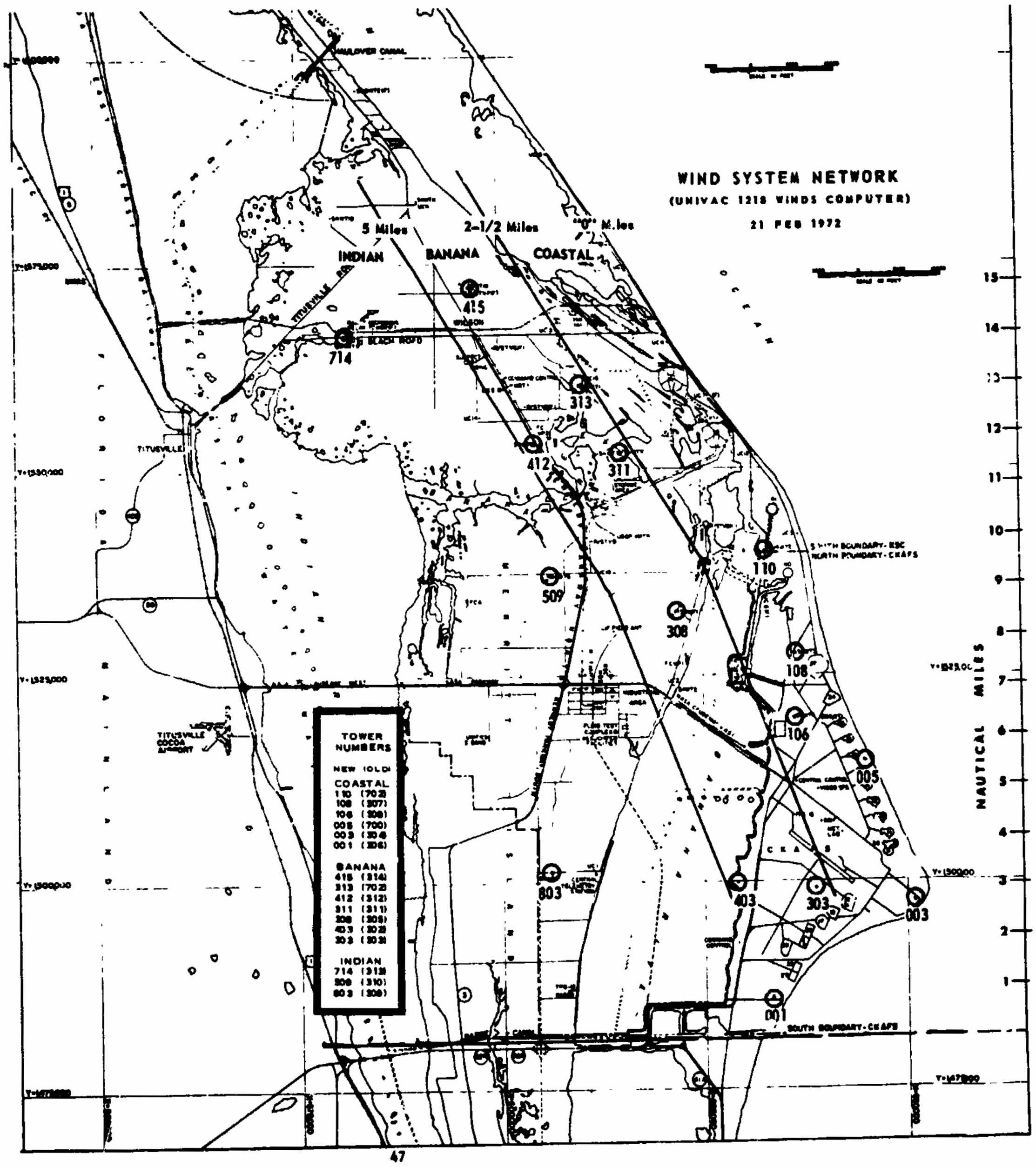

Figure 6. Cape Kennedy wind system network (taken from Reference 15).

B. Support Required for Vandenberg AFB, California

Type of Facility[a]	Installed or Programmed Date[b]	Requirement Phase[c]	Remarks[d]
C-Band Tracking Radar AN/FPS-16	Inst.	II,IV	Jimsphere Upper Air Wind System.
Weather Surveillance Radar, FPS-77	Inst. [370 km (200 mi) range]	I,II,IV FF	
Meteorological Measurement Equipment:			
Wind Measurements:		DT,I,II,IV,FF	
Surface	Inst.		
Tower	Inst.		91 m (300 ft) Tower Inst
Upper Air	Inst.		Rawinsonde and Jimsphere/FPS-16
Wind System	Inst.		VAFB
Network		DT,I,II	See Figure 7
Ceilometer	Inst.	DT,II,IV FF	
Cloud Height Set GMR-13	Inst.	DT,I,II	
Transmissometer	Inst.	DT,II,IV FF	
Barometer	Inst.	DT,II,IV FF	
Thermometers:			
Standard	Inst.	DT,I,II	
Runway	Inst.	IV,FF	
Rocketsonde	Inst.	DT	Pt. Mugu (Navy operated)
Weather Satellite Readout	Inst	DT,I,II,III,IV,FF	Required as input for synoptic weather assessment.

a. For detailed capabilities at Vandenberg AFB, see Reference 16.

b. Inst. – Installed.

c. DT – Development Tests, I – Prelaunch, II – Launch, III – On Orbit, IV – Landing, FF – Ferry Flights.

d. Level II Program Definition and Requirements, Vol. IX, Ground Operations Requirements. JSC 07700, NASA, JSC, Houston, Texas (not published).

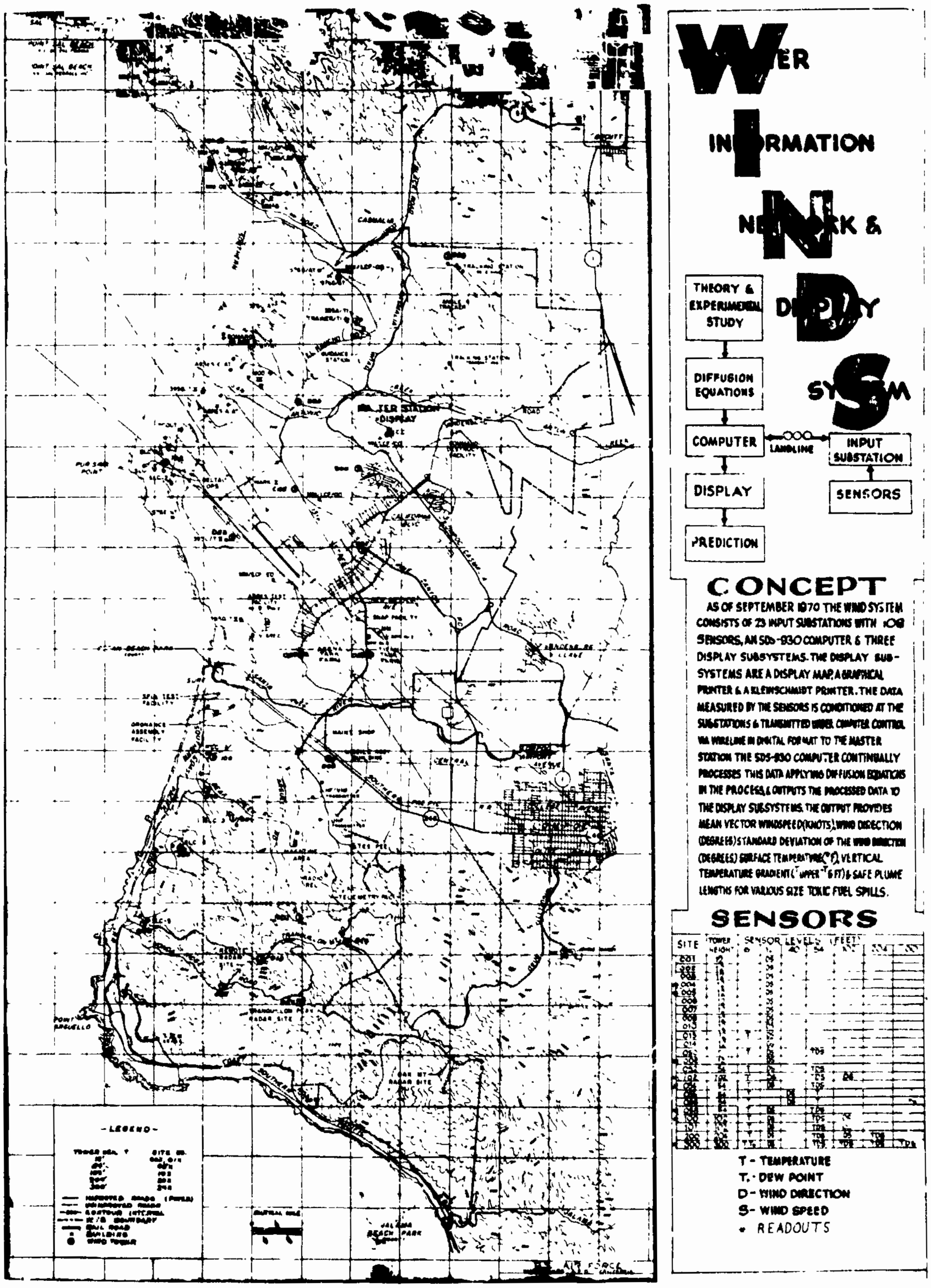

Figure 7. Vandenberg AFB weather facilities (taken from Reference 16).

SECTION III. DEVELOPMENT TESTS

Test Event 1	Natural Environment Interface Requirements
☒ Solid Rocket Boosters Test Firing: Acoustic Prediction Tests Also Operations Event II-2	Observations: Surface: Pressure, temperature, humidity and wind observations are required near the tests. Aloft: Winds, pressure, temperature and humidity profiles from the surface to 6 km are required prior to firing tests and as near the time of test as possible. Predictions: Predictions of items listed under observations and predictions of acoustic propagation are required prior to test firing time. Communications: No special requirements. Comments: Observations and predictions may be required at frequent intervals beginning several hours before test time.

Code: ☐ Inconvenience ☒ Caution X Safety

Test Event 2	Natural Environment Interface Requirements
☒ SRB Static Firing, Pollution Prediction Tests (Abatement and Control of Impurities)	Observations: Surface: Micro-winds surface to 1500 m altitude, temperature and humidity profile to 1500 m altitude are required. Aloft: Wind and temperature profiles from the surface to 3 km altitude are required prior to tests and as near the time of tests as possible. Exhaust velocities and temperature desirable. Precipitation radar coverage during the life-history of the exhaust cloud is required.
Also Operational Event II-2	Predictions: Predictions of items listed under observations and a prediction of the exhaust cloud path and concentration levels for up to 2 hours after firing are required, or until the diffusion model shows predicted concentrations < (TBD) ppm. Precipitation predictions in the vicinity of the cloud are required. Communications: No special requirements. Comments: A trace capability of the exhaust cloud may be required by cameras or a traceable ingredient inserted in the exhaust. MSFC multilayer diffusion model will be used to make exhaust cloud predictions.

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

Test Event 3	Natural Environment Interface Requirements
⊠ SRB Recovery Tests Also Operational Event II-11	Observations: Surface: Clouds, visibility, pressure, temperature, humidity, and wind; wind profile from surface to drop altitude (may vary for each test) observations for recovery zone are required for 6 hours prior to tests until recovery is complete. Sea state observations are also required for this period. Predictions: Predictions for all items listed under observation are required from 6 hours prior to tests to test completion. Communications: Two-way transfer of data between test control and recovery operations is required. Comments: Special sea state observations may be desirable from buoys, satellites, or special radars.

Code: ☐ Inconvenience ⊠ Caution X Safety

Test Event 4	Natural Environment Interface Requirements
☐ SSME Test Firing Test Only	Observations: Same as for booster tests 3. 1. 1 for acoustic predictions. Predictions: Same as 3. 1. 1 for acousitc predictions. Communications: No special requirements Comments: Tests begin in 1975, see Table 2.

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

Test Event 5	Natural Environment Interface Requirements
X Orbiter Atmospheric Flight Test (AFT)	Observations: Surface: Pressure, temperature, humidity, winds, clouds, visibility, and hydrometeors for test period are required. Also runway temperatures may be required. Aloft: Winds, temperature, clouds and other information for aerospace flight are required. Aerial reconnaissance of the test flight path is required.
Test Only	Predictions: Predictions for all parameters listed under observations prior to and during tests are required. Flight following during all tests is required. Predictions for aircraft icing and critical turbulence (CT) are required. Communications: Two-way communications between the flight vehicle and flight control is required. Comments: See Table 2. EAFB and Cape Canaveral Air Force Station have the capability to support these tests conducted at their locations. USAF-AWS should be notified of support requirements and test plans. Monitoring of atmospheric conditions during tests will be desirable for analysis of test results.

Code: ☐ Inconvenience ☒ Caution X Safety

Test Event 6	Natural Environment Interface Requirements
X Orbiter Vertical Flight Tests (VFT) and Atmospheric Entry Tests (May Be Manned or Unmanned) Also Operational Event II-1	Observations: See Comments Predictions: See Comments Communications: See Comments Comments: VFT will be conducted at KSC 1978 and 1979, see Table 2. These tests may be a complete mission under test conditions, in which case all support will be the same as that required for an operational mission.

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

Test Event 7	Natural Environment Interface Requirements
☒ Orbiter Wake Vortex Detection and Life History Prediction Also Ferry Flight 8.2.4	Observations: None Predictions: Vortex formation and life history for Orbiter landing; will use FAA vortex prediction procedures when required. Communications: No special requirements. Comments: If vortex predictions are not available nor reliable, the Orbiter wake should be avoided for 5 min. Wake vortex detection and prediction should not present a problem since no other aircraft is expected to land behind the Orbiter.

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

SECTION IV. PHASE I EVENTS – PRELIMINARIES AND PRELAUNCH

Operations Event I-1	Natural Environment Interface Requirements
☐ Storage of Equipment	Observations: Temperature, temperature change, compartment temperatures, and absolute humidity are important. Special observations may be required in assembly and storage areas. Predictions: Climatology information is required and provides information on which to base storage decisions. Predictions of hydrometeors, lightning and items listed under observations are requi[illegible]. Communications: No special requirements. Comments: The types and concentrations of atmospheric impurities and constituents and their interaction with equipment are important. In outside storage, protection from hail and other hydrometeors is necessary.

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event I-2	Natural Environment Interface Requirements
☒ Surface Transportation of Equipment	Observations: Synoptic observations and storm tracks are required. Predictions: Severe storm warning bulletins are required. Communications: No special requirements. Comments: Su..ace transportation follows a well established procedure. Only unusual conditions (severe storms) need be monitored.

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event I-3	Natural Environment Interface Requirements
☒ Air Transportation of Equipment	Observations: Normal observations in support of air traffic are required. Predictions: Predictions for the time of the flight plus 2 hours (about 6 hours) are required for all items listed under observations. Communications: Normal in-flight communications are adequate. Comments: Special precautions are required to accommodate unexpected changes in pressure, temperature, and humidity. Sealed compartments must be able to withstand pressure changes between high and low elevations, buildup from increased temperatures, and condensation resulting from decreased temperatures.

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

Operations Event I-4	Natural Environment Interface Requirements
☒ Orbiter Preparation and Tow to Vehicle Assembly Building (VAB)	Observations: Normal terminal weather observations and weather radar if needed. Predictions: Normal terminal weather predictions. Communications: No special requirements. Comments: At present this is not known to present any significant environmental problems but is included in the event that high compartment temperatures or severe weather may present special problems.

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

Operations Event I-5	Natural Environment Interface Requirements
⊠ Orbiter (with ET and Boosters) Transfer to Launch Pad	Observations: Surface: Micro-winds from the surface to ~91 m altitude from a nearby meteorological tower is required. Weather radar is desired. Predictions: Accurate predictions of wind and temperature from the surface to 150 m altitude continuously for up to 6 hours in advance is required. Hydrometeors and severe weather predictions are required. Communications: No special requirements. Comments: VAFB may have unique wind requirements due to the long distance and rough terrain involved.

Code: ☐ Inconvenience ⊠ Caution X Safety

AS61-01 (Jul 74) (OT)

Operations Event I-6	Natural Environment Interface Requirements
☒ Prelaunch Preparations and Exposure (Fuel, Payload Service, Passenger and Crew Loading).	Observations: Surface: Mirco-winds surface to ~91 m altitude, temperatures, skin temperatures, compartment temperatures, humidity, hydrometeors are required. Storm observations including electric potential and hail are required. Storm radar observations are required. Predictions: Predictions for all items under observations are required for the entire time ot vehicle exposure. Special predictions should be made for certain operations such as electric potential during fueling operations. Communications: Normal communications are adequate. Telemetered surface observations with warning signals at established criteria would be desirable. It should be possible to change the warning criteria easily for short periods. Comments: In addition to the continuous predictions for exposure, special events will require more detailed forecasts for special criteria at times when the vehicles are more vulnerable. The micro-winds are necessary to predict vehicle response to "ground winds" effects. Special wind measurements near the vehicle at the launch complex may be desirable.

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event I-7	Natural Environment Interface Requirements
X Decisions to Launch	Observations: Surface: Micro-winds surface to 150 m altitude, temperatures, clouds, visibility, hydrometeors, electric potential, abort, and alternate site data are required. Aloft: Detailed winds, temperature, humidity, pressure and density (surface to 18 km altitude), CT, aerial reconnaissance are required. Radar observations are required. Predictions: Predictions for all items listed under observations are required as far in advance as possible. Predictions of acoustic propagation, exhaust diffusion, weather in the booster recovery area, all potential alternate and abort sites, and solar activity are required. A long range prediction of Orbiter recovery site weather should be considered. Requirements start 72 hours in advance and continue until launch. Communications: Special communications with forecast and observed data telemetered to the launch controller. Comments: The launch decision will be continually revalidated during the final 72 hours. Gathering data is repeated on critical items each time the decision requires revalidation. Environmental information applicable to the entire mission should be reviewed at this time.

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event I-8	Natural Environment Interface Requirements
X Mission Abort a. Preignition b. From Loss of One Orbiter Main Engine or One SRB c. With One SSME Out to Abort Once Around or Return-To-Site Capability d. Abort After Insertion	Observations: Observations of terminal conditions for abort locations are required continually throughout the mission from decision to launch to landing. Locations will be established for each mission. Predictions: Predictions for entry path and for abort locations are required continually throughout the mission for items necessary for entry and landing. Communications: Communications are required for real-time monitoring of the natural environment for occurrences which may indicate that launch abort or hold is advisable. Comments: Launch abort recycles the environmental requirement back through the exposure and prelaunch events. The four operational conditions which dictate differing abort procedures have been identified. Environmental support for abort should be included in mission launch requirements to be available prior to an emergency. The natural environment support for mission abort contingencies requires continuous anticipation of emergencies and continuous predictions to be available and stored. If conditions do not meet abort requirements, this information should be in the system before the emergency develops.

Code: ☐ Inconvenience ☒ Caution X Safety

SECTION V. PHASE II EVENTS – LAUNCH TO ORBIT

Operations Event II-1	Natural Environment Interface Requirements
X Booster and Orbiter Ignition, Lift-Off and Tower Clearance	Observations: Surface: Micro-winds surface to ~91 m altitude, temperatures, pressure, electrical potential are required. Predictions: Two-hour predictions of items listed under observations are required. Communications: Telemetered surface observations to the launch controller are required with warning when established criteria are exceeded. Comments: These events are an irrevocable sequence and the natural environment effects will have been previously considered.

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event II-2	Natural Environment Interface Requirements
☐ Environmental Effects of Launch (Pollution Control and Noise Abatement)	Observations: Surface: Micro-winds surface to 1500 m altitude and temperature and humidity profile to 1500 m altitude are required. Aloft: Wind and temperature profiles from the surface to 3 km altitude are required prior to launch and as near the time of launch as possible. Exhaust velocities and temperature desirable. Precipitation radar coverage during the life history of the exhaust cloud is required.
See Test Events 1 and 2	Predictions: Predictions of items listed under observations and a prediction of the exhaust cloud path and concentration levels for up to 2 hours after firing are required, or until the diffusion model shows predicted concentrations < (TBD) ppm. Precipitation predictions in the vicinity of the cloud are required. Communications: No special requirements. Comments: A trace capability of the exhaust cloud may be required by cameras or a traceable ingredient inserted in the exhaust. MSFC multilayer diffusion model will be used to make exhaust cloud predictions.

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event II-3	Natural Environment Interface Requirements
☒ Ascent, Boosters and Orbiter Mated Subsonic	Observations: Continuous monitoring of electrical potential is required. Detailed wind profile surface to 18 km altitude is required. Prior aerial reconnaissance is required, including CT observations. Predictions: Predictions of all items listed under observations are required at the time launch decisions are made. Communications: Normal communications of observations and predictions to the launch controller are adequate. Comments: None

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

Operations Event II-4	Natural Environment Interface Requirements
⊠ Transonic Flight, Boosters and Orbiter Mated (7 km)	Observations: Aloft: Detailed wind profile at altitudes of transonic flight, temperature profile from surface to supersonic flight. Aerial reconnaissance and measurements of CT at transonic altitudes are desirable. Predictions: Predictions of items listed under observations are required at times launch decisions are made. Predictions of sonic boom effects are required. Communications: Normal communications to control authority are required. Comments: The natural environment requirements will be the same for booster or Orbiter transonic flight, individually.

Code: ☐ Inconvenience ⊠ Caution X Safety

Operations Event II-5	Natural Environment Interface Requirements
☒ Dynamic Pressure Transition. Boosters and Orbiter Mated. Max q ≈ 11.25 km, although the vehicle will be within 10 percent of max q from about 5.8 km (19 000 ft) to 16.5 km (54 000 ft) altitude	Observations: Aloft: Detailed wind observations are required from 5 to 17 km altitude. Aerial reconnaissance and measurements of CT between 5 and 17 km altitudes are desirable. Predictions: Predictions of items listed under observations are required at times launch decisions are made. Communications: Normal communications to control authority are required. Comments: None

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event II-6	Natural Environment Interface Requirements
X Transition Through Maximum Winds	Observations: Aloft: Detailed wind profiles from surface to 18 km altitude are required. Predictions: Predictions of detailed wind profiles from surface to 18 km altitude are required when decisions to launch are made. Communications: Normal communications are adequate. Comments: The level of critical maximum winds is between 8 and 15 km altitude. Both maximum dynamic pressure and transonic flight are expected near these same levels.

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event II-7	Natural Environment Interface Requirements
⊠ Boosters and Orbiter Separation (≈41 km altitude)	Observations: None Predictions: Climatology Communications: No special requirements. Comments: Climatology and persistence provide the basis for predictions at these altitudes. Atmospheric models may provide a better understanding of these altitudes.

Code: [ ] Inconvenience ⊠ Caution X Safety

AS61 01 (Jul 74) (OT)

Operations Event II-8	Natural Environment Interface Requirements
X Boosters Free-Flight Trajectory [to ≈ 64 km altitude then fall to about 6 km (20 000 ft) altitude]	Observations: Aloft: None required. Predictions: Climatology provides the basis for design and is expected to be adequate for predictions. Atmospheric models under development may provide improvements for predictions. Communications: Normal communications are adequate. Comments: The present concept is that unfavorable natural environment conditions for successful booster recovery will not constitute a launch constraint.

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event II-9	Natural Environment Interface Requirements
☒ Booster Descent, Parachute Opening Between 5.2 and 6 km Altitude	Observations: None. Predictions: A wind profile prediction from the surface to 6 km is desired. Communications: No special requirements. Comments: The philosophy of SRB design and operation precludes specifying natural environment requirements for SRB descent and impact. Experience indicates, however, that wind profile (and perhaps other) predictions will be desired.

Code: [] Inconvenience ☒ Caution X Safety

ASCII-01 (Jul 71) (OT)

Operations Event II-10	Natural Environment Interface Requirements
X Boosters Impact	Observations: None. Predictions: Wind profile to 300 m altitude and sea state conditions are desired. Communications: No special requirements. Comments: Although launch may not be delayed if predictions for booster impact and recovery operations are unfavorable, booster survival is highly desirable. The philosophy of SRB design and operation precludes specifying natural environment requirements for SRB descent and impact. Experience indicates, however, that wind profile (and perhaps other) predictions will be desired.

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

Operations Event II-11	Natural Environment Interface Requirements
X Boosters Recovery	Observations: Surface: Ceiling, visibility, hydrometeors, winds, and sea state during booster recovery are required. Predictions: Predictions of items listed under observations are required when decisions to launch are made. Predictions and monitoring are required to continue until recovery is complete. Communications: Real-time communications link between recovery ship and recovery director (natural environment support group) are required. Comments: The U.S. Navy Fleet Numerical Weather Central, Monterey, Calif., has available sea-state forecasts for the impact area and for booster recovery operations transit areas.

Code: [ ] Inconvenience ☒ Caution X Safety

Operations Event II-12	Natural Environment Interface Requirements
☐ Orbiter Powered Ascent	Observations: None. Predictions: Climatology and space environment information in Reference 18 are required. Orbiter Powered Ascent after Booster Separation. Communications: None. Comments: Natural environment within climatic extremes are not expected to affect this operation.

Code: ☐ Inconvenience ☒ Caution X Safety

AS31-01 (Jul 71) (OT)

Operations Event II-13	Natural Environment Interface Requirements
☒ External Tank (ET) Separation, Freefall, Impact and Disposal. (Does not achieve orbit so falls back into the atmosphere).	Observations: None. Predictions: Predictions of atmospheric density from the 4D Global Reference Atmosphere along the reentry path may be desired. Communications: No special requirements. Comments: Simulations using the 4D Global Reference Atmosphere can be made prior to launch.

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event II-14	Natural Environment Interface Requirements
☒ Orbiter Enter Orbit	Observations: Sensors to detect solar radiation desired. A continuous worldwide meteorological watch of possible landing sites applicable to each orbit is required. Predictions: Predictions of solar activity and effects are required. Predictions for emergency abort and return are required. Communications: Space communications are required. Comments: The AWS Environmental Forecast Center at Offutt AFB and the NOAA facility at Boulder, Col., have the capability to provide predictions of solar activity and radiation support. It is recommended that emergency abort sites, other return sites, and solar activity be continuously monitored by the Air Force Global Weather Central or another agency with flight-following capability.

Code: ☐ Inconvenience ☒ Caution X Safety

ASGI-01 (Jul 74) (OT)

SECTION VI. PHASE III EVENTS – ORBIT MANEUVERS AND OPERATIONS

Operations Event III-1	Natural Environment Interface Requirements
☐ Burn to Change Orbits	Observations: Solar activity, proton events, magnetic field. AWS and NOAA at Boulder, Col., are receiving full-time, real-time readout of a neutron monitor of solar activity located near Ottawa, Canada, and these data are required during all space operations. Also data from the solar optical telescope system and the solar radio telescopes are required. Predictions: Predictions of items listed under observations are required. Communications: Continuous two-way, space-to-ground communications are required. Telemetering of sensor data to ground control is desirable. Comments: It is believed that all space environment requirements will have been included in design and operation but all possible factors must be monitored for caution and emergencies. The AWS Environmental Forecast Center and the NOAA facility at Boulder, Col. have the capability to provide this information (Reference 2, pp. 3-11).

Code: [ ] Inconvenience [X] Caution X Safety

Operations Event III-2	Natural Environment Interface Requirements
☐ Accomplish Space Mission	Observations: Solar activity, proton events, magnetic field. Sun angle for maneuver. Continuous monitoring of near-earth space environment is required. Predictions: Predictions of items listed under observations are required. Communications: Continuous two-way, space-to-ground communications are required. Telemetering of sensor data to ground control is desirable. Comments: Planning for the Natural Environment Support for mission payload and experiments is a responsibility of payload managers as Space Shuttle missions are conceived. It is recommended that payload managers specify and coordinate special mission requirements with the Space Shuttle natural environment support personnel.

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event III-3	Natural Environment Interface Requirements
☒ Emergency Requiring EVA	Observations: Solar activity, proton events, and magnetic field are desired. Predictions: Predictions of items listed under observations are required. Also predictions for emergency entry and landing are required. Communications: Continuous two-way, space-to-ground communications are required. Telemetering of sensor data to ground control is desirable. Comments: None

Code: ☐ Inconvenience ☒ Caution X Safety

ASCI-01 (Jul 71) (OT)

Operations Event III-4	Natural Environment Interface Requirements
☐ Reload Orbiter and Return Preparations	Observations: Solar activity, proton events, magnetic field, and sun angle for maneuver are desired. Satellite observations of return and abort sites should be recorded. Predictions: Predictions of space environment for return are required. Predictions of densities along entry path and abort or emergency paths are required. If a predicted entry atmospheric model is available it may be stored to select any entry path. Predictions of landing conditions are required. Communications: Continuous two-way, space-to-ground communications are required. Telemetering of sensor data to ground and prediction data to Orbiter for return are desirable. Comments: None

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

SECTION VII. PHASE IV EVENTS — DEORBIT AND ENTRY

Operations Event IV-1	Natural Environment Interface Requirements
X Selection of landing site	Observations: Aloft: Satellite observations of proposed landing areas should be available. Surface: Ceiling, visibility, winds, hydrometeors, radar observations at proposed landing sites are required. Paths of major storms are required. Predictions: Predictions of all items listed under observations for landing time are required. Communications: Continuous two way, space-to-ground communications required. Telemetered surface observations to landing control is desirable. Comments: Predictions of density and wind along entry path should be made from the 4D Global Reference Atmosphere

Code: [ ] Inconvenience ☒ Caution X Safety

Operations Event IV-2	Natural Environment Interface Requirements
X Deorbit and Descent to ≈ 122 km altitude	Observations: Satellite observations of return and alternate sites should be available. Predictions: Predictions of densities and winds along entry path and alternate paths required. Predictions of approach and landing conditions required. Prediction of landing footprint based on predicted atmospheric conditions required. Flight following is required. Communications: Continuous two-way, space-to-ground communications desirable. Telemetering of sensor data to ground and prediction data to Orbiter desirable. Comments: Atmospheric models may provide a better understanding of these altitudes. Predictions of densities and winds should be made from the 4D Global Reference Atmosphere.

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

Operations Event IV-3	Natural Environment Interface Requirements
X Reconfirm Landing Procedure	Observations: Surface: Ceiling, visibility, hydrometeors, winds, radar observations at proposed landing sites are required. Predictions: Predictions of all items listed under observations for landing time are required. Flight following is required. Communications: Continuous two way, space-to-ground communications desirable. Telemetered surface observations to landing control are desirable. Comments: Reconfirmation of landing procedure is required immediately subsequent to communications blackout. At this point a landing procedure such as change in runways could be made, if dictated by runway wind conditions for example, but landing site cannot be changed.

Code: [ ] Inconvenience ☒ Caution X Safety

Operations Event IV-4	Natural Environment Interface Requirements
☒ Entry 122-24 km Altitude	Observations: None Predictions: Entry path parameters from the 4D Global Reference Atmosphere. Flight following is required. Communications: Continuous two-way, space-to-ground communications desirable. Telemetered density data from the Orbiter to controller are desirable. A communications blackout in this region exists with current entry procedures. Comments: Maximum entry heating and communications blackout are expected about 30-80 km altitude. The onboard Orbiter guidance system defines and controls the Orbiter to desired density-velocity (ρ-V) profile. If density variations occur more rapidly than the guidance can respond, larger temperature deviations will occur.

Code: ☐ Inconvenience ☒ Caution X Safety

Operations Event IV-5	Natural Environment Interface Requirements
X Entry 24-3.6 km Altitude. Terminal Area Energy Management (TAEM)	Observations: Winds and densities along flight path are desirable. Predictions: Predictions of winds along flight path are required. Flight following is required. Communications: Continuous two-way, space-to-ground communications are required. Comments: It is anticipated that a prediction of the TAEM wind profile, at least in a gross sense, will be required before deorbit.

Code: [] Inconvenience ☒ Caution X Safety

ASGI 01 (Jul 74) (OT)

Operations Event IV-6	Natural Environment Interface Requirements
X Final Approach and Landing	Observations: Surface: Ceiling, cloud conditions, visibility, hydrometeors, wind, and temperature are required for the landing site. Aerial reconnaissance is desirable. Predictions: Predictions for all items listed under observations for arrival time are required continuously from decision to return until landing is complete. Flight following is required. Communications: FAA and Air Force approach and landing procedures. The Microwave Landing System (MLS) is to be installed at KSC, EAFB, VAFB, Hickam AFB, Hawaii, and Anderson AFB, Guam. Comments: None

Code: ☐ Inconvenience ☒ Caution X Safety

SECTION VIII. SERVICE REQUIRED FOR ORBITER FERRY FLIGHTS

Ferry Event 1	Natural Environment Interface Requirements
☒ Flight Planning	Observations: Normal weather data available from National Weather Service and Air Force Communications Networks for flight planning are required. Runway air temperatures and temperature profile for climb out are required. Special observations of CT may be desired. Predictions: In-flight and terminal weather for the entire flight with special emphasis on icing and CT are required. Communications: No special requirements. Comments: As presently envisioned, the ferry flights will involve outsized aircraft which may be very susceptible to turbulence and icing.

Code: ☐ Inconvenience ☒ Caution X Safety

Ferry Event 2	Natural Environment Interface Requirements
X Take-off	Observations: Normal terminal weather data. Runway air temperatures are required. [illegible] require special observations of low level turbulence near the runway. Predictions: Runway air temperatures, winds, and turbulence during take-off and climb are required. A temperature profile from the surface to 610 m (2000 ft) altitude for take-off and climb is required. Communications: FAA and Air Force normal aircraft support. Comments: Turbulence immediately after take-off may be critical at VAFB due to orographic effects. Crosswinds may constitute a severe take-off constraint.

Code: ☐ Inconvenience ☒ Caution X Safety

Ferry Event 3	Natural Environment Interface Requirements
X Flight Following	Observations: Normal weather data available from National Weather Service and Air Force Communications Networks are required. In-flight weather reports from the aircraft being monitored and other aircraft are required. Predictions: Continuous short range predictions for the remainder of the flight and for landing conditions are required. Special criteria for aircraft icing and critical turbulence (CT) may be desired. Communications: Normal weather service and FAA in continuous contact with the aircraft being monitored is required. Comments: It is recommended that this support service be a responsibility of the Air Force Global Weather Central (GWC) or another agency with flight following capability. That agency may establish operational support procedures with all concerned.

Code: ☐ Inconvenience ☒ Caution X Safety

AS81-01 (Jul 74) (OT)

Ferry Event 4	Natural Environment Interface Requirements
X Approach and Landing	Observations: Terminal weather reports are required. Predictions: Predictions of terminal conditions are required from flight planning until mission completion. Communications: FAA and Air Force normal aircraft support. Comments: Turbulence may be a constraint due to local orographic effects. Crosswinds may constitute a severe landing constraint.

Code: ☐ Inconvenience ☒ Caution X Safety

Ferry Event 5	Natural Environment Interface Requirements
X Wake Vo[illegible]x Prediction and Life History	Observations: Routine FAA observations. Predictions: Vortex formation and life-history will use FAA vortex prediction procedures when required. Communications: All other aircraft along the flight path should be warned of possible wake turbulence until more is known about the wake vortex life history. Comments: It is recommended that this be a responsibility of the forecast facility at the landing and take-off installation.

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

Ferry Event 6	Natural Environment Interface Requirements
☒ Orbiter and Carrier Care Ground Operation and Parking to Avoid Natural Environment Hazards	Observations: Normal terminal weather reports are required. Compartment temperatures in the Orbiter may be required on clear, hot days. Predictions: Normal terminal weather predictions, to include weather warnings and compartment temperatures. Communications: Normal. Comments: The natural environment hazards should be included in ground protection and security plans.

Code: ☐ Inconvenience ☒ Caution X Safety

AS61-01 (Jul 74) (OT)

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APPROVAL

NATURAL ENVIRONMENT SUPPORT GUIDELINES FOR SPACE SHUTTLE TESTS AND OPERATIONS

By E. A. Carter and S. C. Brown

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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