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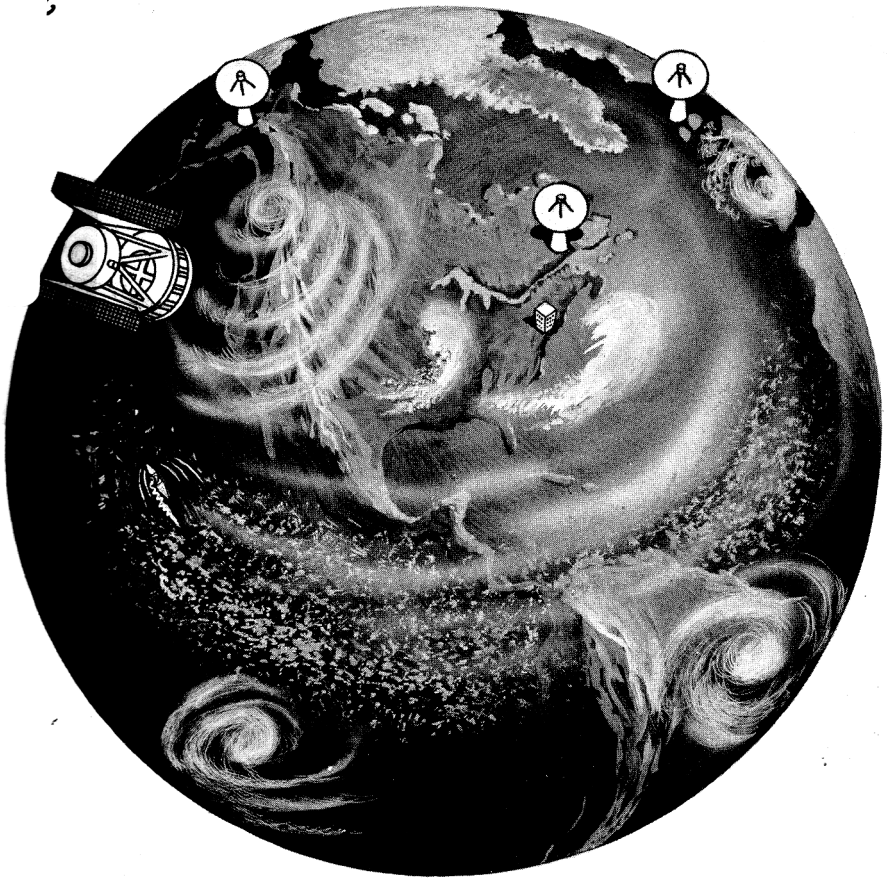

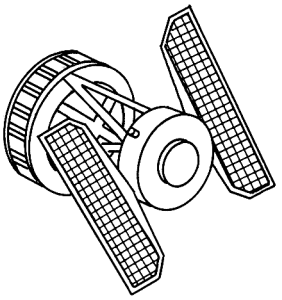

PLAN FOR A NATIONAL OPERATIONAL METEOROLOGICAL SATELLITE SYSTEM

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PLAN FOR

A NATIONAL OPERATIONAL METEOROLOGICAL SATELLITE SYSTEM

Prepared by

Panel on Operational Meteorological Satellites*

under the auspices of

NATIONAL COORDINATING COMMITTEE
FOR AVIATION METEOROLOGY

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1961

*Participating Agencies:

Department of Defense
- U.S. Army
- U.S. Air Force
- U.S. Navy

Department of Commerce
- U.S. Weather Bureau

Federal Aviation Agency

National Aeronautics and Space Administration

APRIL 1961

National Oceanic and Atmospheric Administration
TIROS Satellites and Satellite Meteorology

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ABSTRACT

THIS REPORT of the Panel on Operational Meteorological Satellites, a working group of the National Coordinating Committee for Aviation Meteorology, describes and recommends a plan for the implementation of a National Operational Meteorological Satellite System. The proposed system is designed to phase into operation at the earliest date consistent with the requirements of the various U.S. weather services and the current state of technology. It has a progressively increasing capability to serve the needs of both the United States and the international meteorological community.

During the period from mid-1962 through 1963, the system will make maximum practical application of the data to be obtained from an augmentation of the NASA Nimbus research and development program to provide an expanded operational capability. Independent operational status would be attained by the beginning of 1964. By 1966, the system contemplates two Nimbus-type satellites continuously in polar orbits and operational application of the data from the NASA R. & D. Aeros-type stationary equatorial satellites.

The initial capability would include both day and night cloud cover observations, heat balance measurements and direct transmission of local cloud cover data to local weather stations. The observational potential of the system would be increased in accordance with the progress of the supporting NASA research program.

The system plan includes command and data acquisition stations in northern latitudes and communications for relaying the data to the National Meteorological Center. At this center the data would be processed, analyzed and disseminated over both domestic and international weather circuits.

Overall management of the system would be assigned to the U.S. Weather Bureau, which would be directly responsible for data acquisition, communications, processing, analysis, and dissemination. Development and procurement of spacecraft and launch vehicles, including the actual conduct of launch operations, would be delegated to NASA. It is contemplated that NASA would also participate in spacecraft control and programing and in data acquisition. Participation of the military services and other user agencies, as required, is expected.

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CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Continuous worldwide meteorological coverage is now within the grasp of any nation, or group of nations, possessing the necessary interest, skills, and resources to develop an operational meteorological satellite system.

2. Based on the solid accomplishments of its research and development program, the United States could now undertake the establishment of an operational meteorological satellite system with every confidence of success. The system could become fully operational before the middle of this decade, evolving from the flight hardware developed by the NASA R. & D. program.

3. An operational meteorological satellite system would constitute an extremely powerful complement to the present observational networks. It would provide coverage of important geographic areas not now adequately observed. Furthermore, it would make available new types of meteorological observations which would improve our understanding of meteorological events.

4. Weather exerts a tremendous influence on all mankind. From its careful observation and study can come untold benefits, including improved weather analyses and forecasts over the entire earth. The potential savings in life, property, produce, natural resources, and even in personal convenience are difficult to assess. That a meteorological satellite system can make a major contribution is beyond doubt.

5. It is both possible, and clearly in the national interest, to satisfy the requirements of all the U.S. weather services for meteorological satellite observations with a single, *national* system. This same system could provide major services to the international community of nations.

Recommendations

1. That the United States undertake to develop a National Operational Meteorological Satellite System at the earliest possible date.

2. That this document be accepted as the basis for initial planning and implementation of such a system.

3. That funds be made available in early fiscal year 1962 to begin implementation of the system.

4. That assignment of management responsibility for the National Operational Meteorological Satellite System be made at the earliest possible date, and that this responsibility be placed with the U.S. Weather Bureau of the Department of Commerce. That appropriate legislative changes be made to permit the Department of Commerce to effectively carry out this responsibility.

5. That the U.S. Weather Bureau create a new organizational segment to manage the operational satellite system.

6. That the Department of Commerce contract with the National Aeronautics and Space Administration to develop and/or procure for the U.S. Weather Bureau the spacecraft, launch vehicles, and ground support equipment and to accomplish the launchings. Further, that the NASA shall participate in such post-launch activities as command and data acquisition, as required by the interrelationship of ground equipment and spacecraft.

These recommendations are designed to support a national policy which centralizes certain types of space flight activities within the NASA and the USAF without precluding operational use of satellite observations by other organizations.

7. That the satellite data users participate in the staffing of the operational system organization through assignment of appropriate personnel.

8. That the operational system evolve from the NASA R. & D. program, initially making use of the Nimbus satellite now under development, and continue to draw on new developments resulting from the R. & D. program. That the Aeros satellite be supported for eventual incorporation into the operational system.

9. That the TIROS program be extended to provide some measure of operational capability prior to the first Nimbus launch.

10. That consideration be given to the eventual replacement of ground communications by satellite data relay.

11. That immediate engineering attention be directed to the following long-range problem areas:

(*a*) Possible replacements for the Thor-Agena B launch vehicle *if* it is to be made unavailable by early Thor phase-out.

(*b*) Optimum number and location of command and data acquisition stations.

12. That foreign countries be phased into the program at an early enough date to allow them adequate time to develop their roles.

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DEFINITION OF TERMS AND ABBREVIATIONS

AMR—Atlantic Missile Range: Satellite launching facility on the east coast of Florida.

CDA—Command and Data Acquisition Station: A facility for retrieving stored global data from the satellite and for transmitting to the satellite commands which establish its future program.

LMC—Local meteorological central

or

LWS—Local weather station:

A weather analysis and forecasting facility, either civilian or military (including ships at sea), primarily concerned with the weather in its vicinity. It is dependent on Regional Meteorological Centrals and/or the National Meteorological Center for analyses covering extended areas and forecasts for extended periods. It is particularly interested in the detail of nearby weather systems within a range of approximately 1,000 miles and is responsible for detailed local forecasts for periods up to approximately 12 hours.

NMC—National Meteorological Center: The primary weather analysis and forecasting facility of the United States for providing global and nationwide analyses and for preparing general forecasts for periods ranging from about six hours to as far in advance as technically feasible. For the purposes of this system, the NMC will also play the role of a World Meteorological Center.

NWRC—National Weather Records Center. The permanent national archives for meteorological data.

PMR—Pacific Missile Range: Satellite launching facility in California, the only U.S. range for placing spacecraft in polar orbits.

RMC—Regional Meteorological Central: This term includes such weather analysis and forecasting facilities as:

(1) Cooperative centrals serving several contiguous nations.
(2) The national centrals of nations of large geographical extent.
(3) Centrals serving major segments of the larger nations, such as a U.S. Weather Bureau region.
(4) Specialized centrals, such as those of a military weather service or a major subdivision thereof.

An RMC would normally be concerned with areas and forecast periods intermediary between those of an LMC and the NMC.

WMO—World Meteorological Organization: The specialized body, operating under the United Nations, concerned with international cooperation in meteorology and through which standards and procedures for the exchange of weather information are established.

INTRODUCTION

METEOROLOGISTS have long desired an observational system equal in scope to the global problems which face them. With the advent of the artificial earth satellite, continuous worldwide meteorological coverage is now within the grasp of any nation possessing the necessary interest, skills and resources to develop an operational system. Project TIROS demonstrated to the entire world the dramatic capabilities of weather satellites. Launched on April 1, 1960, TIROS I made 1302 orbits around the earth during its three months of useful life and produced nearly 23,000 pictures of the earth and its cloud cover (see fig. 1). Potential users of an operational system participated in the program and conducted experiments in the practical day-to-day applications of TIROS data. TIROS II, launched November 23, 1960, has established an equally impressive record of solid contributions to meteorological operations.

On October 10, 1960, top officials of the National Aeronautics and Space Administration, the Department of Commerce, the Federal Aviation Agency, and the Department of Defense, met and decided that the time had come to lay plans for a national operational meteorological satellite system. As a consequence, the Panel on Operational Meteorological Satellites (POMS) was established as an interagency working group under the auspices of the National Coordinating Committee for Aviation Meteorology (NACCAM) and with the participation and endorsement of the agencies listed above. POMS was instructed to develop a plan for the operational system; this report presents such a plan.

The Panel agreed at the outset that an operational system should—

1. Constitute a major contribution toward the satisfaction of the meteorological requirements of all the users.
2. Phase into operation at the earliest date consistent with sound development practices and reasonable costs.
3. Capitalize on the continuing research and development program by—
   (*a*) Making use of the best available technology in the fields of instrumentation, spacecraft and launch vehicles.
   (*b*) Having growth potential to profit from experience and new technology as they become available.
4. Be manageable.
5. Serve primarily the national interests of the United States; but simultaneously—
   (*a*) Provide where reasonably possible for the requirements of the international meteorological community.
   (*b*) Be capable of ultimate integration into a worldwide meteorological service.

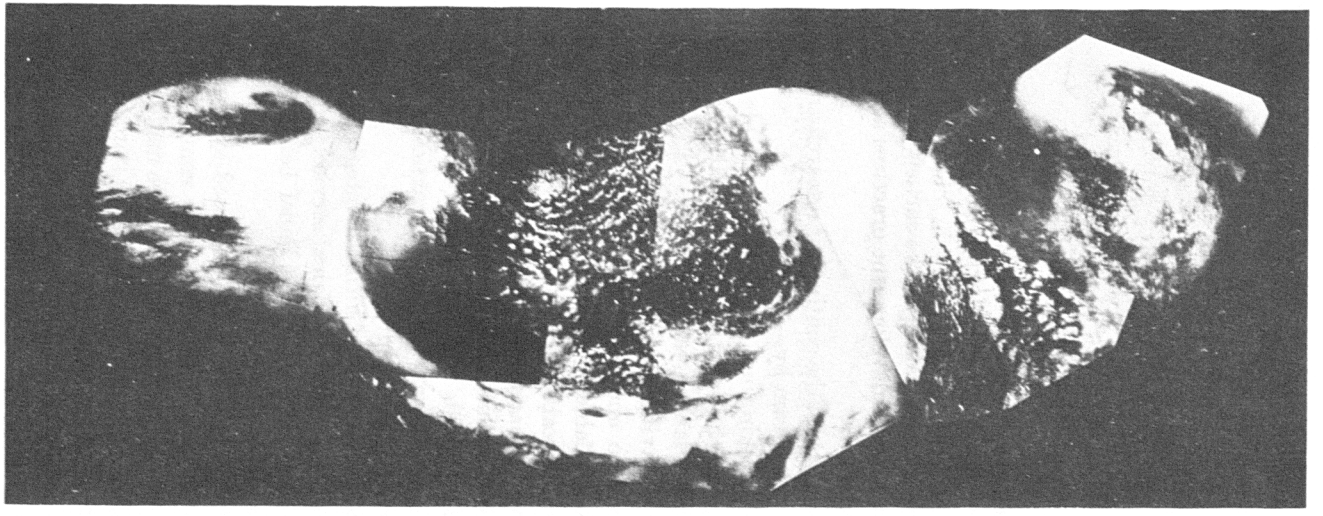
In submitting this plan, the Panel believes that the above criteria have been met.

The Panel feels that the proposed system can be undertaken at once with every confidence of success. It recommends that funds be made available in fiscal year 1962 to begin the implementation of the National Operational Meteorological Satellite System. Furthermore, it suggests supplementary fiscal year 1961 funding to extend the TIROS program and thus provide some measure of continuous operational capability during fiscal year 1962.

REQUIREMENTS AND BENEFITS

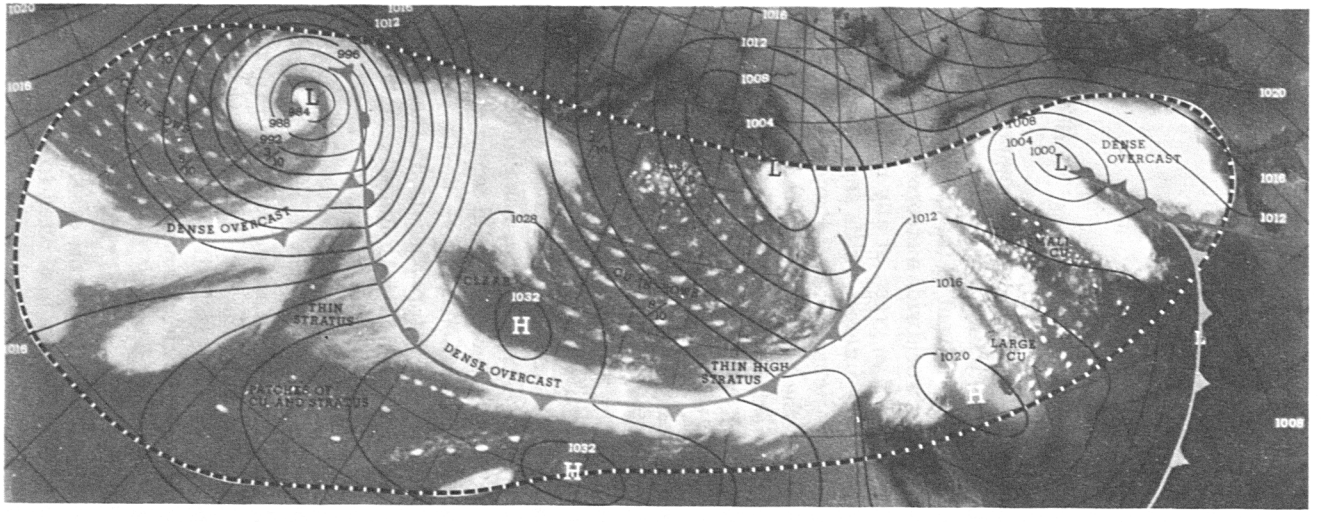
IT IS NO EXAGGERATION to state that nature uses clouds to draw its own weather map; satellites permit us to both see and use this map. The satellite will be a powerful tool, complementing existing systems by filling observational voids which exist even within dense data areas. Over immense oceanic expanses and over sparsely settled land areas, where present meteorological observations are meager and economic considerations make any significant improvement using conven-

A TIROS VIEW OF STORMS AND FRONTS



MOSAIC OF TIROS PHOTOGRAPHS

A Family of Weather Systems



WEATHER MAP, MAY 20, 1960, WITH TIROS CLOUD DATA

FIGURE 1

tional techniques prohibitive, the satellite will be especially useful. Less graphic than the clouds, but possibly more important for the future of weather prediction, are observations of the various radiations entering and leaving the atmosphere. The full potential of such data awaits the results of current research and the development of techniques for their utilization.

The data that an operational meteorological satellite system can provide will be of immeasurable assistance in detecting and predicting severe storms of all types that cause considerable loss of life and property each year. The requirements for an operational satellite system derive from the following types of direct applications that can be made of its data:

1. Some of the most destructive storms are those of tropical origin which form near the equator in areas that are practically devoid of weather information. Quite frequently, the first warning of such a storm is when it strikes an island, ship, or continental shoreline. Satellites can provide surveillance of these data-sparse ocean regions on a global basis, permitting early detection and accurate tracking of storm systems. Based on such observations, timely warnings can be issued to both populous areas and vessels at sea. Such information would be of value not only to this nation, but also to other countries, particularly those which border on tropical oceans.

2. In the same manner, accurate tracking of extra-tropical storms in data-sparse regions (including ocean areas adjacent to our own coasts) would aid more accurate forecasting of these systems.

3. Routine hemispheric weather charts are prepared in the Northern Hemisphere but are nonexistent in the Southern Hemisphere. Satellite observations will improve the Northern Hemisphere charts and permit the routine preparation of Southern Hemisphere charts to satisfy an urgent need for weather information.

4. The identification and tracking of smaller scale phenomena, such as showers, thunderstorms, and, ultimately, tornadoes, will facilitate the dissemination of explicit and detailed short-term forecasts of these phenomena for the general public and for aviation interests.

5. Of special importance to aircraft will be the identification of—

(*a*) Turbulent areas by observing the towering cumulus clouds with which such turbulence is associated; and

(*b*) The strong jet stream winds, marked by the parallel cirrus bands frequently located in close association with the jet stream.

6. Data gathered on a global basis will provide the information which may greatly accelerate development of new and refined forecasting techniques. Of particular value will be heat balance and temperature data, which are eventually expected to enable meteorologists to predict, with greater reliability, the longer term weather trends so vital to many types of planning.

Meteorological Requirements for National Defense

Since the armed forces must operate in the air, on land, and on and under the sea, they are particularly sensitive to environmental conditions.

In the past, the lack of adequate weather information in a theater of military operations has all too frequently resulted in loss of life, loss of millions of dollars, crippling damage, disruption of plans, and the reduction of readiness and effectiveness. Adequate weather information of the type required is most difficult to obtain over inaccessible areas such as the vast oceans and certain land areas of the world. Satellites can be used to obtain much of this information, which would otherwise not be available and which can be the controlling factor in decisions of far-reaching importance.

International Aspects and Applications

International cooperation in the exchange of weather observations is of long standing and represents one of the outstanding examples of amicable international relationships. It would be to the advantage of the United States to take the lead in extending such international meteorological cooperation to include satellite data. It should be noted that it becomes no burden for the satellite system to satisfy simultaneously national requirements and many of those of the international meteorological community.

The fully operational system is dependent on at least one command and data acquisition station on foreign soil. In its earliest phase, the reduced

and analyzed products of the global observations can be disseminated internationally, and it is contemplated that they will be. Furthermore, any nation that so desires can, at minimum expense, establish stations to obtain, directly, cloud pictures in its immediate vicinity. Later, significant portions of the global data can be transmitted from the satellites directly to cooperative regional weather centrals in other parts of the world. One can foresee a truly international system with the satellites transmitting their observations to a world meteorological center as well as to more specialized regional, national, and local weather centrals.

Specific Observational Requirements

Obviously, it would be desirable if satellites could satisfy *all* observational requirements. Such a capability is beyond the current status of technology. The requirements of the several U.S. weather services were examined in terms of their importance, technical and economic feasibility, and the present effectiveness with which the meteorologist could utilize new observations. The parameters considered include:

Cloud cover
Wind
Surface pressure
Sea conditions
Precipitation
Atmospheric heat balance
Atmospheric temperature
Surface temperature
Atmospheric water vapor
Ground cover
Atmospheric density
Total emitted radiation
Sferics

Satisfaction of the requirements of the United States weather services also makes it necessary that the system have not only global capability but also provision for direct read-out of local cloud cover to users. The requirements of all the U.S. weather services, with regard to meteorological satellite observations, are not only compatible, but, in the majority of aspects, so similar that *it is clearly in the national interest to satisfy them through the use of a single system designed to satisfy all the users.*

It is clear that some of the observational requirements can be met now (and, to a limited degree, have been by TIROS), some in the near future, some in the distant future, and some perhaps never. This suggests gradually increasing the observational capabilities of the proposed system by phases.

THE PROPOSED SYSTEM

THE PROPOSED SYSTEM rests on a successful and continuing research and development program started at least a decade ago, whose demonstrated successes most recently include the two TIROS satellites. From this program, the plan for an operational system has evolved. This plan is based on three phases, described below, which are summarized in figure 2; the corresponding flight schedule is shown in figure 3. Prior to the beginning of Phase I in mid-1962, one or two TIROS satellites in addition to the two remaining in the NASA R. & D. program could provide a nearly continuous supply of operationally useful data over limited portions of the earth. These additions are recommended for both operational and training purposes.

Phase I (Mid-1962 Through December 1963)

OBSERVATIONAL CAPABILITIES

1. Global cloud cover observations at approximately local noon and midnight. Qualitative estimates of several of the other desired parameters will be possible from such cloud observations.

2. Global observations, at about local midnight, of cloud top temperatures, which will permit an estimation of cloud top altitudes. In cloud-free areas, the temperature will be that of the radiating ground surface.

3. Global heat balance measurements at about local noon and midnight.

4. Global surface cover (i.e., snow and ice) in cloud-free areas, near local noon.

5. Direct read-out, to local forecast activities, of local, daytime cloud photographs.

SPACECRAFT

This phase is based on the maximum practical use of data from:

1. The four Nimbus R. & D. satellites presently scheduled by NASA.

2. One additional Nimbus launch added as a part of this plan.

3. Provision of two additional Nimbus, as backup to the above, as a part of this plan.

Nimbus, shown in figure 4, is an advanced earth-oriented meteorological satellite to be launched by the Thor-Agena B (see fig. 5) into a retrograde, quasi-polar orbit. The flexibility of the Nimbus design readily permits the addition of improved and new sensory systems. The sensory system of Nimbus I, scheduled for launch in 1962, will include:

(*a*) A vidicon camera system to provide complete coverage of the globe. To increase reliability and lifetime, this subsystem will be installed in redundant units.

(*b*) A radiation subsystem including high resolution sensors for nighttime cloud observations and low resolution sensors for measurements of the earth-atmosphere heat balance.

(*c*) Devices to measure solar radiations of importance to meteorology.

Later Nimbus Satellites may test new and improved sensors such as electrostatic tape cameras, spectrometers, image orthicon cameras and radar.

The Nimbus R. & D. program is already well underway under the direction of NASA's Goddard Space Flight Center. The major contract, for integration and testing of the spacecraft, was awarded to General Electric, Missile and Space Vehicle Division, in early 1961. Contracts for the several functional and sensory subsystems (approximately 15 in number) were awarded in late 1960 and early 1961. All contractors and the program as a whole are proceeding on schedule.

During the early part of Phase I, there may be some periods with no satellite in orbit. Such gaps would occur because it is only prudent to delay launching a satellite until malfunctions in the previous one are corrected. To minimize such gaps, two backup spacecraft and launch vehicles are provided. Those not used will be deferred for use in Phase II.

COMMAND AND DATA ACQUISITION

Command and data acquisition at the beginning of Phase I will be limited to the Nimbus R. & D. stations located at Fairbanks, Alaska, and another proposed for the east coast of the United States, with the consequence that the daylight data over portions of the Central Pacific Ocean and nighttime data over the great majority of Europe and Africa cannot be acquired. In view of the interest shown by other countries it may be possible that a country in Northwestern Europe would construct locally an additional data acquisition station before the end of 1962. This would permit acquisition of global data.

SPECIAL COMMUNICATIONS

A wide-band communications system from the two North American Command and Data Acquisition (CDA) stations to the National Meteorological Center at Suitland, Md., is required to permit transmission of one orbit's complete data during a single orbital period. Full fidelity transmission of data from the European CDA site will not be possible until the establishment of a satellite relay and communications system. Communications from the European CDA site will initially be by a 3-kcs channel and will relay analyses of the cloud and other data in facsimile or teletype forms, the necessary data reduction having been performed at the site. This will inevitably result in undesirable degradation of the data, but no economically feasible alternative exists at this time.

DATA ANALYSIS AT NATIONAL METEOROLOGICAL CENTER

Data reduction, processing and analysis at the National Meteorological Center (NMC) will be by semiautomatic procedures, employing a judicious combination of man and machine techniques. The degree of automation will increase during the course of this phase. Similar techniques are proposed for the European site. The basic nature of the ground-based components and the flow of data are shown in figure 6.

DISTRIBUTION TO USERS

The resulting analyses will be disseminated over domestic and international weather communication circuits. In general, further dissemination is beyond the scope of the system (except for assuring that the data are reduced to forms compatible with available communications). However, it is recommended that plans for such weather communications be reviewed to insure their adequacy in terms of the satellite data and analyses to become available.

DIRECT READOUT

Development of comparatively inexpensive receiving and recording equipment will enable

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FIGURE 2

Phasing Diagram of the Components of the Operational Meteorological Satellite System

COMPONENTS	PHASES		
	I. JULY 1962–DECEMBER 1963	II. JANUARY 1964–DECEMBER 1965	III. JANUARY 1966→
Satellite System	1 Nimbus in orbit most of the time with 600 mile, polar retrograde, high noon orbit.	1 Nimbus continuously in orbit, a second Nimbus in orbit most of the time (Orbits as in Phase I). 1 Aeros* part of the time in an equatorial "stationary" orbit.	2 Nimbus continuously in orbit. 1 Aeros* in orbit part of the time.
Observational Capability	Global Cloud Cover. Temperature of radiating surfaces. Global Heat Balance measurements. Direct readout of daytime cloud pictures. Qualitative estimates of cloud types and heights and wind circulation patterns.	Frequency of observations doubled over those of Phase I *most* of the time. Improved cloud cover details over limited, remote but programable areas. Direct readout of nighttime cloud cover. Hourly cloud cover pictures over most of Western Hemisphere when Aeros satellites are operative.*	Frequency of observations doubled over those of Phase I *all* of the time. Increased reliability of hourly cloud pictures from Aeros.* Additional observations such as atmospheric mean temperatures and experimental wind measurements that may evolve from the NASA R. & D. effort.
Spacecraft Launches	5** Nimbus launches with 2 backups in the event of premature failure. Launches at approximately 6-month intervals.	6 Nimbus launches with 2 backups. 2 Aeros launches.*	3 Nimbus with 1 backup per year. Increased reliability of both spacecraft and launch vehicles anticipated. 2 Aeros launches* per year.
Launch Vehicles and Ground Support	Thor-Agena B at Pacific Missile Range (PMR).	Thor-Agena B for Nimbus at PMR. Centaur for Aeros* at Atlantic Missile Range (AMR).	Same as Phase II, except that it may be necessary to use another launch vehicle to replace the phased-out Thor-Agena B.
Tracking	Minitrack.	Minitrack or other national system.	Same as Phase II.
Command and Data Acquisition Stations (CDA's)	Fairbanks, Alaska. East Coast United States station. Northwestern European station.	Fairbanks, Alaska. East Coast United States *or* northeastern North American station. Northwestern European station. East Coast United States station for receiving Aeros observations.*	Same as Phase II.

Special Communications for Data Transfer	Wide band links between North American CDA's and the National Meteorological Center (NMC). Narrow band (facsimile quality) link between Europe and NMC.	Width of communication bands will be doubled to handle the increased kinds and frequency of observations.	Same as Phase II except that communication satellites would probably be used, when available.
Direct Readout	If technically feasible, installation of relatively inexpensive receiving and recording equipment at local weather stations would enable them to receive cloud pictures, for their area of local interest, directly from the satellite.	In addition to the Phase I direct readout, it is anticipated that a nondestructive readout capability of stored data for use by major regional centers may become available during this period. This will permit these centers to obtain all observational data from the several orbits passing within their receiving ranges each day.	Same as Phase II with regional readouts being fully implemented.
Data Analysis and Distribution	Data reduction, processing and analysis at NMC using combination of manual and automatic methods. Analyses will consist of cloud depictions, analyses showing relationship between satellite and conventional data as well as conventional analyses based on the additional satellite information. Existing domestic and international meteorological circuits will be used initially with a review of their adequacy in terms of the increased data and analyses which will result from this plan.	The main change will be toward more fully automatic processing methods. New types of analyses and presentations will be the outgrowth of research and development on the new and more extensive data.	Fully automatic processing and analysis is to be expected by this phase. Means for processing and continuously displaying the data from Aeros will be developed. National dissemination will be by improved facsimile circuits. Communication satellite relay between international centers may be used.

*The NOMSS will make maximum use of the data from the NASA R. & D. Aeros satellites prior to incorporation of Aeros in the operational system at some future date.

**4 of these are scheduled NASA R. & D. launches.

OPERATIONAL METEOROLOGICAL SATELLITE SYSTEM
FLIGHT SCHEDULE

CY	1962	1963	1964	1965	1966	1967 AND BEYOND
PHASE I 1 NIMBUS IN ORBIT MOST OF THE TIME	2 NIMBUS* 1 BACKUP	2 NIMBUS* 1 NIMBUS 1 BACKUP				
PHASE II 1 NIMBUS IN ORBIT CONTINUOUSLY, A SECOND IN ORBIT MOST OF THE TIME. INITIATE USE OF DATA FROM R&D AEROS			3 NIMBUS 1 BACKUP 1 AEROS*	3 NIMBUS 1 BACKUP 2 AEROS*		
PHASE III 2 NIMBUS IN ORBIT CONTINUOUSLY. 1 AEROS (R&D) IN ORBIT PART OF THE TIME					3 NIMBUS 1 BACKUP 2 AEROS*	STEADY RATE OF NIMBUS LAUNCHES CONTINUE R&D UNTIL OPERATIONALLY READY

* INCLUDED IN PRESENT NASA R&D PLANNING

FIGURE 3

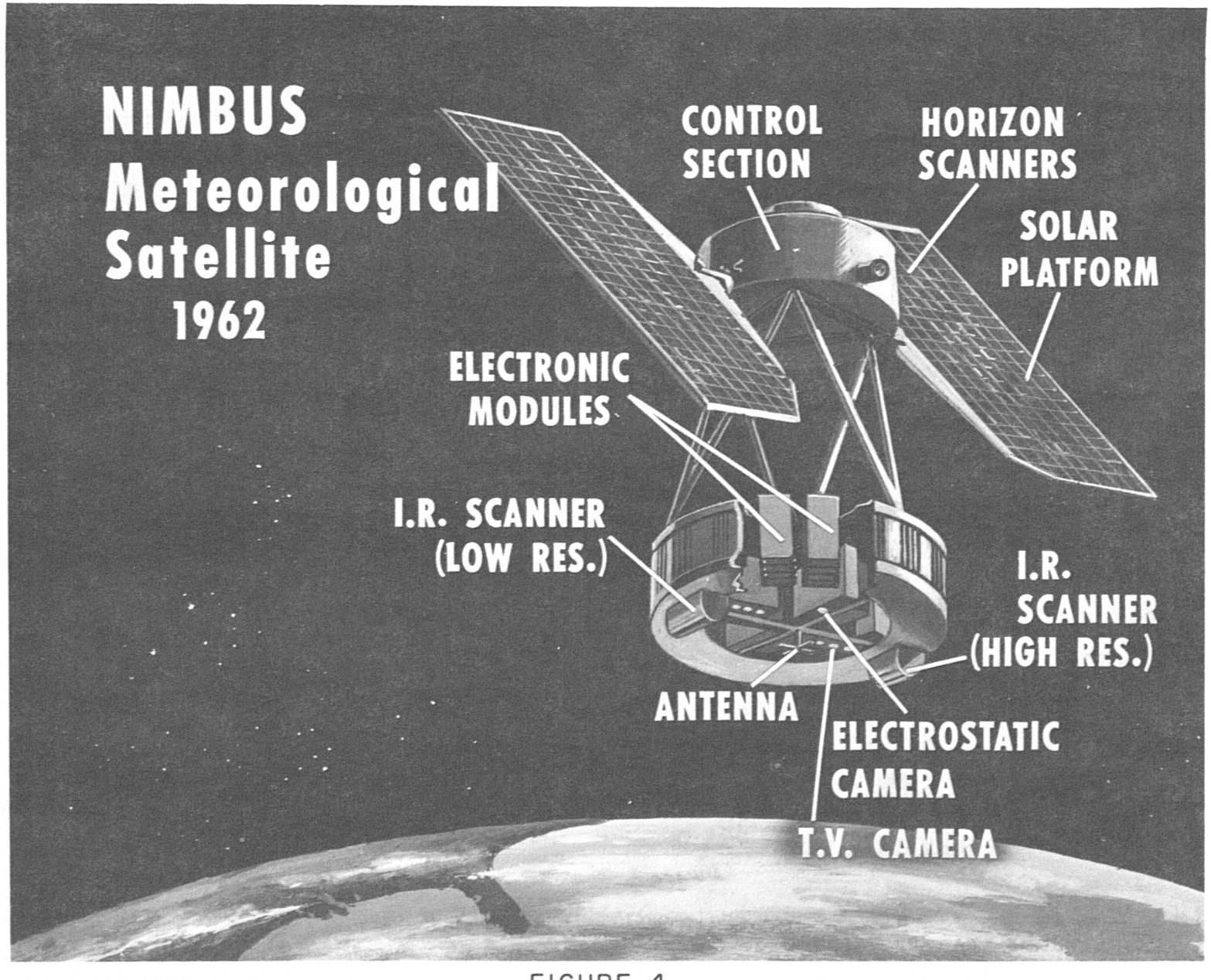
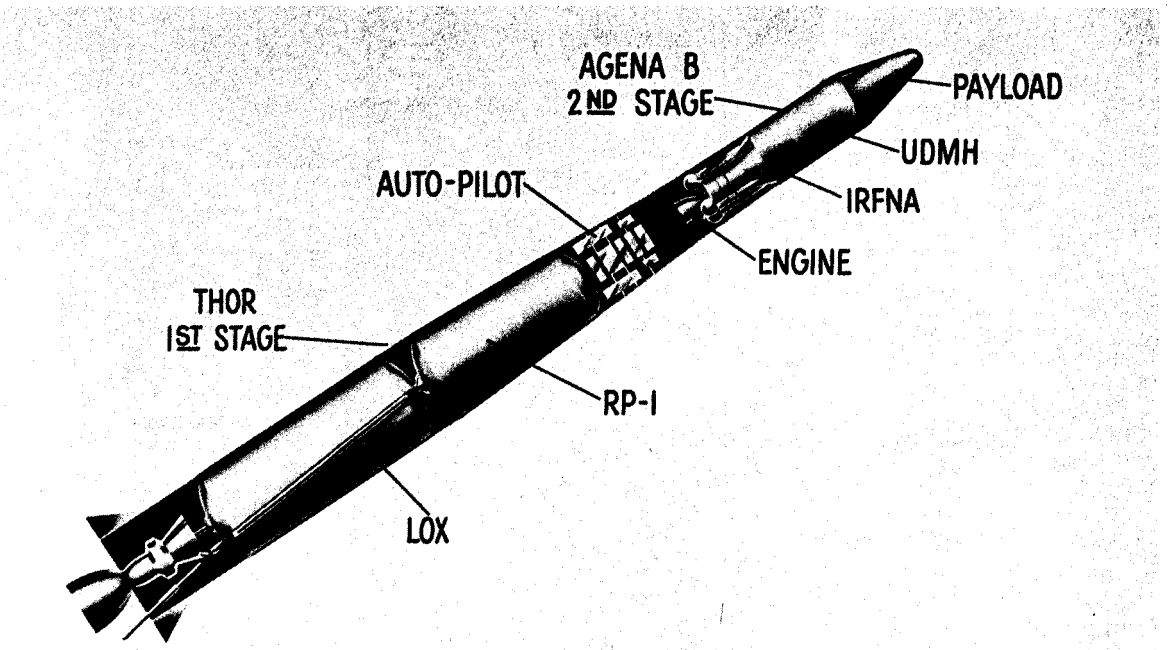
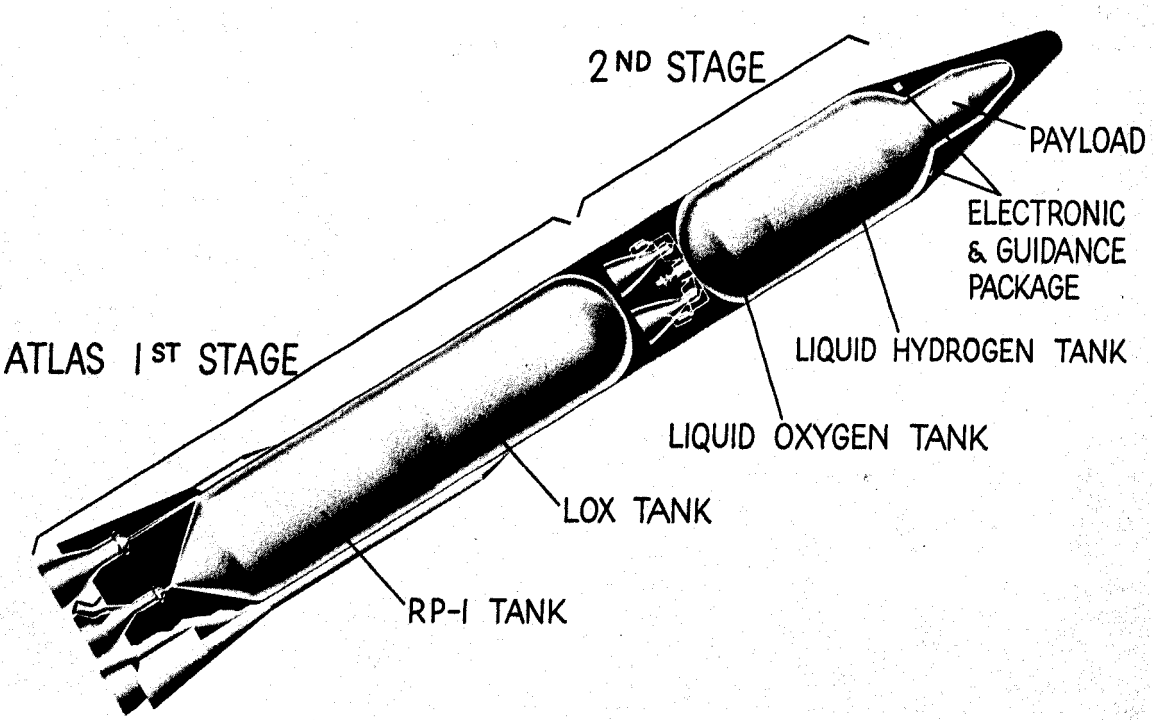

NIMBUS
Meteorological
Satellite
1962
CONTROL SECTION
HORIZON SCANNERS
SOLAR PLATFORM
ELECTRONIC MODULES
I.R. SCANNER (LOW RES.)
I.R. SCANNER (HIGH RES.)
ANTENNA
ELECTROSTATIC CAMERA
T.V. CAMERA

FIGURE 4

LAUNCH VEHICLES



THOR-AGENA B



CENTAUR

FIGURE 5

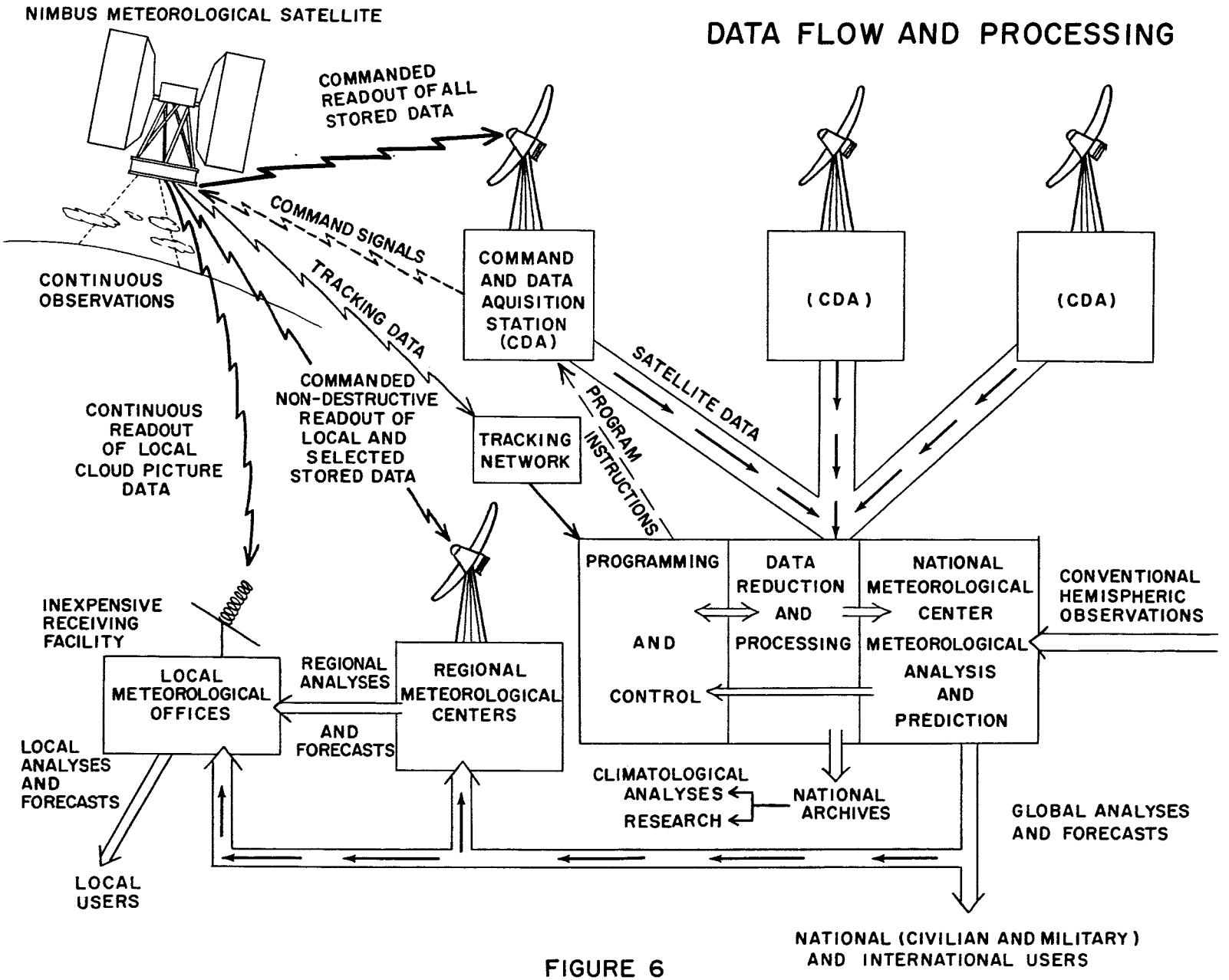

DATA FLOW AND PROCESSING
NIMBUS METEOROLOGICAL SATELLITE
COMMANDED READOUT OF ALL STORED DATA
COMMAND SIGNALS
TRACKING DATA
CONTINUOUS OBSERVATIONS
COMMAND AND DATA AQUISITION STATION (CDA)
(CDA)
(CDA)
SATELLITE DATA
PROGRAM INSTRUCTIONS
COMMANDED NON-DESTRUCTIVE READOUT OF LOCAL AND SELECTED STORED DATA
TRACKING NETWORK
CONTINUOUS READOUT OF LOCAL CLOUD PICTURE DATA
PROGRAMMING AND CONTROL
DATA REDUCTION AND PROCESSING
NATIONAL METEOROLOGICAL CENTER METEOROLOGICAL ANALYSIS AND PREDICTION
CONVENTIONAL HEMISPHERIC OBSERVATIONS
INEXPENSIVE RECEIVING FACILITY
LOCAL METEOROLOGICAL OFFICES
REGIONAL ANALYSES AND FORECASTS
REGIONAL METEOROLOGICAL CENTERS
LOCAL ANALYSES AND FORECASTS
CLIMATOLOGICAL ANALYSES
RESEARCH
NATIONAL ARCHIVES
GLOBAL ANALYSES AND FORECASTS
LOCAL USERS
NATIONAL (CIVILIAN AND MILITARY) AND INTERNATIONAL USERS

FIGURE 6

weather stations to receive, directly, cloud pictures for their area of local interest. The procurement of such receiving equipment is the responsibility of the users.

Phase II (January 1964 Through December 1965)

OBSERVATIONAL CAPABILITIES

At least the following capabilities will be added to those continuing from Phase I:

1. The frequency of the Phase I observations will be doubled by the use of two operational satellites concurrently in orbit most of the time. Most of the satellites will be launched such that the observations will be taken at about 0300–1500 and 0900–2100 local time.
2. The direct readout capability should be improved so as to provide nighttime cloud cover.
3. Improved cloud cover detail will be available over limited but programable areas.
4. During periods when the recommended NASA R. & D. Aeros satellites are operating, nearly continuous daylight surveillance of the weather over the North and South American continents and adjacent ocean areas will be possible.

SPACECRAFT

The spacecraft used will be the operational Nimbus scheduled for launch at a rate of three plus one backup per year. Some operational use will be made of data from the three R. & D. Aeros spacecraft (see fig. 7) recommended for launch during this period. These Aeros will be launched into synchronous equatorial orbits by means of Centaur launch vehicles (see fig. 5).

COMMAND AND DATA ACQUISITION

CDA stations located on the East Coast of the United States and in Europe, in addition to that at Fairbanks, Alaska, are expected to be used during this phase. Additional antenna and console facilities will be provided during this period, however, so that the operational system will not depend on the use of R. & D. facilities. It may prove advantageous to use an operational station elsewhere in the northeastern part of the continent of North America. The optimum number and location of CDA stations require further engineering study, which should proceed immediately.

SPECIAL COMMUNICATIONS

Communication bandwidths will be doubled during Phase II to permit transmission without delay of the more frequent observations and the additional types of data which will become available as new and improved sensors are phased into the operational spacecraft.

DATA ANALYSIS AND DISTRIBUTION

Data reduction and processing will become essentially fully automated. No major changes in the methods of disseminating the reduced and analyzed data are expected.

DIRECT READOUT

In addition to the direct readout of cloud pictures to local weather stations, during the course of this phase it is anticipated that it may be possible to provide a nondestructive read-out capability for use by regional weather centrals. This will permit these centrals to obtain extensive observational data from the several orbits passing within their receiving range.

Phase III (Beyond December 1965)

OBSERVATIONAL CAPABILITY

It is anticipated that additional measurements, such as temperature structure, precipitation, and refined radiation data will be observed from the Nimbus satellites.

SPACECRAFT

The continued scheduled launching of three Nimbus per year plus one backup and the expected increase in reliability of the spacecraft and launch vehicles should provide essentially a continuous capability of two operational satellites in orbit. Only during brief periods immediately following satellite malfunction will the observing capability be reduced; such periods will be minimized by provisions for short leadtimes for launching a replacement. Operational use of data provided by R. & D. Aeros will continue.

COMMAND AND DATA ACQUISITION

CDA stations are expected to remain the same as those for Phase II.

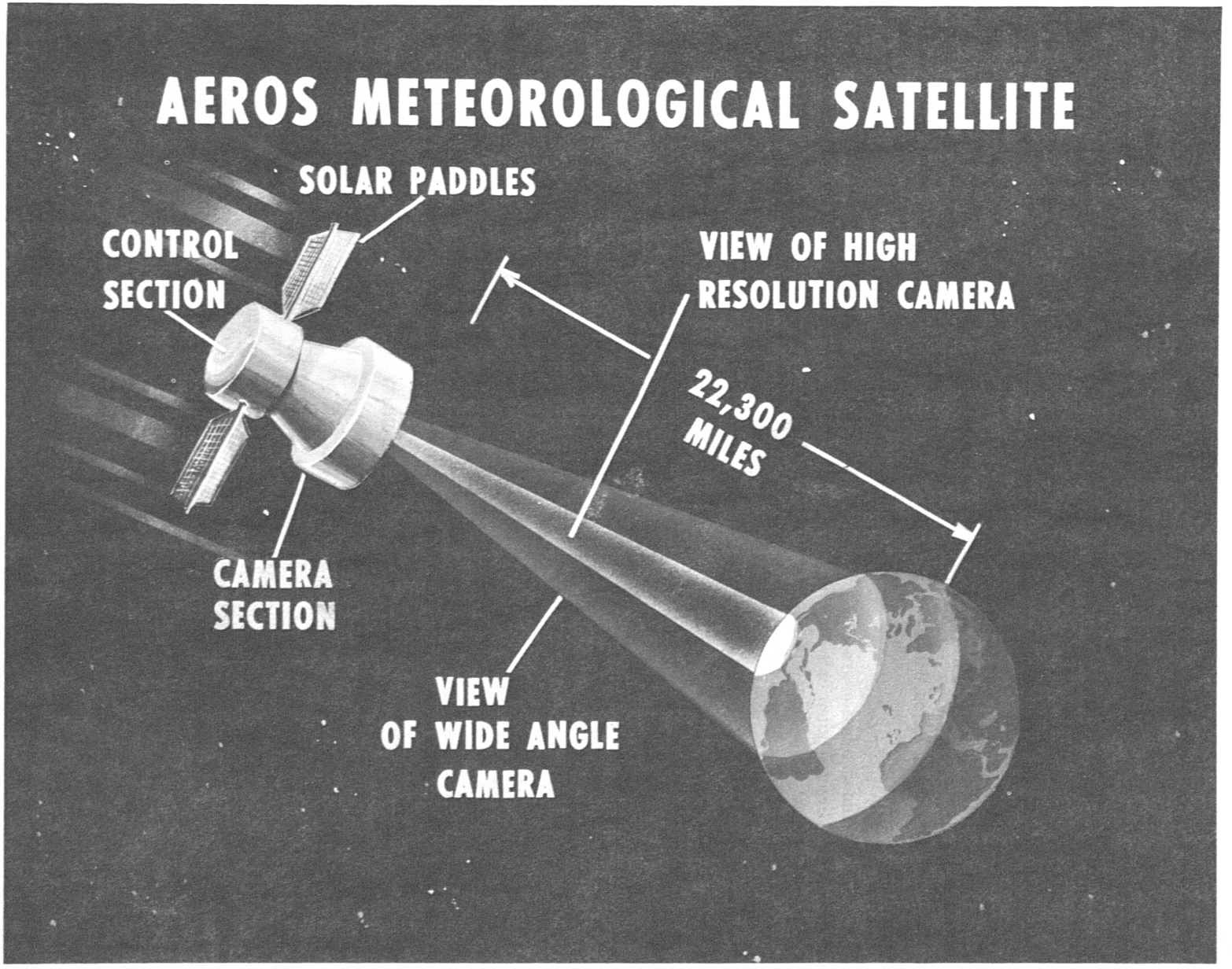

AEROS METEOROLOGICAL SATELLITE
SOLAR PADDLES
CONTROL SECTION
VIEW OF HIGH RESOLUTION CAMERA
22,300 MILES
CAMERA SECTION
VIEW OF WIDE ANGLE CAMERA

FIGURE 7

SPECIAL COMMUNICATIONS

The communications from the CDA stations to the NMC will remain the same as in Phase I until it becomes feasible to use communications satellites for this purpose.

DATA ANALYSIS AND DISTRIBUTION

Only nominal improvements in reduction, processing, analysis and dissemination of Nimbus data will be required. Means for processing and displaying the data from Aeros will be developed.

DIRECT READOUT

The direct readout functions in Phase II will be continued. Direct acquisition of Nimbus data by weather stations throughout the world should be fully implemented to supplement the Nimbus coverage.

Other Operational Factors

ORBITS

All Nimbus vehicles will be placed in 600 nautical mile, quasi-polar orbits maintaining approximately a constant local time orientation. All Phase I orbits will be in the noon-midnight orientation. Early in Phase II, there will be a transition to 0300–1500 and 0900–2100 local time orientations. Figure 8 shows typical orbit traces and their relationships to CDA stations.

All Aeros satellites will be in 22,300 mile "stationary" equatorial orbits.

LAUNCH VEHICLES AND FACILITIES

Nimbus launches during Phase I will use the Thor-Agena B (illustrated in fig. 5) from existing NASA facilities at PMR. The contemplated rate will require augmentation of the (contractual) launch crew. Laboratory and checkout space will be designed for expansion as launches and complexity increase.

The optimum launch vehicle for later stages will require investigation, due to the scheduled phaseout of Thor production. It is understood that provisional orders for any Thor vehicles required, in addition to those presently scheduled, must be placed by early May 1961. Therefore, immediate consideration must be given to the procurement of such additional vehicles. It is recommended that other launch vehicles also be investigated.

Separate PMR facilities for the use of the operational system may be required by the beginning of Phase III.

Centaur vehicles, shown in figure 5, will be required for the Aeros. Launch will be from AMR. NASA preparatory facilities should suffice, at least until it is decided to phase the Aeros into the operational system.

TRACKING

Phase I tracking will be provided by the NASA Minitrack network. The workload in suceeding phases suggests several possible alternatives, including augmentation of Minitrack, use of Spasur-Spacetrack and consideration of SECOR.

The tracking of Aeros may be accomplished by existing precision tracking antennas and/or by photogrammetry, using transmitted pictures.

OPERATIONS CONTROL AND PROGRAMING

The system requires continuing programing on a day-to-day basis. Recommendations of meteorologists familiar with the current weather must be considered. Likewise, rapid access to computer facilities is mandatory.

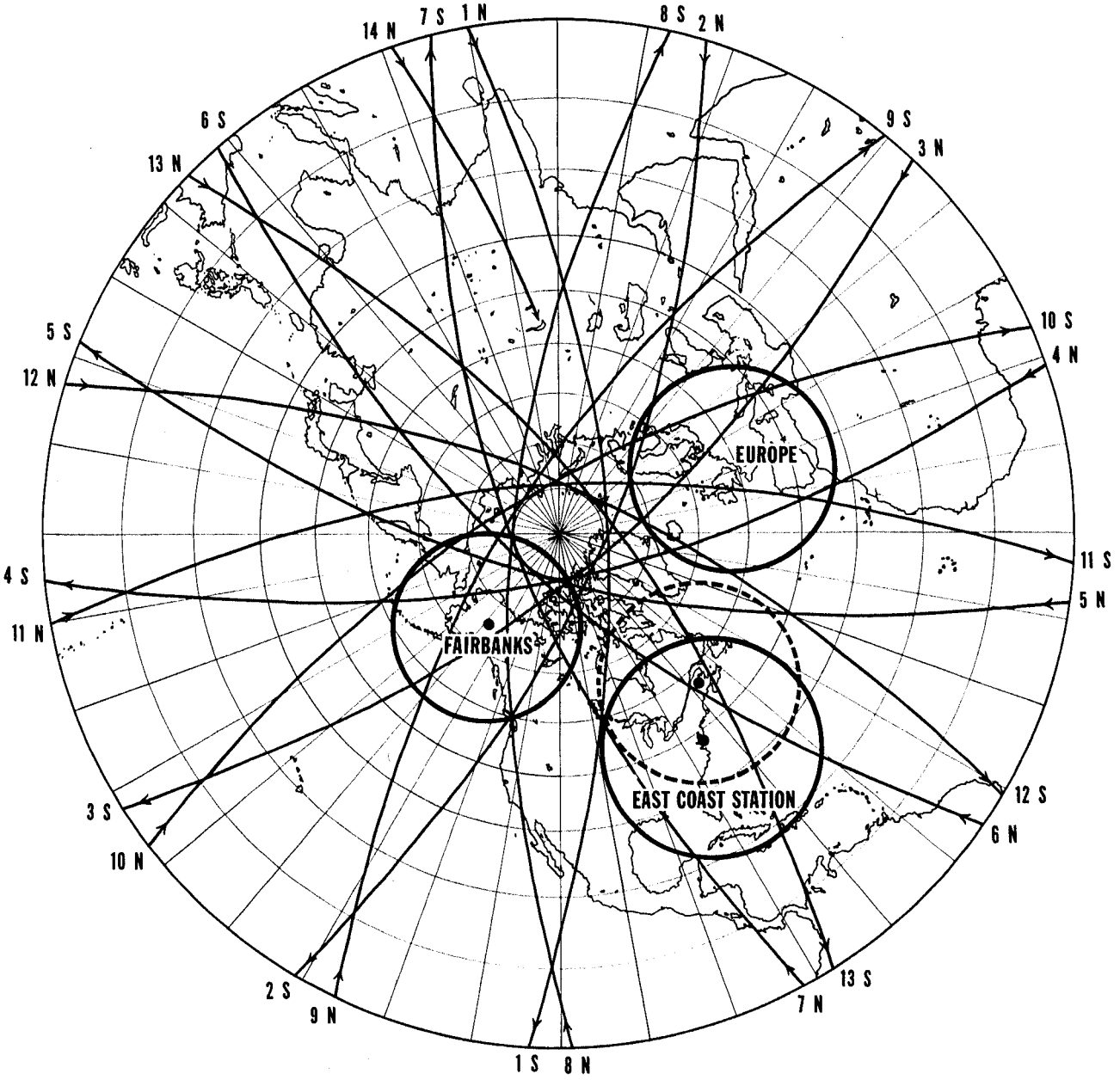
The Programing and Control group will be located in the NMC and share the computer facilities used for data processing. A computer equivalent to the IBM 7090 will supplement the NMC's present 7090. During Phase I, programing will be under NASA Space Control.

RELIABILITY

As the system attains full operational posture, a target of 90–95 percent system reliability will be established. Such reliability will be attained through stringent engineering design, quality control and testing, plus the use of redundant subsystems or components. By Phase II, average spacecraft lifetimes hopefully would approach 6 months and continue to increase. By Phase III, the total system reliability will be accentuated by a quick launch capability. Reliability, where dependent on ground facilities, will be optimized by redundant facilities or by arrangements for the temporary use of R. & D. or other existing facilities.

ARCHIVES

Operational data remain indispensable for climatological studies and for research and devel-



MAP OF ORBITS AND CDA STATIONS

FIGURE 8

opment. They permit determination of environmental conditions for strategic planning and as engineering design criteria. Applied to research, they provide material necessary to the development of improved operational techniques. Accordingly, all meteorological data obtained by the system will be forwarded to the National Weather Records Center for retention and general availability. Techniques for the processing and retrieval of such archival data are being developed.

SUPPORTING RESEARCH AND DEVELOPMENT

THE PROPOSED SYSTEM for Operational Meteorological Satellites rests firmly upon the past, present and future meteorological satellite research and development program. This program did not culminate with TIROS II; it is continuing with the objectives of—

1. Obtaining the data necessary for (*a*) an improved understanding of the atmosphere, and (*b*) the development of better techniques for the practical analysis and forecasting of the weather.
2. Formulating and testing development versions of the equipment and associated techniques which will form the basis of the national operational meteorological satellite system.
3. After the implementation of the system, insuring its continued improvement through a continuing basic and applied R. & D. program.

Project TIROS

Two additional launches of TIROS (fig. 9) are planned before the end of fiscal year 1962.

The TIROS data have been valuable not only for research but also for practical weather analysis and forecasting. An example of an operational transmission (corresponding to fig. 1) is shown in figure 10. Both civil and military field users indicate that they consider the data to be of very substantial value.

It is strongly recommended that, in addition to the two TIROS launches now scheduled, one additional TIROS launch be scheduled, plus one backup. This will result essentially in a continuing program between the presently scheduled TIROS and the initial Nimbus. It will provide for additional operational experience and will provide additional research data. At present, there are no funds programmed to implement this recommendation.

Project Nimbus

This program was described earlier in this report.

Project Aeros

Aeros is a family of earth-stabilized meteorological satellites to be placed in "stationary" equatorial orbits at 22,300 miles. Primary instrumentation will be redundant cameras of both wide-angle and variable focus types.

As yet the Aeros program remains to be officially approved. However, present considerations contemplate an initial launching, using Centaur, in 1964. A total of five R. & D. launchings is currently shown in the NASA long range plan. One proposed configuration of Aeros is illustrated in figure 7. For operational utilization, one or more Aeros satellites would be equally spaced about the equator.

It is strongly recommended that the R. & D. Aeros program be supported, with early funding made available. This recommendation is based on the fact that Aeros provides the only economically feasible means of *continually* viewing weather processes. This is particularly important with respect to weather systems, such as severe local storms, having very short lifetimes.

Based on the results of the early R. &. D. flight program, a decision will be made, probably in 1965, as to the role of Aeros satellites in the operational system.

Advanced Spacecraft R. & D.

Following the flight of the four scheduled Nimbus research and development satellites, it is expected that NASA will continue to launch one Nimbus type R. & D. meteorological satellite per year (not shown on the launch schedule), in addition to the Aeros series. These satellites will be used (*a*) to test new and improved sensors and techniques designed for later incorporation into the operational system and (*b*) to provide special meteorological observations for research on better analysis and forecasting techniques. The Nimbus configuration provides a highly flexible capability for the inclusion of new sensory systems. The flexibility is illustrated in Figure 11.

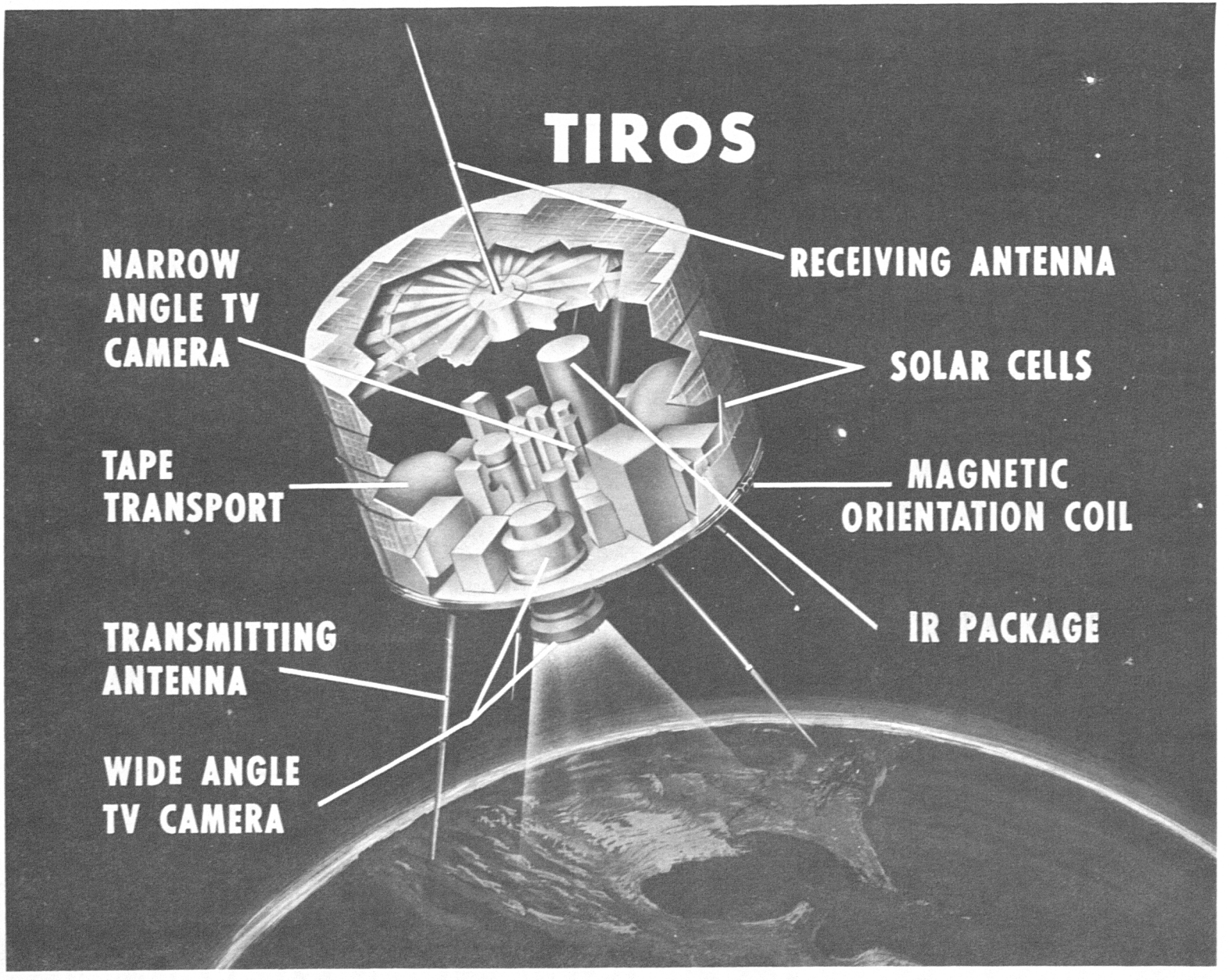

TIROS
RECEIVING ANTENNA
NARROW ANGLE TV CAMERA
SOLAR CELLS
TAPE TRANSPORT
MAGNETIC ORIENTATION COIL
IR PACKAGE
TRANSMITTING ANTENNA
WIDE ANGLE TV CAMERA

FIGURE 9

AN OPERATIONAL FACSIMILE TRANSMISSION OF WEATHER DATA FROM TIROS

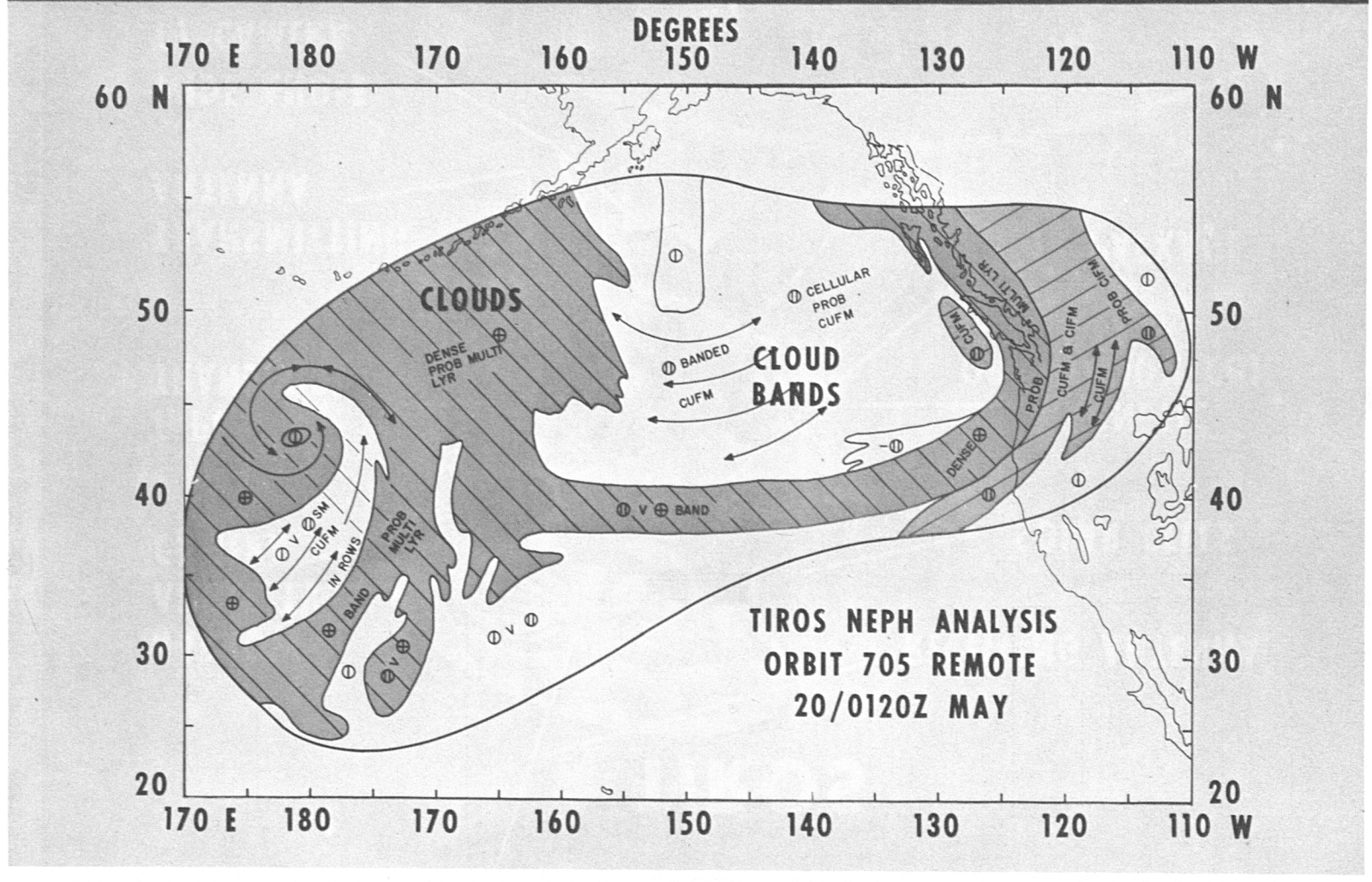


FIGURE 10

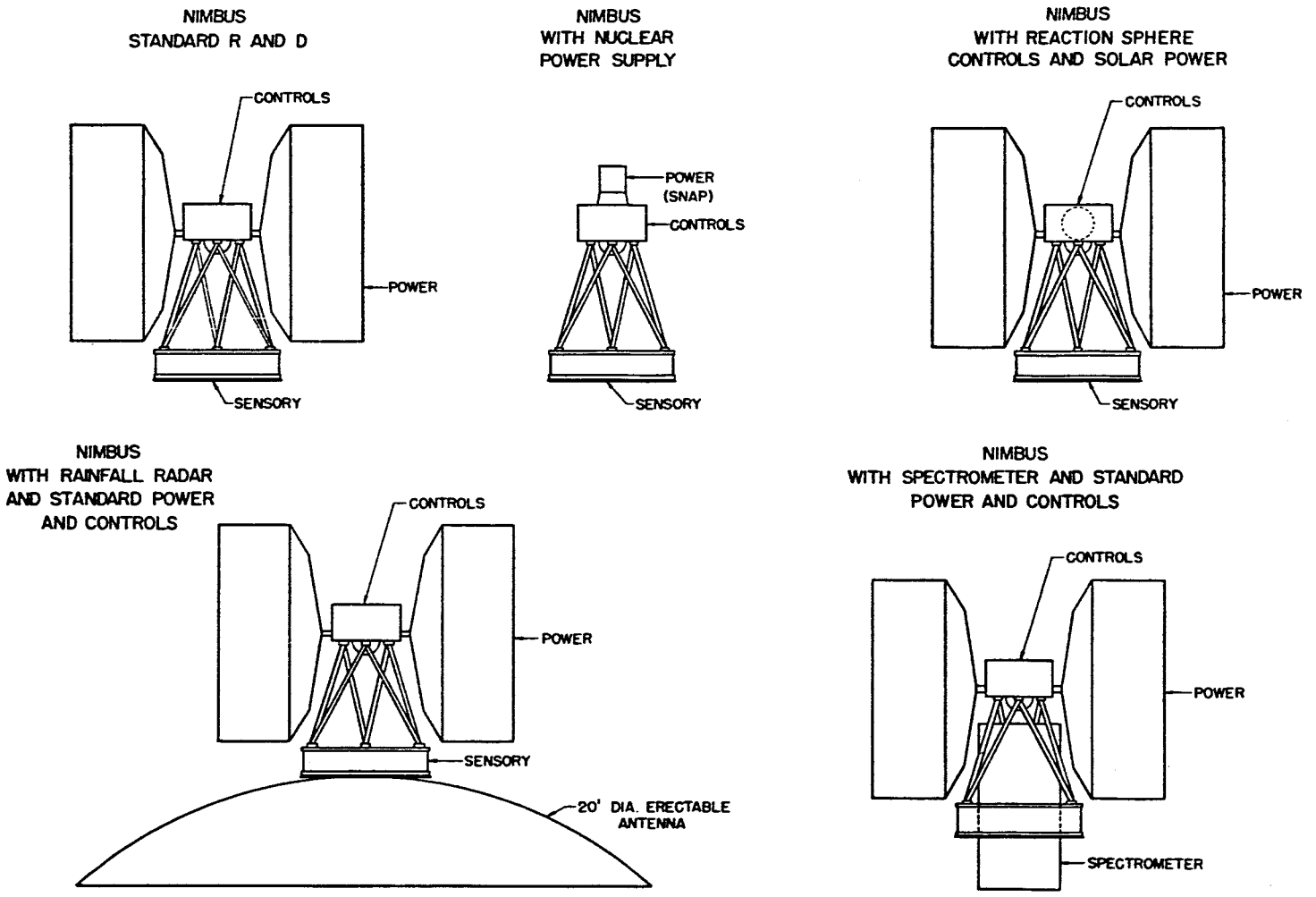


ILLUSTRATION OF NIMBUS FLEXIBILITY AND GROWTH POTENTIAL

FIGURE 11

Data Processing and Utilization

Programs for the analysis and study of meteorological satellite data and the development of analysis and forecasting techniques exist under the cognizance of both the USWB and DOD.

The Weather Bureau has the responsibility in the research and development program for data analysis and subsequent basic and applied research. The Meteorological Satellite Laboratory has been established for this purpose. This organization is interpreting meteorological satellite data to increase our understanding of the atmosphere and its processes. The Laboratory utilizes the results of these basic studies in developing practical analysis and forecasting techniques for operational use. Laboratory personnel at the command and data acquisition stations perform operational meteorological analysis of data from R. & D. satellites and participate in the programing of the satellite measurements. The NMC of the Weather Bureau carries out the central analysis of data from meteorological satellites, incorporates these analyses into more conventional analyses, and transmits the results over civil and military communications circuits.

The Air Force and Navy are participating with the Weather Bureau in the staffing of the meteorological groups at the CDA stations. In addition, these organizations are conducting research to develop techniques for utilizing meteorological satellite data to meet specialized military requirements. The U.S. Navy Photographic Interpretation Center has been participating in the R. & D. program by assisting in the processing of satellite cloud pictures.

MANAGEMENT

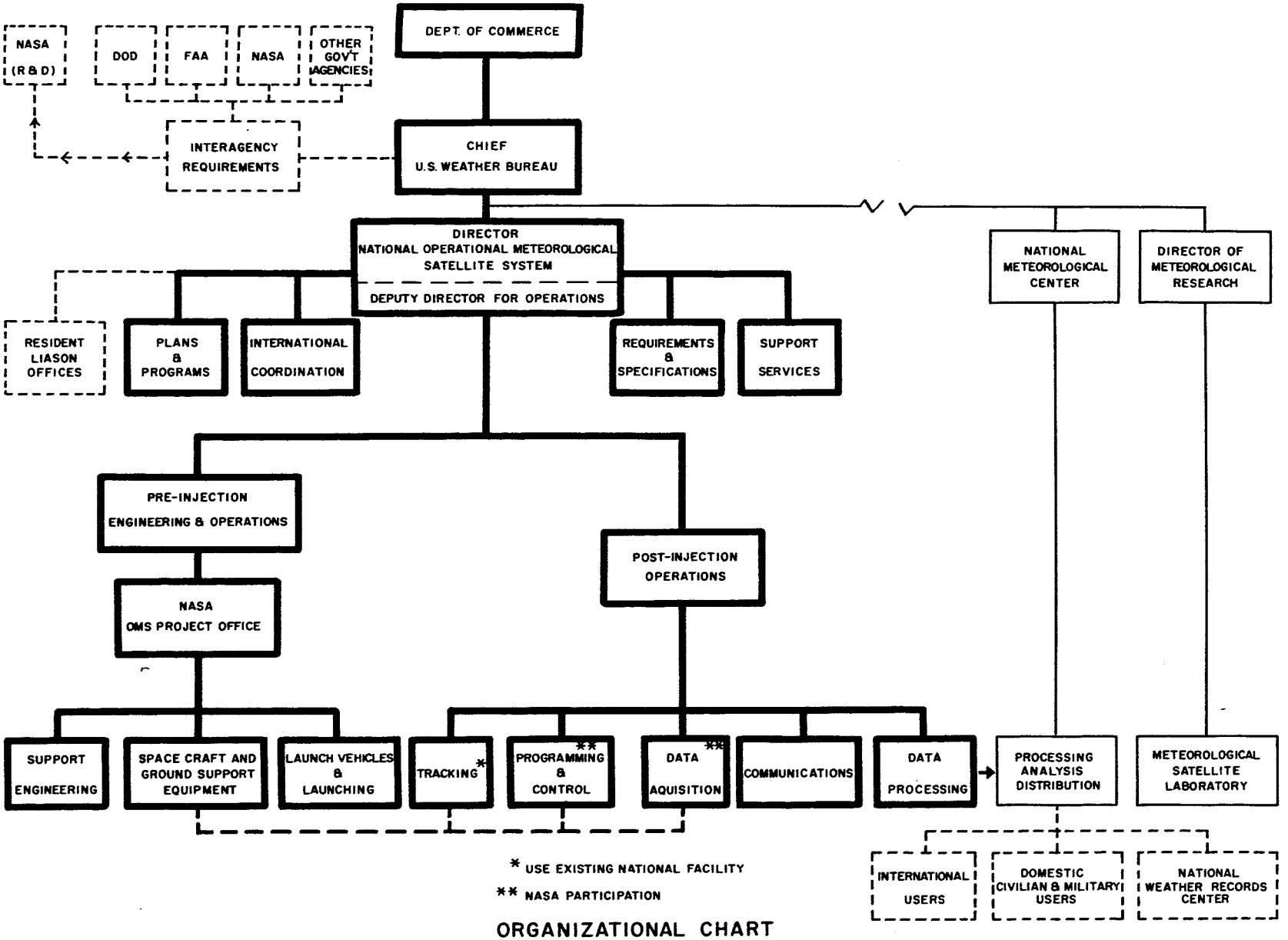
An illustrative organization chart depicting the management structure of the Operational Meteorological Satellite System is shown in figure 12. This plan proposes that the United States Weather Bureau, as the existing National Meteorological Service, be assigned the overall management responsibility for the National Operational Meteorological Satellite System. The system office would be a self-contained newly created team within the USWB. Because of its projected experience and capability in the development and launching of the Nimbus and Aeros spacecraft, the National Aeronautics and Space Administration will carry out these portions of the operational meteorological satellite program under contract to the Department of Commerce and will participate in spacecraft control and programing, tracking, and data acquisition.

Advice to the Chief of the U.S. Weather Bureau concerning the requirements of other agencies will be provided through an interagency coordinating group.

The project management structure and field operational offices will be staffed primarily by personnel supplied by the Managing Agency. User participation is, however, considered to be highly desirable. This can be accomplished by the assignment of personnel from the interested agencies to tours of duty in staff and operating positions of the satellite system, as is done now in the Federal Aviation Agency, NASA, and the Weather Bureau. The assignment of such personnel will aid in effective working level liaison and coordination between the agencies concerned, as well as contributing directly to the accomplishment of the work objectives. In those instances where significant portions of the operation are being conducted by contractors, full-time resident representatives of the contractor will be stationed with the management agency. All staff assigned to the organization for a tour of duty will be administratively as well as technically responsible to the Director.

A. Project Director

The Project Director will report directly to the Chief, U.S. Weather Bureau. He will receive advice on user requirements and maintain direct working coordination with the several government agencies associated with or interested in the program through the Resident Liaison Office. This group will consist of the official liaison representatives of both civilian and military agencies, as contrasted to personnel of such agencies assigned for tours of duty as full members of the system. As requirements for their services exist, consultants (such as university scientists) may be associated with this group or other offices of the system on either a permanent or an ad hoc basis.



ORGANIZATIONAL CHART

NATIONAL OPERATIONAL METEOROLOGICAL SATELLITE SYSTEM

FIGURE 12

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1. PLANS AND PROGRAMS

Planning and programing functions will be placed in one office which will serve as part of the general technical staff of the Director. The Plans and Program Office will collect and consolidate the user requirements as the basis for formulating plans and preparing budget requests relating to operations and contract activities. Program evaluation and monitoring will also be a function of this Office.

2. INTERNATIONAL COORDINATION

The Office of International Coordination will be concerned with all aspects of the program involving other nations. This Office will represent the system in negotiations with the Department of State and other agencies with regard to necessary tracking and CDA stations and communications facilities on foreign territory. It will also be responsible for determining and recommending ways in which the system can be of maximum benefit to the international meteorological community, including dissemination of data and analyses, and providing assistance in the establishment of local direct readout facilities and later of local data acquisition stations.

3. REQUIREMENTS AND SPECIFICATIONS

This Office will develop technical requirements and specifications for the system and its components. It will review contractor proposals, make engineering systems analysis, and maintain liaison with research and development activities of other agencies or institutions, particularly NASA.

4. SUPPORT SERVICES OFFICE

Management support services will be provided directly to the system by an Office responsible to the Director. Emphasis will be placed on effective contractual activities. The division will furnish general and administrative services relating to such matters as personnel, procurement, security, public information, legal and contractual activities, budget and fiscal, accounting, and other general support functions.

B. Pre-Injection Engineering and Operations

The engineering, fabrication, and launching of meteorological spacecraft, including ground support equipment, will be the responsibility of an Associate Director for Pre-Injection Engineering and Operations. These functions will be implemented, under contract to the Department of Commerce, by an Operational Meteorological Satellite Office of the National Aeronautics and Space Administration. Within this office, the (1) Support Engineering, (2) Spacecraft and Ground Support Equipment, and (3) Launch Vehicles and Launching groups will perform the functions their names imply. Necessary technical engineering support and coordination for (post-launch) space flight operations will be carried out between the Spacecraft and Ground Support Equipment group of NASA, and the Programing and Control, and Data Acquisition groups of the System.

C. Post-Injection Operations

An Associate Director for Post-Injection Operations will be responsible for basic satellite tracking, which will be accomplished through existing national facilities. Programing and control of the spacecraft while in orbit, and the acquisition of data at CDA stations will also be a responsibility of this office. These latter activities will require close technical coordination with the Spacecraft and Ground Support Equipment group of NASA. Participation of NASA personnel, particularly during early phases, is mandatory due to the close tie between ground support equipment and spacecraft subsystems. The communication of data from CDA stations to the NMC and the central data processing facility located at the National Meteorological Center will be under the direction of this office. These activities will be carried out by (1) Tracking, (2) Programing and Control, (3) Data Acquisition, (4) Communications, and (5) Data Processing groups.

FUNDING REQUIREMENTS

THE FUNDING REQUIREMENTS of the proposed system are shown in figure 13. In preparing these estimates, costs already budgeted in connection with the scheduled NASA R. & D. Nimbus program and the planned Aeros program have been considered and are *not* included here.

The total capital costs of the system are estimated as about $29 million; the long-term annual recurring costs are expected to stabilize in fiscal year 1967 at a level of about $60 million. To these must be added costs of office space for the technical management of the system and augmentation of space at the National Meteorological Center.

The following explanations of certain items may be helpful:

Spacecraft

Estimated at $4.0 million each with a 21-month leadtime, completely funded at the time an order must be placed.

Launch Vehicles, Etc.

If it is preferred to use incremental funding to reduce the early rate of cost buildup, the following would apply:

[Figures in millions of dollars]

	Leadtime from launch (months)					
	21	18	12	6	3	Total
Thor-Agena B	0.2	1.0	1.1	2.9	1.3	6.5
Atlas-Agena B	0.2	1.5	2.2	3.4	1.0	8.3

FIGURE 13

Funding Requirements

[Millions of dollars]

	Fiscal year					
	1962	1963	1964	1965	1966	1967
Spacecraft	12.00	16.00	16.00	16.00	16.00	16.00
Launch vehicles, launch, and facilities:						
Thor-Agena B, launched (6.50 each, 21 month lead)	26.00	19.50				
Atlas-Agena B, launched (8.30 each, 21 month lead)		8.30	33.20	33.20	33.20	33.20
Command and data acquisition stations:						
Fairbanks, Alaska (duplicate facilities for backup):						
General construction and equipment	5.14	4.16				
Special purpose equipment:						
Ground consoles		3.50				
Data processing and terminal equipment		1.00				
Operating costs (including personnel)		0.80	1.60	1.60	1.60	1.60
East Coast North America:						
General construction and equipment	4.54					
Special purpose equipment:						
Ground console	1.75					
Data processing and terminal equipment	1.00					
Operating costs (including personnel)		0.63	1.26	1.26	1.26	1.26
Europe (assumed funded by participating countries)						
Communications:						
Fairbanks, Alaska, to Suitland, Md.:						
Equipment and installation	0.29		0.10			
Operating and rental costs		0.78	1.09	1.40	1.40	1.40
East Coast North America to Suitland, Md.: Operating and rental costs		0.13	0.16	0.18	0.26	0.33
Europe to Suitland, Md.: Operating and rental costs		0.52	0.66	0.75	0.75	0.75

FIGURE 13—Continued

Funding Requirements—Continued

[Millions of dollars]

	Fiscal year					
	1962	1963	1964	1965	1966	1967
Spacecraft programing and control:						
Equipment	--------	3. 00	--------	--------	--------	--------
Operating costs (including personnel)	--------	--------	0. 25	0. 25	0. 25	0. 25
Central data processing and analysis:						
Capital equipment	1. 00	0. 75	0. 75	0. 50	--------	--------
IBM 7090 rental	--------	1. 50	2. 20	2. 20	2. 20	2. 20
IBM 1401 rental	--------	0. 08	0. 15	0. 15	0. 15	0. 15
Operating costs (including personnel)	--------	0. 50	0. 75	0. 85	0. 85	0. 85
Archives:						
Capital equipment	0. 25	0. 50	0. 25	--------	--------	--------
Operating costs (including personnel)	--------	0. 20	0. 30	0. 30	0. 30	0. 30
Technical management:						
Capital equipment and furniture	0. 10	0. 20	0. 20	--------	--------	--------
Personnel:						
USWB	0. 40	0. 70	1. 00	1. 00	1. 00	1. 00
NASA	0. 50	0. 75	0. 75	0. 75	0. 75	0. 75
Total of above items:*						
Capital costs	14. 07	13. 11	1. 30	0. 50	--------	--------
Recurring costs	38. 90	50. 39	59. 37	59. 89	59. 97	60. 04
Total costs	52. 97	63. 50	60. 67	60. 39	59. 97	60. 04
General facility requirement (in square feet):						
(Lease: $4 per square foot per year; purchase: $30 per square foot.)						
Technical management (USWB and NASA, total)	8, 000	increasing to	15, 000			
National Meteorological Center	3, 000		5, 000			
Total	11, 000	--------	20, 000	--------	--------	--------
European command and data acquisition station (if not funded by participating countries):						
General purpose equipment and facility, construction and installation	4. 54	--------	--------	--------	--------	--------
Special purpose equipment:						
Ground console	1. 75	--------	--------	--------	--------	--------
Data processing and terminal equipment	1. 00	--------	--------	--------	--------	--------
Operating costs (including personnel)	--------	0. 70	1. 43	1. 43	1. 43	1. 43
Total capital costs	7. 29	--------	--------	--------	--------	--------
Total recurring costs	--------	0. 70	1. 43	1. 43	1. 43	1. 43
Recommended extension of TIROS program:						
3 spacecraft	3. 00	--------	--------	--------	--------	--------
2 Thor-Deltas, launched	5. 00	--------	--------	--------	--------	--------
Operation of 2 read-out stations	1. 00	--------	--------	--------	--------	--------
Communications	0. 20	--------	--------	--------	--------	--------
Data processing	0. 50	--------	--------	--------	--------	--------
Total	9. 70	--------	--------	--------	--------	--------

*See below for: General facility requirements, Possible European CDA costs, Costs of recommended TIROS extension

The Thor-Agena B has been scheduled as the launch vehicle through CY 1964; beyond that, Atlas-Agena B costs have been used for lack of realistic cost data on possible alternative, but currently unprogramed, vehicles.

Costs of a separate launch pad for the system and the associated costs of maintaining a "rapid" launch capability have not been included. It seems likely that these would be shared with other national operational systems.

Costs of possible later integration into the system of an operational configuration of Aeros have not been included; estimated cost of the required Centaur vehicle, launched, is presently $8.7 million per flight.

Command and Data Acquisition Stations

Complete redundancy of appropriate facilities and equipment is scheduled at the Fairbanks, Alaska, site to insure operational reliability. This is because this one site acquires nearly three-quarters of the data and, because of this work load, a single set of equipment would not allow sufficient "down-time" to permit necessary maintenance without significant loss of data.

Special Costs

The following items have not been included in the totals for the reasons stated:

(*a*) General facility requirements, because of the uncertainty as to whether these would be constructed or leased.

(*b*) Construction and operation of the European CDA station, in the expectation that the participating countries would assume responsibility for these costs.

(*c*) The recommended extension of the TIROS program, which is not part of the system per se.

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