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1963 NASA AUTHORIZATION

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Storage

HEARINGS

BEFORE THE

SUBCOMMITTEE ON APPLICATIONS AND TRACKING AND DATA ACQUISITION

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS

U.S. HOUSE OF REPRESENTATIVES

EIGHTY-SEVENTH CONGRESS

SECOND SESSION

ON

H.R. 10100

(Superseded by H.R. 11737)

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JUN 12 1962
MANHATTAN, KANSAS

MARCH 5, 6, 8, 12, 14, AND APRIL 10, 1962

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Part 5

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NOTE.—The chairman of the full committee and the ranking minority member, Hon. Joseph W. Martin, Jr., are ex officio members of all subcommittees.

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1963 NASA AUTHORIZATION

MONDAY, MARCH 5, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON APPLICATIONS AND
TRACKING AND DATA ACQUISITION,
Washington, D.C.

The subcommittee met, pursuant to call, at 11:03 a.m., in room 214B, New House Office Building, Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. The Subcommittee on Applications and Tracking and Data Acquisition will come to order.

At this initial hearing of the Subcommittee on Applications and Tracking and Data Acquisition, I would like to summarize our jurisdiction, our procedures, and our objectives.

This subcommittee has the responsibility of examining in detail the budget of the meteorological and communications satellite programs, and tracking and data acquisition activities. The total amount involved in the authorization is $360,577,000.

It will be our subcommittee's objective, first, to become as fully informed as possible with the many details with which we must concern ourselves; second, to evaluate the proper allocation of amounts to each item in terms of their adequacy in relation to schedules; and third, of course, to recommend to the full committee the results of our proceedings.

The subcommittee will consider, first, the meteorological satellite program, then the communications satellites system, and, lastly, tracking and data acquisitions.

At this point, without objection, I would like to place in the record three memoranda by the staff outlining the jurisdiction of this subcommittee and the area in the NASA budget that will be covered and also a copy of the text of H.R. 10100 which will authorize appropriations for the National Aeronautics and Space Administration.

(The documents referred to are as follows:)

COMMITTEE ON SCIENCE AND ASTRONAUTICS

MEMORANDUM NO. 1

To: Hon. Ken Hechler, chairman, Subcommittee on Applications and Tracking and Data Acquisition.
From: Raymond Wilcove and Richard P. Hines, staff consultants.
Subject: NASA authorization bill for 1963 fiscal year.

Chairman Miller has assigned the following NASA categories to the Subcommittee on Applications and Tracking and Data Acquisition:

Communications satellites.
Meteorological satellites.
Tracking and data acquisitions.

NASA is requesting the authorization of $360,577,000 for these categories, as follows:

Research, development, and operation (RDO)	$294, 972, 000
Construction	65, 605, 000

The research, development, and operations funds would be divided among the three categories as follows:

Meteorological satellites	$51, 185, 000
Communications satellites	85, 377, 000
Tracking and data acquisition	158, 410, 000

NASA would allocate RDO funds as follows:

R. & D.:	
Meteorological satellites	45, 894, 000
Communications satellites	79, 624, 000
Tracking and data acquisition	121, 871, 000
Total	247, 389, 000
Institutional support (inhouse):	
Meteorological satellites	2, 737, 632
Communications satellites	2, 542, 427
Tracking and data acquisition	19, 060, 233
Total	24, 340, 292
Personnel:	
Meteorological satellites	2, 553, 368
Communication satellites	3, 210, 573
Tracking and data acquisition	17, 478, 767
Total	23, 242, 708

The $23,242,708 being requested for personnel would be employed for the recruitment of an additional 2,494 employees, broken down as follows:

Meteorological satellites	268
Communications satellites	339
Tracking and data acquisition	1, 887

NASA would allocate the construction funds as follows:

Goddard Space Flight Center, Greenbelt, Md.:	
Spacecraft operations facility	$7, 500, 000
Tracking and telemetry laboratory	3, 175, 000
Jet Propulsion Laboratory, Pasadena, Calif.:	
Data operations and command facility	2, 240, 000
Telecommunications laboratory	2, 860, 000
Langley Research Center, Langley, Va.: Vehicle antenna test facility	1, 725, 000
Marshall Space Flight Center, Huntsville, Ala.:	
Addition to computation division building	1, 255, 000
Expansion of instrumentation systems	4, 000, 000
Mississippi Test Facility: Data acquisition and reduction center	2, 600, 000
Various locations:	
Advanced antenna station, Goldstone Station, Barstow, Calif	14, 250, 000
Antenna facility, Johannesburg Station, South Africa	5, 000, 000
Antenna facility, Woomera Station, Australia	5, 000, 000
Data acquisition facility, Far East Station	6, 000, 000
Data acquisition facility, Rosman Station, N.C	3, 500, 000
Modifications to the Mercury Control Center	5, 000, 000
Wallops Station, Wallops, Va.:	
Advanced data acquisitions system	1, 500, 000
Modification and expansion of range control, safety and support systems and equipment	2, 000, 000

MEMORANDUM No. 2

This is an analysis of the fiscal year 1963 NASA requests for construction authority that appear to fall within the jurisdiction of the Subcommittee on Applications and Tracking and Data Acquisition.

TOTAL CONSTRUCTION, $65,605,000

ATLANTIC MISSILE RANGE

Under Advanced Saturn-Nova supporting facilities there are several areas of possible subcommittee interest and action. These have to do with data acquisition, range telemetry, and radar facilities. However, as a construction item, this may be a case of dividing jurisdiction into minute areas that will be impractical to handle.

GODDARD SPACE FLIGHT CENTER

Spacecraft operations facility, $7,500,000

This item is concerned primarily with data acquisition reduction. Building and equipment are involved.

Tracking and telemetry laboratory, $3,175,000

This item is limited to construction and installation of supporting services and equipment. It does not involve telemetry nor data processing equipment; 100,000 square feet of floor space at $25 per square foot is involved.

JET PROPULSION LABORATORY

Data operations and command facility, $2,240,000

A 53,800-square-foot laboratory-office building is involved to house computers and provide command and control centers necessary for our unmanned lunar and planetary programs. Construction support services, facilities, and data processing equipment are involved.

Cost of the building, $1,495,000, at $28.40 per square foot.

Telecommunications laboratory, $2,860,000

Involved here is an 82,000-square-foot building at $28 per square foot, as well as laboratory equipment. This installation will be used for advanced work leading to a deep space instrumentation capability, which includes ground tracking and communications facilities required in the lunar and planetary programs.

LANGLEY RESEARCH CENTER

Vehicle antenna test facility, $1,725,000

A 14,820-square-foot building, at $26.32 per square foot, is required to house various equipments and test chambers in the development of noninterfering antenna systems to be used on multistage vehicles and data transmission techniques utilizing radio telemetry.

MARSHALL SPACE FLIGHT CENTER

Addition to computation division building, $1,255,000

Approximately 34,700 square feet added to the computation building, at $30 per square foot, involving two wings in which data reduction equipment such as digital and analog computers along with additional personnel will be housed.

Expansion of instrumentation systems, $4 million

This item involves no building construction. Allocation is for the development, fabrication, and installation of various instruments for data acquisition and reduction of information gathered from tests associated with the Advanced Saturn program.

MISSISSIPPI TEST FACILITY

Data acquisition and reduction center, $2,600,000

This is concerned with a 100,000-square-foot building only, with no requests for instrumentation included in this total. Cost will be $26 per square foot.

VARIOUS LOCATIONS

Goldstone advanced antenna station, $14,250,000

This item involves the construction and installation of an advanced antenna system to be used for deep space vehicle tracking and communication.

Antenna facilities, Johannesburg, Woomera, $5 million each

These are facilities designed to handle future workloads associated with our deep space and lunar spacecraft programs. The antennas will supplement currently installed facilities. In addition to antennas and associated instrumentations, costs include the construction of several buildings at each site; two control buildings, 1,200 square feet at $25 per square foot; two technical buildings, 1,500 square feet at $25 per square foot; and two support buildings, 2,500 square feet at $25 per square foot.

Data acquisition facility, Far East station, $6 million

This is a requirement for a high-gain, wide-band data acquisition facility, to provide coverage for satellite operations in conjunction with the Rosman, N.C., station. Request includes a generator building, 1,600 square feet at $25 per square foot; a hydraulics building, 750 square feet at $20 per square foot; and an operations building, 12,800 square feet at $30.50 per square foot.

Data acquisition facility, Rosman station, $3,500,000

This item is similar to the previous one, in that it is designed to perform the same functions as the Far East station. It will be the primary U.S. data acquisition station for large scientific satellites programed to start during 1962. Involved are three buildings: A generator building addition, 1,600 square feet at $18.50 per square foot; a hydraulics building, 750 square feet, at $20 per square foot; and an operations building addition, 6,000 square feet at $25.60 per square foot.

MANNED SPACE FLIGHT CONTROL CENTERS

Mercury, $5 million

Modifications to the present Mercury control centers are planned as part of the Apollo program which is follow-on to Mercury. In addition to the equipment modifications and additions, small-building construction is requested. This is an addition to a Mercury control center, 1,600 square feet at $50 per square foot.

WALLOPS STATION

Advanced data acquisition system, $1,500,000

This item is principally concerned with the installation of advanced equipment and the erection of an antenna tower. No building construction is involved.

Modification and expansion of range control, safety, and support systems and equipment, $2 million

The expansion and modification is necessary to provide increased photographic and optical tracking capability for more accurate coverage of model flights. In addition to the instrumentation, the construction of three buildings is planned and requested. They are: Pumping station, 320 square feet at $25 per square foot; a pump and chlorination building, 500 square feet at $25 per square foot; and a critical standby power building, 2,500 square feet at $25 per square foot

---

MEMORANDUM NO. 3

Applications, tracking and data acquisition

1. Meteorological satellite systems:		
(*a*) Advanced research		$1,808,000
(*b*) Advanced technical development		9,605,000
(*c*) Flight program:		
TIROS (4th, 5th, 6th, and 7th)	$3,390,000	
Nimbus (1st and 2d)	17,854,000	
Nimbus (3d and 4th)	17,060,000	
Meteorological soundings	1,468,000	
		39,772,000
Total		51,185,000

2. Communication satellite systems:		
(*a*) Advanced research		$2,688,000
(*b*) Advanced technical development		2,473,000
(*c*) Flight program:		
Echo	$135,000	
Rebound	16,747,000	
Relay	19,141,000	
Synchronous communication satellite (SYNCOM)	4,087,000	
Intermediate altitude satellite	21,505,000	
Advanced synchronous communication satellite	18,601,000	
		80,216,000
Total		85,377,000
3. Tracking and data acquisition:		
(*a*) Systems development		15,950,000
(*b*) Network operations		67,815,000
(*c*) Equipment and components		74,645,000
		158,410,000
Total, research, development and operations (applications)		136,562,000
Total, research, development and operations (tracking and data acquistion)		158,410,000
Total		294,972,000
Total, construction of facilities		65,605,000
Total, applications and tracking and data acquisition		360,577,000

[H.R. 10100, 87th Cong., 2d sess.]

A BILL To authorize appropriations to the National Aeronautics and Space Administration for research, development, and operation; construction of facilities; and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That there is hereby authorized to be appropriated to the National Aeronautics and Space Administration the sum of $3,787,276,000, as follows:

(a) For "Research, Development, and Operation", $2,968,278,000.

(b) For "Construction of Facilities", $818,998,000, as follows:

(1) Ames Research Center, Moffet Field, California, $14,439,000.
(2) Atlantic Missile Range, Cape Canaveral, Florida, $359,963,000.
(3) Facility planning and design not otherwise provided for, $10,000,000.
(4) Flight Research Center, Edwards, California, $1,807,000.
(5) Goddard Space Flight Center, Greenbelt, Maryland, $23,780,000.
(6) Jet Propulsion Laboratory, Pasadena, California, $10,360,000.
(7) Langley Research Center, Hampton, Virginia, $8,092,000.
(8) Lewis Research Center, Cleveland, Ohio, $43,833,000.
(9) Manned Spacecraft Center, Houston, Texas, $30,755,000.
(10) Marshall Space Flight Center, Huntsville, Alabama, $33,437,000.
(11) Michoud Plant, New Orleans, Louisiana, $18,400,000.
(12) Mississippi Test Facility, Mississippi, $92,500,000.
(13) Nuclear Rocket Development Station, Nevada, $40,000,000.
(14) Various Locations, $127,332,000.
(15) Wallops Station, Wallops Island, Virginia, $4,300,000.

(c) Appropriations for "Research, Development, and Operation" may be used (i) for any items of a capital nature (other than acquisition of land) which may be required for the performance of research and development contracts, and (ii) for grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities; and

title to such facilities shall be vested in the United States unless the Administrator determines that the national program of aeronautical and space activities will best be served by vesting title in any such grantee institution or organization. Each such grant shall be made under such conditions as the Administrator shall determine to be required to insure that the United States will receive therefrom benefit adequate to justify the making of that grant. None of the funds appropriated for "Research, Development, and Operation" pursuant to this Act may be used for construction of any major facility, the estimated cost of which, including collateral equipment, exceeds $250,000, unless the Administrator or his designee notifies the Committee on Science and Astronautics of the House of Representatives and the Committee on Aeronautical and Space Sciences of the Senate of the nature, location, and estimated cost of such facility.

(d) When so specified in an appropriation Act any amount appropriated for "Research, Development, and Operation" and for "Construction of Facilities" may remain available without fiscal year limitation.

(e) Appropriations other than "Construction of Facilities" may be used, but not to exceed $35,000, for scientific consultations or extraordinary expenses upon the approval or authority of the Administrator and his determination shall be final and conclusive upon the accounting officers of the Government.

SEC. 2. Authorization is hereby granted whereby any of the amounts prescribed in subparagraphs (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12), (13), (14), or (15) of subsection 1(b) may, in the discretion of the Administrator of the National Aeronautics and Space Administration, be varied upward 5 per centum to meet unusual cost variations, but the total cost of all work authorized under such subparagraphs shall not exceed a total of $818,998,000.

SEC. 3. Not to exceed 3 per centum of the funds appropriated pursuant to subsection 1(a) hereof may be transferred to the "Construction of Facilities" appropriation, and, when so transferred, together with $30,000,000 of the funds appropriated pursuant to subsection 1(b) hereof, shall be available for expenditure to construct, expand, or modify laboratories and other installations at any location (including locations specified in subsection 1(b), if (1) the Administrator determines such action to be necessary because of changes in the national program of aeronautical and space activities or new scientific or engineering developments, and (2) he determines that deferral of such action until the enactment of the next authorization Act would be inconsistent with the interest of the Nation in aeronautical and space activities. The funds so made available may be expended to acquire, construct, convert, rehabilitate, or install permanent or temporary public works, including land acquisition, site preparation, appurtenances, utilities, and equipment. No portion of such sums may be obligated for expenditure or expended to construct, expand, or modify laboratories and other installations until the Administrator or his designee has transmitted to the Committee on Science and Astronautics of the House of Representatives and to the Committee on Aeronautical and Space Sciences of the Senate a written report containing a full and complete statement concerning (1) the nature of such construction, expansion, or modification, (2) the cost thereof, including the cost of any real estate action pertaining thereto, and (3) the reason why such construction, expansion, or modification is necessary in the national interest. No such funds may be used for any construction, expansion, or modification if authorization for such construction, expansion, or modification previously has been denied by the Congress.

SEC. 4. The Administrator is hereby authorized to transfer, with the approval of the Bureau of the Budget, funds appropriated pursuant to this Act, to any other agency of the Government whenever the Administrator determines such transfer necessary for the efficient accomplishment of the objectives for which the funds have been appropriated. Not more than $20,000,000 of the funds authorized by this Act may be transferred by the Administrator under this section, and no transfer in excess of $250,000 shall be made under this section unless the Administrator has transmitted to the Committee on Aeronautical and Space Sciences of the Senate and to the Committee on Science and Astronautics of the House of Representatives a written statement concerning the amount and purpose of, and the reason for, such transfer, and (1) each such committee has transmitted to the Administrator written notice to the effect that such committee has no objection to that transfer, or (2) thirty days have passed after the transmittal by the Administrator of such statement of those committees.

Mr. HECHLER. For our witness this morning, we have Mr. Morton J. Stoller, Director, NASA Office of Applications, who will discuss both meteorological and communication satellite systems. Mr. Morris

Tepper, Director of the Office of Meteorological Systems, is also present and will assist Mr. Stoller in his testimony.

At this point, without objection, we will have the biographical sketch of Mr. Stoller copied into the record.

(The document referred to is as follows:)

MORTON J. STOLLER, DIRECTOR, OFFICE OF APPLICATIONS

Morton J. Stoller was designated Director of the Office of Applications on March 1, 1962. He was appointed Acting Director on January 3, 1962, and Deputy Director of that Office on November 1, 1961.

In his present position he is responsible for the development and application of meteorological and communications satellites systems and for recognition and development of areas of future applications for space and aeronautical technology. This responsibility includes the planning and direction of the research and development leading to specific satellite applications, planning and direction of NASA's programs for the establishment and support of operational satellite systems, and the identification of applications of NASA efforts which will lead to broad industrial uses.

Prior to his present assignment, from the time of his appointment in early 1960, Stoller was Assistant Director for Satellite and Sounding Rocket Programs, in the Office of Space Flight Programs at NASA headquarters. He was previously Chief of Space Science Programs in the Office of the Assistant Director for Space Sciences at NASA headquarters, having been appointed shortly after the National Aeronautics and Space Administration was established on October 1, 1958.

In these assignments he was responsible for scientific investigations in near space, using satellites, probes, and sounding rockets. This work included research and development in astronomy and geophysics, the planning and technical direction of development program and flight missions involving scientific spacecraft and sounding rockets, as well as the reduction and evaluation of data therefrom.

He is a native of New York. He earned the degree of bachelor of electrical engineering from the College of the City of New York in 1958. He was awarded a master's degree in electrical engineering from the University of Virginia in 1952.

Stoller joined the National Advisory Committee for Aeronautics, the predecessor of NASA, in 1939, as an electrical engineer at the Langley Aeronautical Laboratory. In 1957 he was named Assistant Chief of the Instrument Research Division at Langley.

His research work has chiefly been concerned with the instrumentation used in aeronautical research. He was in charge of the group at the Langley Aeronautical Laboratory which was responsible for the development of NACA telemetering system for use in free-flight rocket-powered model testing and for the adaptation of radar techniques to the same problem. This group was responsible for the development of the original instrumentation installation at NASA's Wallops station.

He was also responsible for major phases of the planning and applications in the field of large-scale analog and digital computing machinery at the Langley Laboratory.

Stoller is a member of the American Institute of Electrical Engineers, the Institute of Radio Engineers, the American Geophysical Union, and the Association for Computing Machinery.

Stroller resides with his wife, the former Ruth Klarberg, and their two sons and daughter in Bethesda, Md.

Mr. HECHLER. Mr. Stoller, you may proceed.

STATEMENT OF MORTON J. STOLLER, DIRECTOR, NASA OFFICE OF APPLICATIONS, ACCOMPANIED BY MORRIS TEPPER, DIRECTOR, OFFICE OF METEOROLOGICAL SYSTEMS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. STOLLER. Thank you, Mr. Chairman.

I am pleased to have this opportunity to outline to you the 1963 fiscal program of the Office of Applications. The first chart (fig. 493)

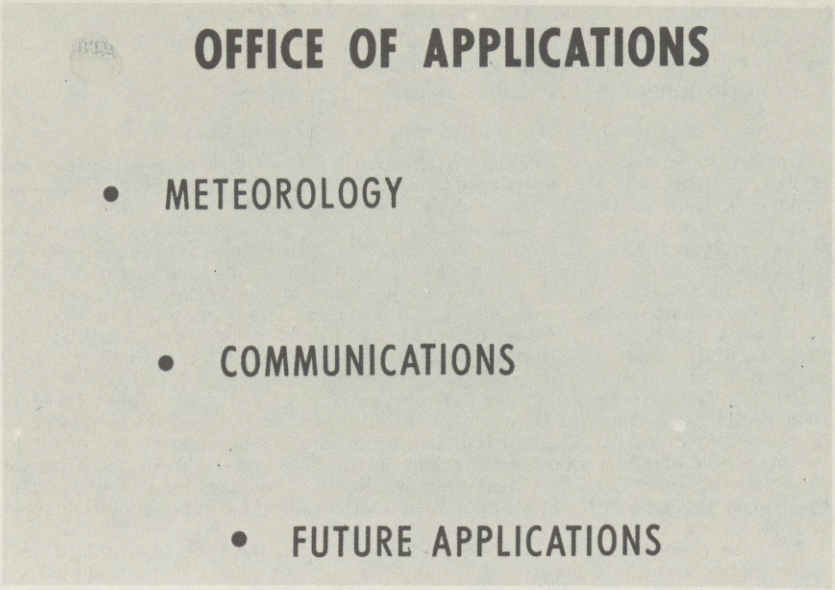

FIGURE 493

shows the functional areas of the Office of Applications. We are concerned with meteorology, meteorological systems, satellites, and sounding rockets in this area. We are concerned with communications satellite systems, and we are also concerned with what we call future applications. Future applications is an effort to identify other promising applications for spacecraft and the rapid dissemination of information on the technological developments which result from NASA research and development activities which appear to be useful for general industrial applications.

In our meteorological systems activity the major accomplishment to date is the TIROS satellite. The cloud cover results that we get from TIROS are an item which we feel will continue to give the meteorological community a tremendous amount of capability in being able to improve their weather prediction work.

The television pictures of the cloud cover which were made available to the meteorological groups in the country have been found to be very beneficial, particularly when used in conjunction with the other data collected by ground observations, to improve the prediction techniques.

Now we are going to extend this capability from the TIROS satellite to the NIMBUS satellite which will give us a more continuous look at the cloud cover by the use of an improved system. I will go into that in somewhat more detail later in this discussion.

In the first phase of the program, as shown in this chart (fig. 494), we are undertaking the development of the equipment and techniques required for the establishment of an operational meteorological satellite system and for the general support of meteorological research. These two end uses may, of course, lead to somewhat different satellite configurations; for example, the operational systems will require

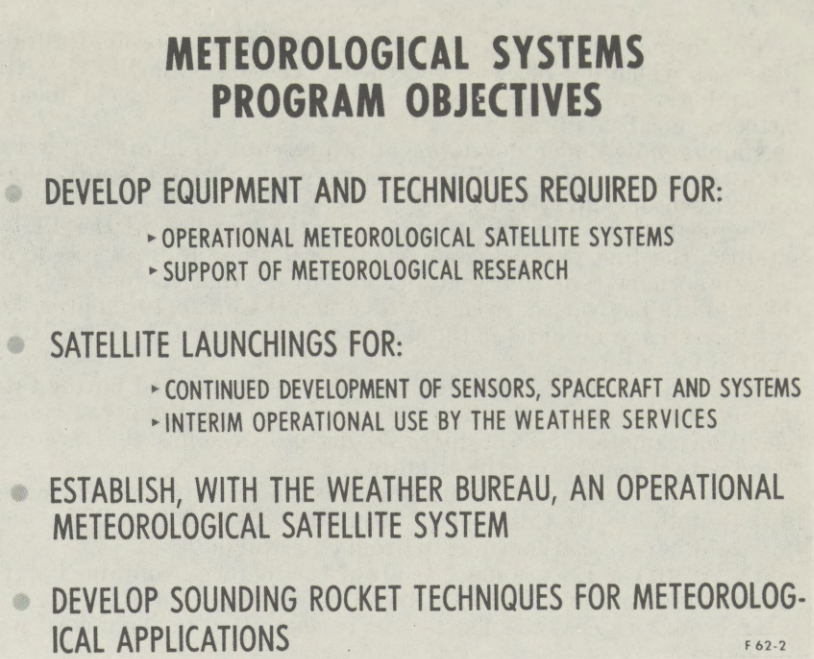

FIGURE 494

equipment with a very high degree of reliability. Successive operational units may be repetitive in their construction, while research and development satellites will change from flight to flight so as to take advantage of new developments. In the second phase of the program there are satellite launchings which will be used for the continuous development of sensors, spacecraft, and systems, as such, and these satellite systems which we would consider to be of an R. & D. nature will be used in an interim operational sense by the weather services.

We are working now with the Weather Bureau in the development of an operational satellite system. That is, we are going ahead with the TIROS satellites and will work with the Numbus satellites when they are in hand, to integrate into the Weather Bureau's normal operating procedures the data from the satellites we fly.

The final phase of our activity in meteorological systems is the development of sounding rocket techniques for meteorological applications. In this case we take advantage of the fact that a sounding rocket gives us data in the altitude range above that for balloons and below that for satellites. In other words, at about 100 miles a satellite reaches its lower limit, you can't collect any more data. Similarly, above 20 to 25 miles you have reached the limit of the balloon. In the region from 20 miles or so to 100 miles a sounding rocket is used to collect wind and temperature data. In this area we work with the Weather Bureau, the Department of Defense, and the NASA space science people who are also concerned with sounding rocket techniques for the determination of upper atmospheric characteristics.

Now the next chart (fig. 495) shows the three meteorological satellites with which our office is concerned. These are the TIROS, Nimbus and Aeros. TIROS was the initial effort in the development of meteorological satellites.

Nimbus, now under development, represents an improved system. Aeros is a conceptual satellite which is going through study phases for both sensors and systems.

The next chart (fig. 496) summarizes the launches of the TIROS satellite, the first one being in April 1960 and the most recent one being February 8 of this year. You will see that the useful life of the satellite has varied from 2½ or 3 months up to 10 months. Of course, we have no data at the moment as to what the useful life of TIROS IV will be.

Some indication of the difference in the sensors used on the satellites is also given in the chart. By "sensors" we mean the type of television camera, and the infrared detector systems that are associated with the camera in the satellite.

We have found it very desirable to use more than one TV system in the satellite. By this type of redundancy, should one TV camera fail, the other one can continue to produce useful data.

Mr. HECHLER. Excuse me. Is all of the material contained on the charts, the dates and so forth, being submitted for the record too?

Mr. STOLLER. Yes; the charts will be submitted in the record with the statement.

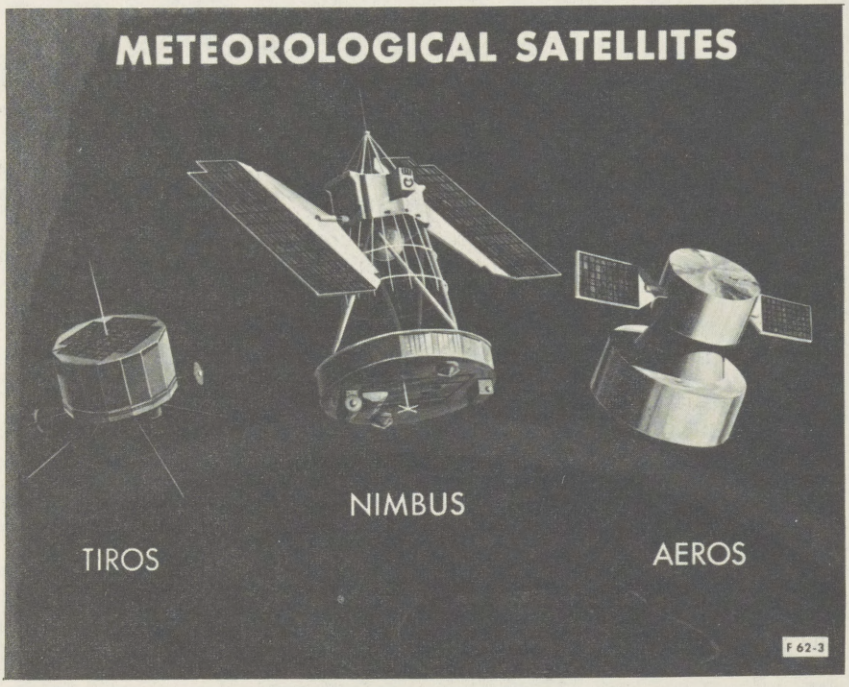

FIGURE 495

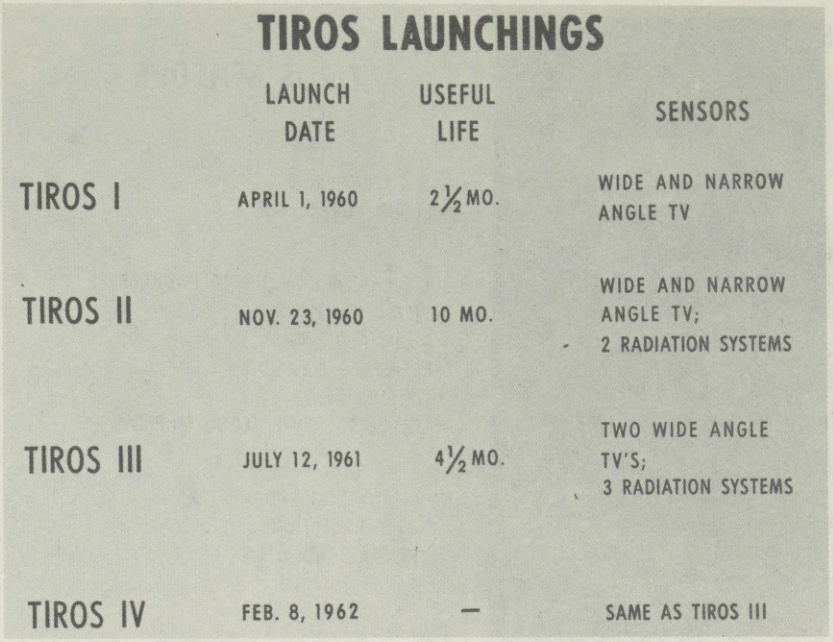

FIGURE 496

Mr. HECHLER. Very well.

Mr. STOLLER. The next chart (fig. 497) gives a little more detail on the sensors for TIROS, which I have just mentioned. There are two TV cameras for cloud cover, as well as a multichannel scanning radiometer. This is an infrared detector system that has various detector elements, each tuned to a different region in the infrared spectrum and from these channels we can determine the temperatures of the water vapor, temperatures of night clouds, reflected sunshine, energies, the emitted heat from the Earth and we can do a low-resolution cloud mapping job.

There is also a nonscanning radiometer associated with TIROS, the two little devices that stick out of the hatbox structure on either side. These are capable of measuring the total radiation emitted from the Earth as well as the reflected thermal (solar) radiation coming from the Earth. By working on our known solar input we can get some idea of what is known as the heat balance of the earth, that is how much heat is coming in and how much is going out, so as to have some idea of what is pumping the atmosphere around.

These sensors are put in on a continuing basis in the TIROS sequence. They are modified from flight to flight in minor details as our experience shows that certain electrical or mechanical details should be improved for better performance.

The next chart (fig. 498) has a breakaway diagram of TIROS itself, and some idea of the complexity of the satellite is given in the chart.

The dimensions are roughly 42 inches in diameter, 19 inches in height and weighs almost 300 pounds. You can see the TV camera

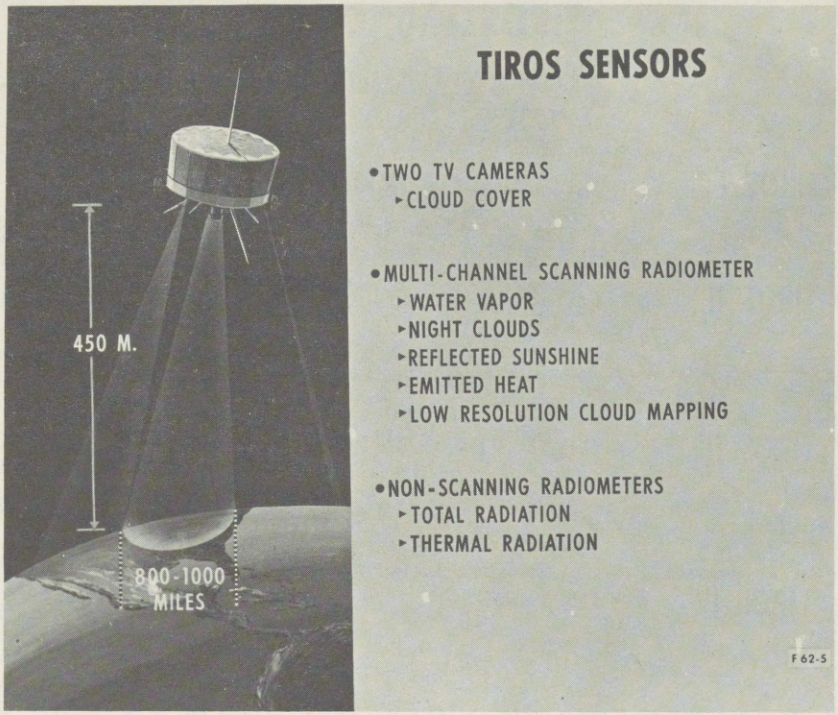

FIGURE 497

unit and the wide-angle radiometers sticking out at the bottom on the side. There is an indication in the chart of the two large antennas, one in the San Nicholas Island on the west coast near the Pacific Missile Range which is used to collect data from TIROS and the other on the east coast of the United States at our Wallops Station which also collects data from TIROS.

There are several tape recorders aboard this satellite which store the data when the satellite is at some other portion of the world than in the immediate vicinity of the receiving stations. The tape recorders are then read out by command when the satellite comes over the receiving station.

It is covered with solar cells and there are nickel cadmium batteries aboard to supply the required power. There are also a couple of other interesting engineering items that I will mention briefly. One of them is an attitude control coil shown which was not there on TIROS I. It is a magnetic coil which interacts with the Earth's magnetic field to give the operator on the ground some control of the attitude of the satellite.

The satellite spins on its axis to maintain a position in space and it was noticed to drift. The original thinking was that a spin stabilized object in space, with very little to disturb it, should remain fixed

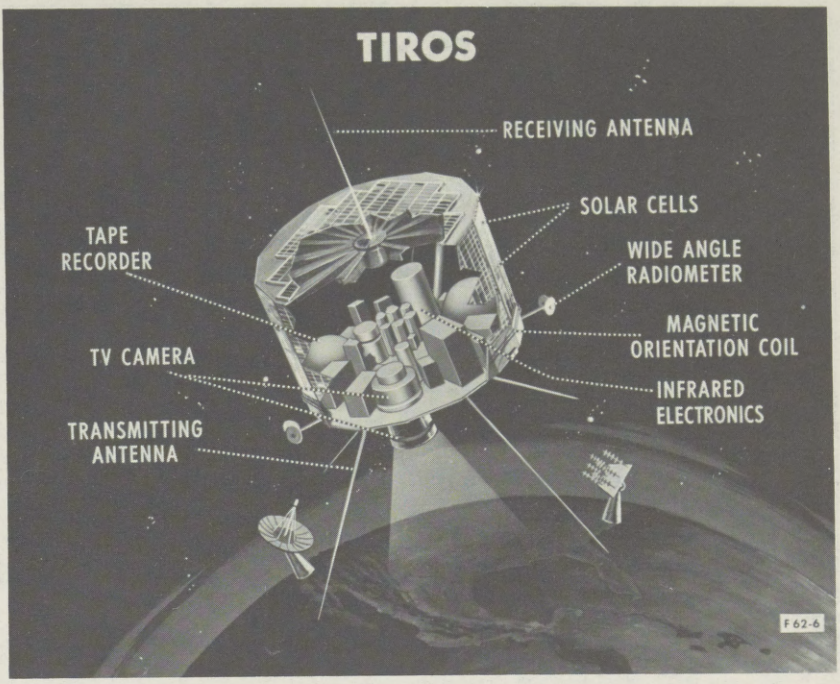

FIGURE 498

in space. However, its magnetic field interacts with the Earth's magnetic field and it tends to drift.

In the second, third, and fourth TIROS satellites a coil was deliberately put on board with a control switch and a command device so that we could generate fields of various strengths and directions and thus force the satellite to drift, insofar as its position in space was concerned, in a desired manner. In this way we are able to extend the time during which TIROS points toward the Earth and gets satisfactory pictures.

The other item that is of interest is there are some small spin-up rockets around the bottom of the satellite which are used to maintain the spin at a reasonable rate. These have been fired after the satellite has been in orbit, one pair as long as 10 months after the initial launch. TIROS IV which is now in orbit, has already had three sets of these spin rockets fired to bring it back to the nominal spin rate.

The next chart (fig. 499) shows the general orbital path for a TIROS satellite. The satellite is injected into an inclined orbit because it is fired from the cape and, because we do want to get to as high a latitude coverage as possible, we use an inclined orbit. It is spin stabilized, which means it tends to stay fixed in space except for the attitude drift I have mentioned. Consequently, when it is in one part of its orbit its cameras are pointing out into space and they see nothing at all. So at best we cover only a small fraction of time of

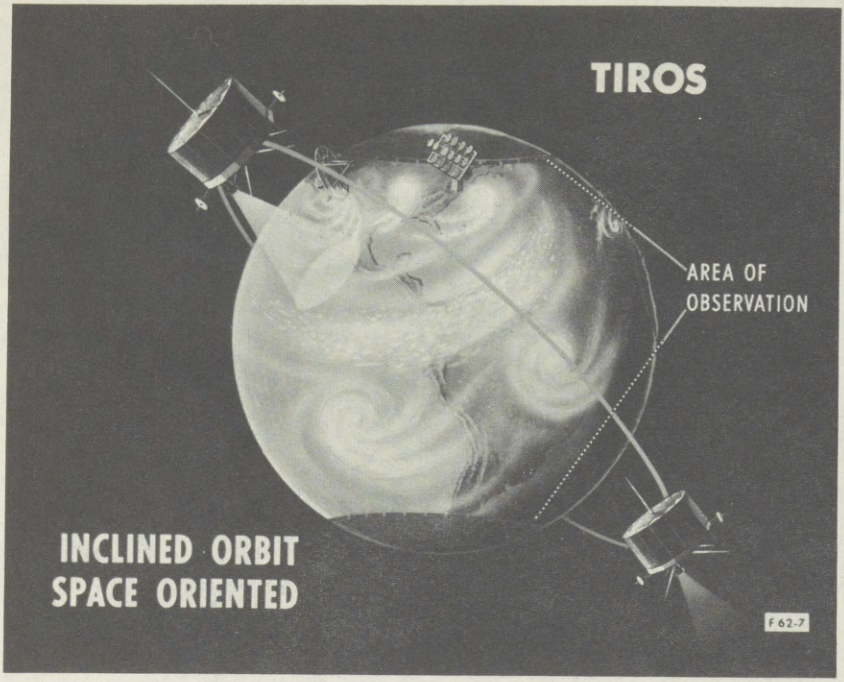

FIGURE 499

the Earth in the time it is in orbit. As the chart indicates, because of the limitations imposed by the inclination of the orbit, we can only see up to a maximum latitude of about 45° or 50° north and south.

I think you have seen many pictures transmitted by TIROS. The next chart (fig. 500) shows a typical hurricane picture. This is Betsy, picked up in the western Atlantic Ocean last September. It is somewhat of a classic photograph of a hurricane, according to the hurricane pattern that you would see on a radar set, and similar to a plotting symbol meteorologists have used for many years, the spiral type of design.

The ability to identify hurricane cloud patterns to locate them with respect to land masses and to follow their motions is one of the major benefits of the meteorological satellite.

The next chart (fig. 501) shows in a very much compressed manner the TIROS global cloud analysis for September 11, 1961. We have here a map of the world looking down on the North Pole. The various areas that are outlined on the chart are assemblages of data from many TIROS cloud cover pictures all taken on the one day. Each finger-shaped area that you see shows in a condensed way the cloud information from a sequence of TIROS photographs. The white represents the clouds and the blue the clear areas as seen by the satellite. For this type of work the photographs are converted to a graphical notation, by meteorologists at the data read-out stations, and cloud cover maps are sent by wirephoto to the U.S. Weather Bureau's National Meteorological Center at Suitland.

FIGURE 500

FIGURE 501

At that center they are combined on maps such as this one and further distributed to weather stations all over the world. On the chart there are indicated the major storm and hurricane centers which could be identified in this global analysis.

You will notice that we have indicated by the three-legged symbols six distinct tropical storm centers, which were located by the detailed analysis of the data used to make this map. One center which is the remnant of Hurricane Betsy and a second, which never grew enough to acquire a name, are also shown.

The next chart (fig. 502) shows some of the details of such a world chart with particular attention paid to Carla as it hit the Texas coast. I have deliberately retained on this chart many of the details of the cloud analysis as they are presented in a graphical form for transmis-

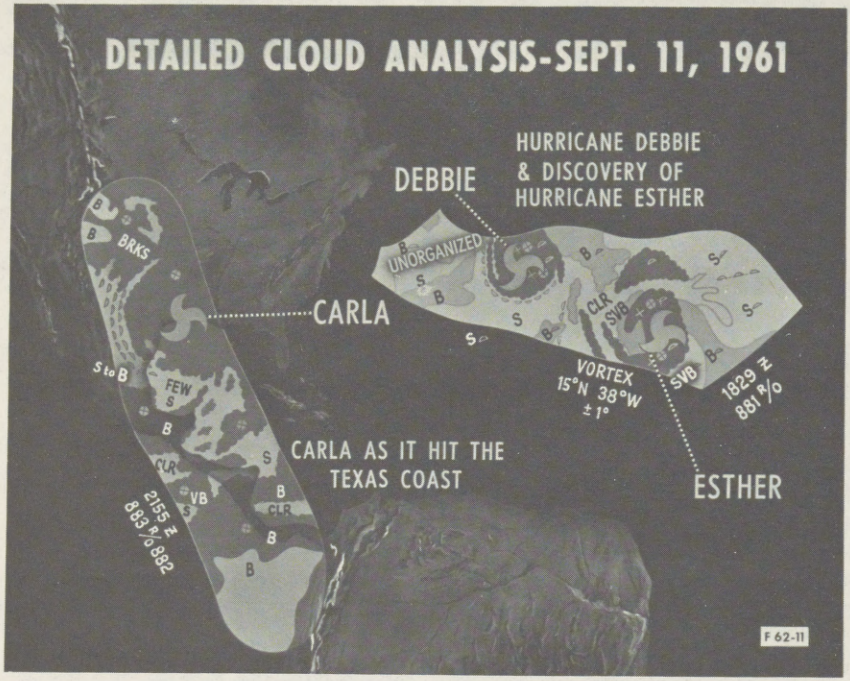

FIGURE 502

sion over the wirephoto network. The Weather Bureau and military services maintain this for passing information from point to point. The various letter symbols and the specific details of the lines of the cloud formations that you can see convey a good deal of information to the trained user of the charts.

Hurricanes Debbie and Esther are also on this chart. This was the day TIROS III discovered Esther, at least 2 days before it would have been likely to have been spotted by aircraft or other techniques.

The cloud analysis charts show the extent to which meteorologists can derive information on large scale weather conditions from a satellite such as TIROS.

The next chart (fig. 503) indicates a type of data that you can get from the TIROS infrared observations. The upper chart shows the temperature contours, each line representing conditions of constant temperature as observed by a particular sensor in the TIROS satellite.

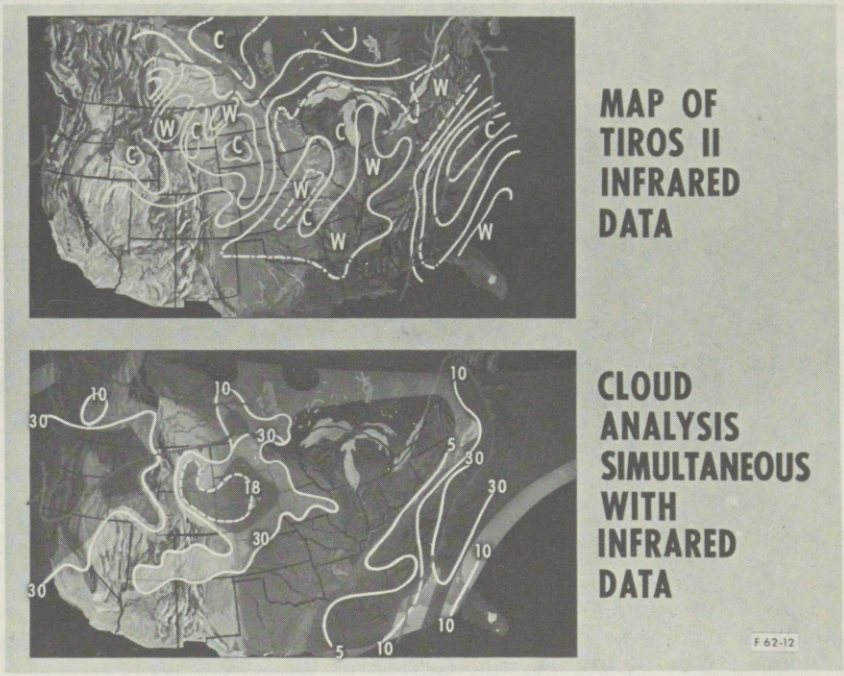

FIGURE 503

This gives cloud top and earth surface temperatures in this case. The letters "W" and "C" are placed on the chart to show warm and cold locations, respectively. Below this is shown a chart for correlation of the cloud cover information for the same period of time at which the infrared data were recorded. In this case the cloud data comes from conventional ground observations not from TIROS data. The lines here show altitude in thousands of feet at which the cloud layers are located.

You can see how the cold areas in the upper chart correspond to the shaded cloudy areas in the bottom one while the warm areas are, in general, clear. Also the coldest areas are those where the clouds extend to the highest altitudes. This correspondence shows how we can use such data to observe general cloud coverage at night and when we are able to process the data without delay this will enable us to get a certain amount of flight coverage that we can not get with a conventional TV system.

The next chart (fig. 504) indicates the way the cloud picture data will flow to the users. You see the general block diagram that the engineering professional generally injects at this point. The satellite transmitting to an antenna system, the data being collected at a data

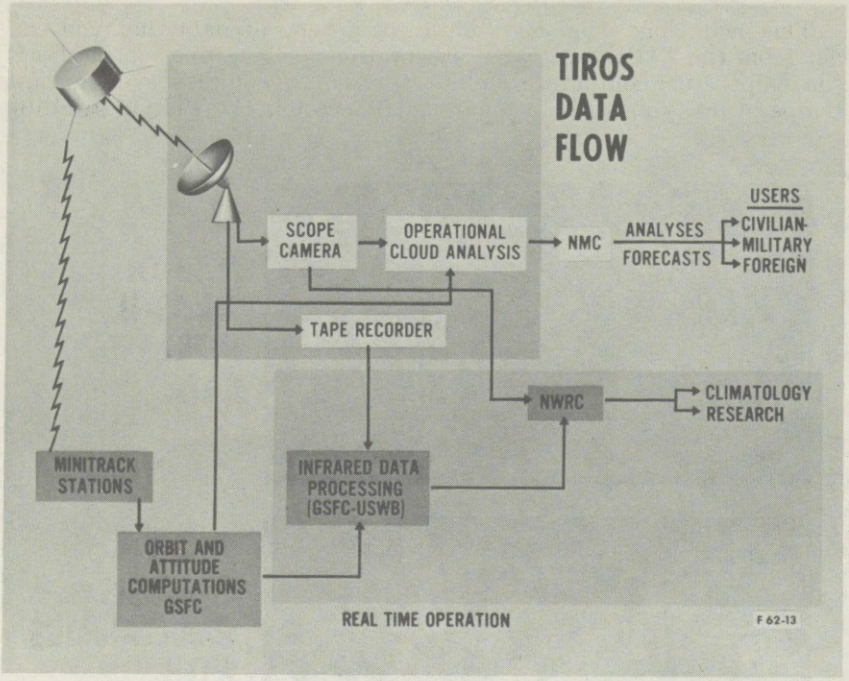

FIGURE 504

acquisition station going to the National Meteorological Center where analyses and forecasts are made, and the results of that going to the various civilian, military, and foreign users.

Data also goes to the National Weather Records Center where climatological research is carried on over a period of time. Tape recorded data goes to our Goddard Space Flight Center where research on the infrared data is carried out. At the same time minitrack stations, part of the worldwide data acquisition and tracking system, are involved in the process because they track the satellite, generate the orbital elements, send the information out to the field stations telling them when and where they should point their antennas to collect the data from TIROS.

As I mentioned before, Nimbus is the satellite to pick up the meteorological support system beyond TIROS. I would also like to say that we have a statement that Dr. Tepper has prepared, giving additional material on TIROS' success and its meteorological output and we can make this available for the record if the chairman pleases.

Mr. HECHLER. Yes, without objection.

(The document referred to is as follows:)

METEOROLOGICAL SYSTEMS—OPERATIONAL VALUE AND USE OF TIROS III DATA

(Based on information provided by the U.S. Weather Bureau and the Air Weather Service)

An intensive TIROS III operational use program was in effect from the day of launch (July 12, 1961) until early December 1961, when degradation of the

quality of the data made further use imprudent. The aims of this program were to make use of the picture data on a real-time basis, to furnish information for incorporation into daily analyses based primarily on meteorological data acquired by conventional means, and to provide warnings of unusual or previously undetected weather to all concerned both in the United States and abroad.

During the 3-month period from launch until October 12, 1961, TIROS III viewed 60 significant storm systems, discovered a hurricane, saw 18 tropical storms, and 6 easterly waves. Actions resulting from TIROS observations included reanalysis on 17 days including the relocation of 2 fronts, the location of 1 squall line, and the reanalysis of surface isobars in 2 cases, plus 50 telephoned, radioed, and telegraphed advisories on tropical cyclones to weather centers in the United States and abroad.

TIROS III has been called the hurricane hunter satellite; how well it justified this title is illustrated by the fact that on more than 50 separate occasions, TIROS III photographed tropical cyclones in all stages of development. Five hurricanes and one tropical storm were seen in the Atlantic; two hurricanes and a tropical storm were seen in the eastern Pacific. Typhoons Kathy through Tilda, nine storms in all, were followed in the central and western Pacific. A total of 50 advisories on these storms, easterly waves, and other significant circulations were phoned, radioed, or otherwise transmitted to Guam, Honolulu, San Francisco, Miami, San Juan, Fuchu, and the Japanese Meteorological Agency, Mexico City, New Orleans, Manila, Hong Kong, and Taipei.

TIROS III provided extensive data on the first two Atlantic hurricanes, Anna and Betsy, although these storms were never an immediate danger to the U.S. mainland. In the case of Carla, limitations imposed by the TIROS orbit and spin stabilization prevented obtaining pictures until a few days before the storm hit the Texas coast. By that time, Carla was under detailed observation by ships, aircraft, and land radar. Even so, the satellite data were of significant value. The Air Weather Service has reported that on September 9 the pictures supplemented surface reports and gave a check on the cloudiness associated with Carla; they served as a basis for coordination calls with McDill AFB (Tampa, Fla.) and Eglin AFB (western Florida) regarding hurricane warnings. On September 11, the day the storm passed across the Texas coast, the TIROS pictures provided the Air Weather Service with information regarding the cloud bands and the southern extremity of the clouds associated with Carla over the Gulf of Mexico. These data helped in analyses over an area lacking other data, and a forecast for an inflight refueling operation over the gulf was based on the TIROS observations.

For Hurricane Debbie, the Air Weather Service has reported that on September 10 the TIROS depiction of cloud distribution and organization associated with Debbie relative to the MATS route from Harmon, Newfoundland, to Lajes, Portugal, was excellent and of great value. MATS planners—controllers and weathermen—were able to "see" Debbie and reroute aircraft around the area. Earlier flights had encountered severe turbulence but depiction of bands on the TIROS nephanalysis (cloud analysis) identified areas of probable convective activity and subsequent flights were rerouted to avoid these areas. Weather Bureau use of TIROS data for Debbie is typified by the following advisory issued the following day:

"San Juan Weather Bureau advisory No. 14: Hurricane Debbie 12 midnight AST September 11, 1961, vessel reports and pictures from the weather satellite TIROS III gave definite information this evening on the location of tropical storm Debbie and indicated it had probably attained hurricane force * * *."

Esther is the storm that will go down in history as the first hurricane ever discovered by a meteorological satellite. On September 10, a vortex which was the formative stages of Esther was seen by TIROS to the west of the Cape Verde Islands at 11° N., 30° W. San Juan and Miami were notified. On September 11, the magnitude of the cloud patterns indicated probable hurricane intensity and another advisory was transmitted to Miami. By September 12, the storm had for the first time moved far enough to the west for aircraft reconnaissance. Based on the confirmation provided by these aircraft reports, bulletin No. 1 on Hurricane Esther was issued by the Weather Bureau at San Juan at 6 p.m., AST, September 12. The first satellite data had been available nearly 48 hours earlier than these first aircraft data but, because the satellite has no way to measure exact wind intensity, were not sufficient by themselves to justify designating the storm a hurricane.

TIROS coverage of Esther continued for nearly 2 weeks. The Air Weather Service has reported that on September 20 the TIROS pictures defined the

southern and eastern extent of the cloud coverage associated with Esther where other data was sparse; very valuable data for briefing the staff of the SAC's 8th Air Force on Hurricane Esther were provided. Still later, on September 24, due to the lack of pilot and ship reports around Esther, the data from orbit No. 1063 helped define the extent of clouds around Esther. These data formed the basis for analyses which assisted in locating Esther's eye and in advising units of SAC's 8th Air Force units with regard to mission planning.

As late as September 29, TIROS provided data on still another Atlantic tropical storm, although in this case it did not reach hurricane force. The Air Weather Service is quoted below:

"The TIROS data indicated a vortex at approximately 16 N., 54 W. This was our first indication that a storm was developing in this area. This established continuity for the new storm or possible hurricane. The vortex was added to our analysis and the staff briefed on possible development that might affect the area of Puerto Rico. Advance detection provided valuable information for the forecast center."

TIROS was equally effective in the eastern Pacific off Baja California. This area is extremely deficient in weather reports but, because of extensive fishing operations, has great commercial significance. The U.S. Weather Bureau has reported that on July 14, a vortex seen over Baja California was used to locate a low on the surface analysis. On July 19, the position of tropical storm, Liza, in this area was moved 4° of latitude on the surface charts to agree with TIROS III pictures. On July 23, 1961, a Weather Bureau analysis summary stated:

"Another nephanalysis from PMR showed a rather large but weak vortex centered at 24.5 N., 136.5 W.—distinct spiral bands were visible. This may be the remains of tropical storm, Liza, which was seen 3 days earlier." (The last bulletin No. 22, was issued by San Francisco on July 19.) "This storm has been dropped from analysis in the meantime, but on this information—current analysis was altered to show an inverted trough over that area. This vortex position and related essentials were given to the San Francisco office via facsimile phone."

In this same eastern Pacific area, on July 20, a tropical depression, Madeline, was observed by TIROS III. Tropical depression advisory No. 4, based solely on the satellite pictures, was issued by the Weather Bureau office in San Francisco. This advisory, locating the storm near 14.1° N. and 111.5° W., proved to be especially valuable to the tuna fishing fleet that operates off the coast of Mexico and southern California. This was the first time that a tropical cyclone advisory was issued on the basis of satellite photographs alone. On July 23, the remnants of Hurricane Madeline, still having a significant circulation, were seen off the west coast of Mexico 48 hours after the final bulletin had been issued. This information was sent to Mexico and the hurricane office in San Francisco, and was used by the National Meteorological Center to revise the surface analysis in the area.

TIROS III data were of similar value with respect to typhoons in the central and western Pacific. The Weather Bureau reports, for example, that on the night of August 29–30, 1961, a vortex, followed for several days, was located at 24.5 N. and 151 E. and showed indications of increased circulation. The TIROS position was phoned to the typhoon duty forecaster on Guam through the SAC hot line in Det. 28 (4WG). They had just received a recon fix at 04Z of 24.7 N., 153.2 E. The phone connection was excellent and the nephanalysis was discussed in detail.

Even more striking was the case of Typhoon Sally. On September 22, tropical depression No. 29 had been dropped from the maps after reconnaissance aircraft had found no further evidence of a storm circulation. On September 24, however, the Joint Typhoon Warning Center was advised of TIROS sightings of an apparent circulation in the area where depression No. 29 had last been seen. Aircraft were dispatched to investigate and on September 25 Bulletin No. 6 warned of regeneration and the birth of Typhoon Sally. A message of thanks and request for further fixes on tropical storm, Sally, was received from Manila, P.I., in acknowledgement of a special U.S. Weather Bureau message sent on September 25, 1961. And the Japanese Meteorological Agency wired:

"Attention: Chief, U.S. Weather Bureau:

"Thank you for your telegram of 25 0536 a.m. U.S. Government PD position of tropical depression 998 MBS was fixed—please continue to send us tropical vortex information."

Although the hurricane and typhoon data from TIROS III provided the spectacular cases, the information from the satellite on more common weather

situations was of equal or possibly even greater total value. Only a limited number of cases can be cited. But the day-to-day observations by TIROS of extratropical storms, cloud bands, and other large cloud formations were used for relocating fronts and pressure centers, reanalysis of isobaric fields, and for confirming analysis in areas of scarce or doubtful data. The National Meteorological Center used information contained in TIROS III pictures as a basis for the reanalysis of surface and upper air charts on 17 days during the first 3-month period of the operation.

On the 15th of July, the orientation of cloud bands seen on the satellite picture was the basis for relocating a surface front in the Atlantic.

In one case (September 6) a squall line extending from Lake Huron to western Texas was discovered in TIROS photographs and entered on the surface chart on this evidence. This was a case where conventional observations over even a dense network failed to uncover a severe weather situation.

The value of such data to aviation is suggested by a memorandum from the supervisory forecaster, International Aviation Forecasting Service, Weather Bureau Airways Station, New York International Airport, N.Y.

"A copy of the depiction (TIROS nephanalysis) was used in lieu of any weather depiction field normally prepared" for the route between New York and Dakar, Africa.

"The response from crewmembers on these procedures [1] has been enthusiastic.

"There is absolutely no question that the TIROS fields are an invaluable aid in our daily activities."

In military operations, reports from Air Weather Service detachments selected to provide a representative cross section of weather support requirements indicated that—

(*a*) Approximately 90 percent of the TIROS nephs (cloud analyses) which covered some portion of the detachment's area of responsibility found useful application in analysis and forecasting.

(*b*) TIROS nephs contained information which—

(1) Aided analysis;

(2) Provided a basis for modification of analyses;

(3) Established continuity;

(4) Confirmed analyses in areas of sparse conventional data;

(5) Aided in briefing air crews and control agencies, particularly on over-water missions;

(6) Led directly to the modifications of forecasts.

Typical extracts from these Air Weather Service reports are quoted below:

"August 10, 1961: Provided basis for horizontal weather depiction analyses and forecasts Travis to Hickam—Used to brief the SAC Alert Force. Pacific coverage on this date excellent. Added more to route forecasts than any other chart information received this date.

"August 20: Briefed SAC Alert Force on extent of frontal cloud south of Alaska.

"August 24: Provided basis for horizontal weather depiction analysis in extensive area east of Bahamas—only one ship report available in this area. Assisted in forecasts for flights down range from Cape Canaveral.

"Assisted in preparation of horizontal weather depiction analysis and forecast for Travis (California) to Hickam (Hawaii) route. Used as briefing aid for MATS and civilian contract carriers.

"August 28: Assisted in route forecast Chateauroux to Lajes.

"August 30: Assisted in route forecast (horizontal weather depiction) used in briefing MATS crew.

"September 4: Atlantic warm front analysis modified on basis of neph (cloud analysis)—assisted in horizontal weather depiction analysis Atlantic area.

"TIROS chart was used to reanalyze frontal position 165–170W. Original analysis carried front 32N with no ship data available—Shows possible wave formation at 38N, 155W.

"NOTE.—TIROS indicated trailing edge of frontal band at 35N—Resulted in 200–250 n. mi. adjustment in frontal position mentioned above.

"September 4: Relocated wave based on TIROS vortex at 37N, 172E.

"September 8: Assisted in preparation of local terminal forecast—Used in briefing MATS crew eastbound over United States.

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[1] "I.e., the use of TIROS III nephanalyses in place of conventional weather depiction charts."

"September 16: Gave us good continuity for carrying forward the cloud cover over Labrador and Newfoundland—By knowing the western extent of the cloud cover over eastern Canada we were able to forecast an improving trend in the Goose and Harmon area.

"September 19: TIROS data verified extent of overcast cloud cover over the mid-Atlantic and indicated clear/hazy conditions over Spain and North Africa—Very useful in briefing (SAC) reflex missions across the Atlantic.

"September 24: Indicated boundaries of cloud system affecting Lajes (Portugal) as well as showing organization—Led to forecast of improving conditions—Less rain and Binovc (breaks in overcast).

"September 25 and 26: Modified (SAC support) cloud analysis and forecast over mid-Atlantic."

Mr. STOLLER. The summary is based in part on information provided by the Weather Bureau Service and by the Air Weather Service. It is additional material.

The TIROS program calls for three more satellites and we plan to fly these on about 3- or 4-month intervals, until the Nimbus satellite comes into being. We hope to overlap Nimbus for a while, because as it initiates in an R. & D. sense we have to have satellite coverage to be sure that we have a functional Nimbus system.

The next chart (fig. 505) shows for comparison TIROS and Nimbus orbits and some major differences. TIROS as I have already said flies in an inclined orbit and is space oriented. It is spin stabilized. Nimbus will fly in a nearly polar orbit, slightly inclined, but almost polar and will be Earth-oriented so that the cameras are always looking down at the surface of the Earth, so we will have much improved coverage.

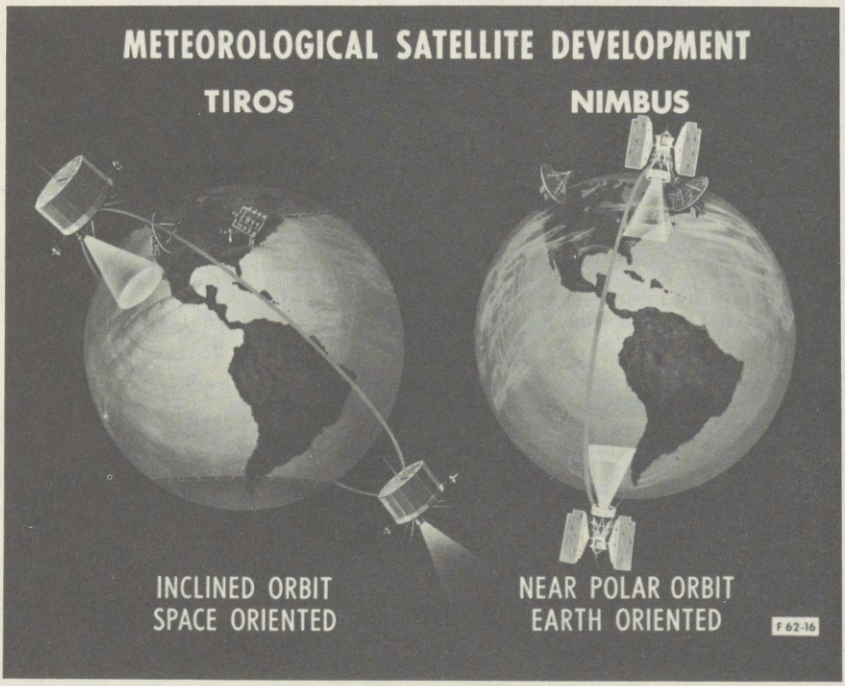

FIGURE 505

The way we get this improved coverage is quite interesting. We use an inclined polar orbit. It turns out that if you examine orbital characteristics in some detail you can find an orbit at about some 85 degrees inclination in which the satellite will continue to go around almost all the time with the Sun looking down over its shoulder. The orbital plane tends to turn due to the fact that the Earth is not a perfect sphere and the sphere-action of the Earth's shape with the orbital characteristics leads to an orbit rotation which is just right to match the motion of the Earth around the Sun. So the orbital plane stays alined with the line to the Sun and the Sun is always over the satellite's shoulder.

The next chart (fig. 506) repeats one side of the previous chart but on a larger scale.

The following chart (fig. 507) shows a breakout of a Nimbus satellite system. The large blue units are of course the solar paddles. Here again storage batteries are used on board. The paddles are so oriented in the satellite that they are always looking at the Sun. The satellite is so oriented that it always looks at the Earth.

The paddles turn about the horizontal axis as you can see. The batteries are charged by the solar energy. The control section up at the top contains the stabilizing devices, detectors for position, and so forth and are used to maintain the cameras looking at the Earth's surface as indicated in the chart.

There are three cameras in the instrument ring down below, the circular structures contains the electronics, TV cameras, infrared

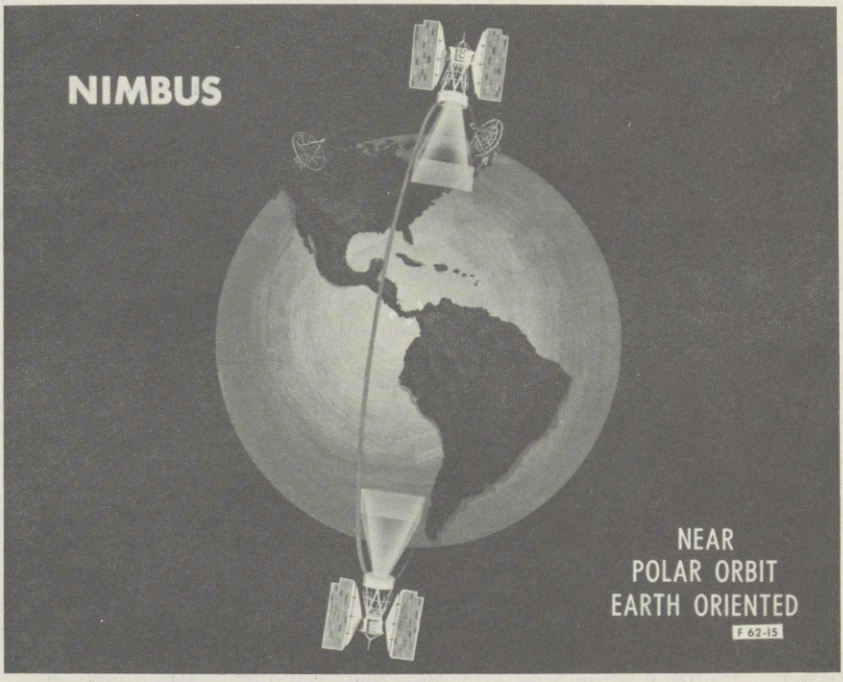

FIGURE 506

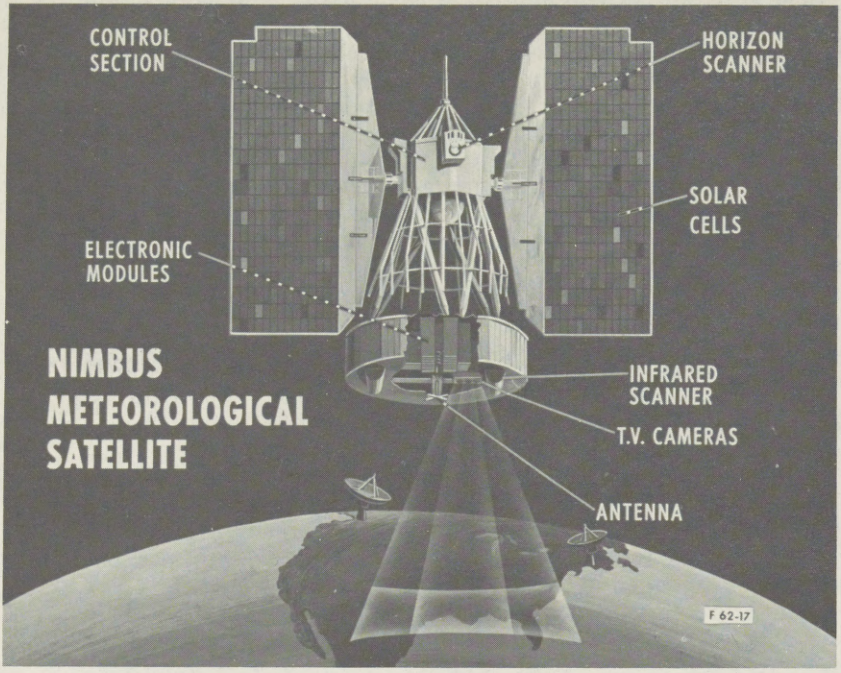

FIGURE 507

sensors. The cameras, set up to overlap, produce the rectangular pattern that the chart indicates.

The point on the top is one of the command antennas. It is a tubular structure that connects the control system with the instrument ring and there is some tubular elements at the upper part there, immediately below the control section, which tend to form part of the antenna structure for better patterns.

One of the characteristics of Nimbus is the fact that there are electronic modules as indicated in the chart. This makes it somewhat easier, we hope, to undertake replacement of parts during the testing phase in case something goes bad. We can pull out a bad module and replace it with a satisfactory one rather quickly.

The chart indicates that there will be two data acquisition stations for the Nimbus system. One of them will be in Alaska, the other one will be on the east coast of North America, as far north as we can get. Discussion will be initiated with the Canadian Government as to the possibilities of locating such a station somewhere in Canada.

The Nimbus orbit is such that more than one station is required if we are going to get essentially continuous coverage which the satellite is capable of developing, therefore we have to plan on at least these two data acquisition stations.

Nimbus design started over 2 years ago. Most of the major contracts have been underway now for over 12 months. The next chart (fig. 508) shows a mockup of the prototype satellite. The prototype itself is now being assembled. It gives you an idea of the large size of

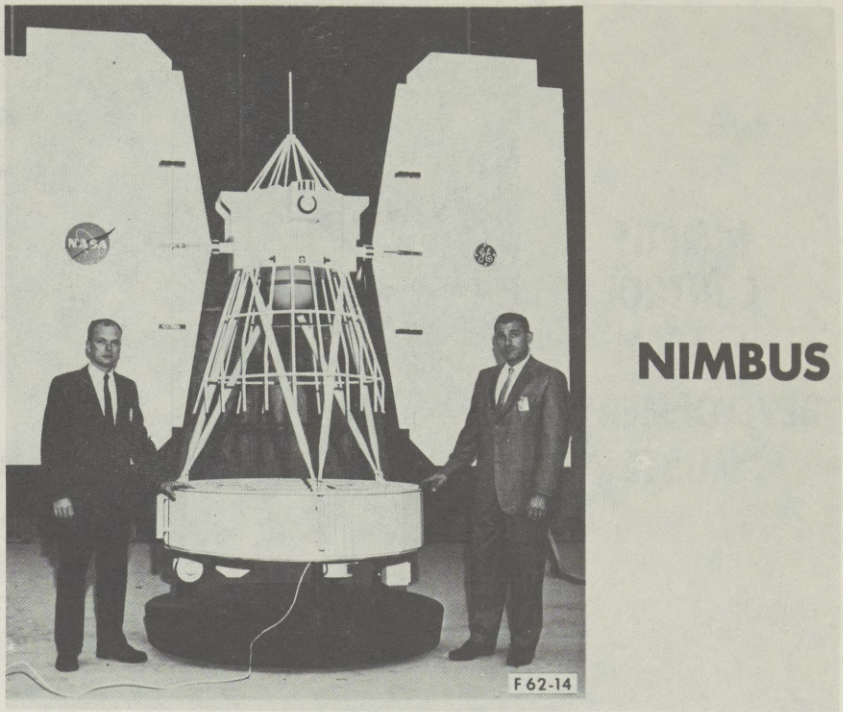

FIGURE 508

the satellite itself which is to be launched, in its R. & D. phases, on a Thor-Agena launch vehicle.

I guess I should mention the notches in the solar paddles because when these charts were shown around our office people generally ask what they are for. The paddles, themselves, fold up so as to fit within the shroud at launch time. The shroud diameter is just a little larger than that of the ring at the bottom.

The paddles are turned about the horizontal axis so that the notches clear at the bottom—they sort of tuck in there.

This is only one of the positions that the paddles will take for since they have to point at the sun continuously in orbit, the paddles will rotate continuously about their axis.

Mr. HECHLER. How large are the paddles?

Mr. STOLLER. Approximately 7 feet—6, 7 feet in height as you can see from the chart. About 3½, 4 feet in width. There is about, I think, 250 watts of electrical power available, roughly, from the paddles.

The next chart (fig. 509) is a photograph of the Nimbus control system in its development stages. The model is open so that the test engineers can get at the various pieces of electronics with test prods and so forth. This control system is quite complex and this is one of the problems that we will have with stabilized satellites for some time, being able to deal with very complex devices both electrically and mechanically and maintaining long life in orbit, getting sufficient reliability.

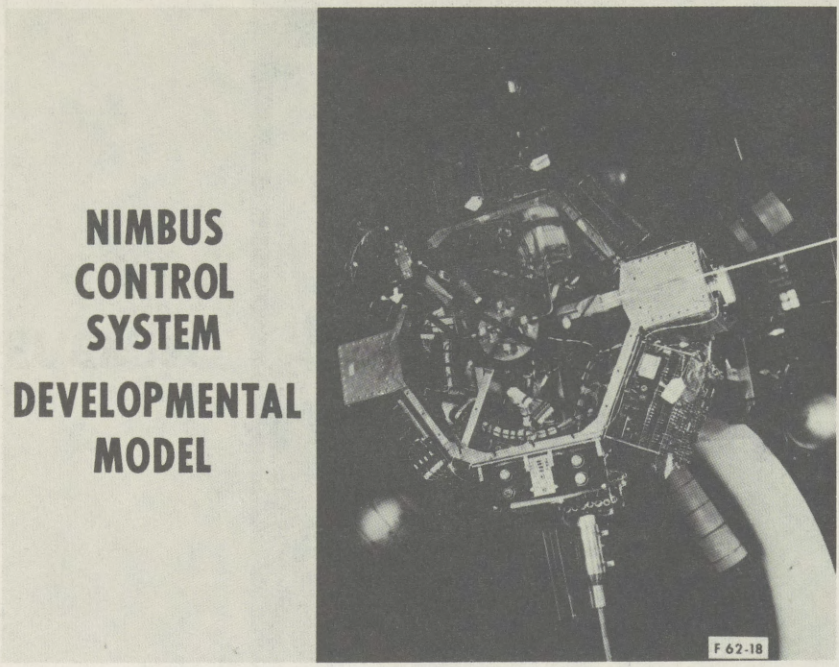

FIGURE 509

We are going to investigate, and I will mention it again later in communication satellite systems, other stabilization systems in addition to the one being used on Nimbus in an effort to get reliability for communications satellite systems as well, which will also benefit from stabilization.

We are trying to make an effort in developing Nimbus to end up with a satellite, or spacecraft as we call it very often, which will be usable for many purposes in meteorological systems.

The next chart indicates this (fig. 510). On one edge of the chart you see the basic system showing the sensory package, solar paddles, and the controls. Should we desire to work on a rainfall radar system, which has been suggested several times as a desirable satellite system to have to supplement ground observations of rainfall with radar, we hope to be able to do it by going about it in the way indicated on the chart. We will substitute the radar electronics for the electronic modules in the bottom ring and couple the antenna system at the bottom end, keeping the same controls, power supply, in general. Similarly, a spectrometer unit which will do a detailed investigation of the radiation from the Earth could be inserted in the sensory ring and mounted instead of the TV cameras or other IR sensors.

The next chart (fig. 511) shows the Nimbus data flow. Nimbus' data flow is generally similar to that of TIROS. There are command and data acquisition stations, data flows to the National Meteorological Center, Goddard Space Flight Center and from there to the National Weather Records Center and then goes for research purposes and for day-to-day use from the various analysis points.

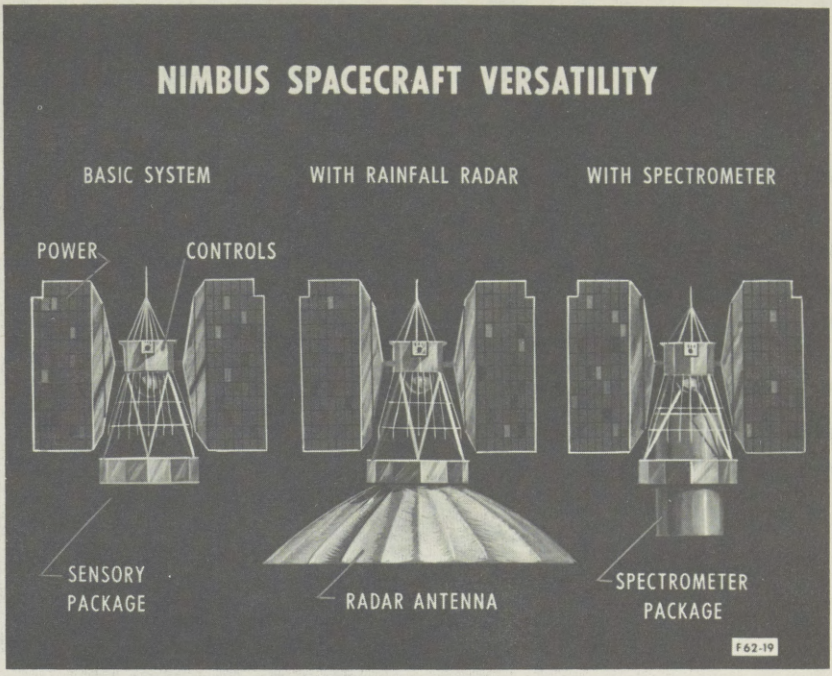

FIGURE 510

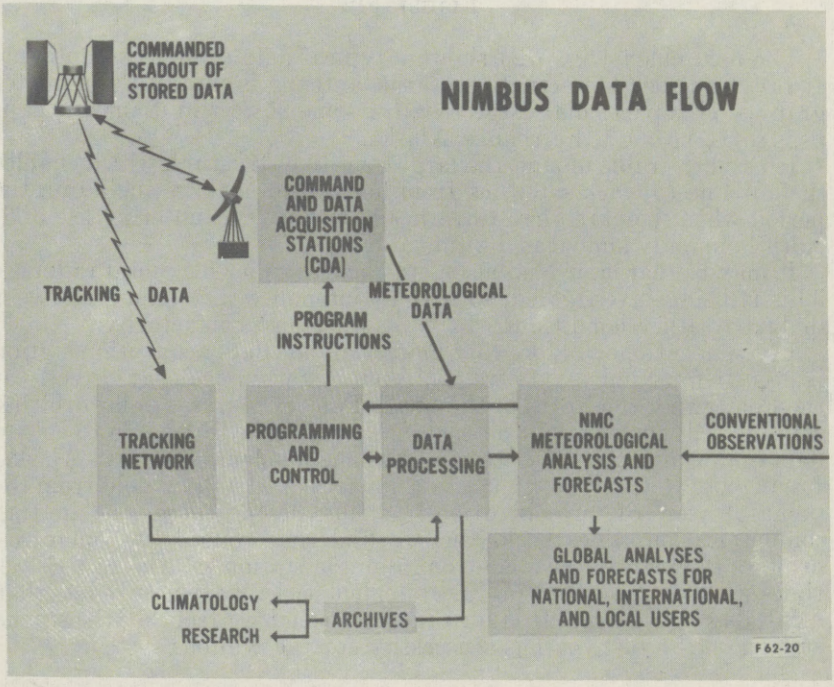

FIGURE 511

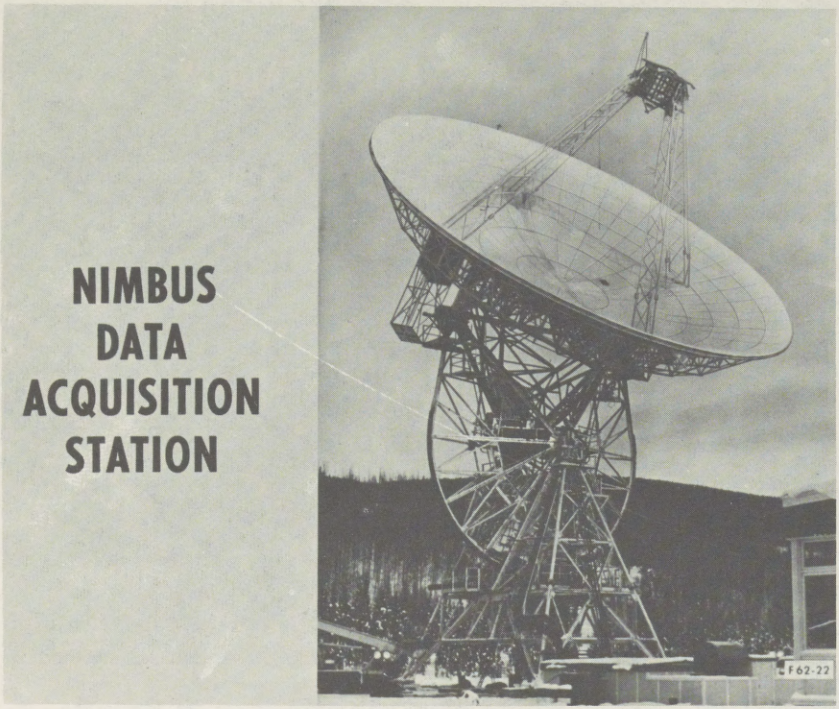

FIGURE 512

The next chart (fig. 512) shows a typical data acquisition antenna. It says "station" but actually only the antenna is shown in the photograph. This particular large reflector some 85 feet in diameter, happens to be the one at Fairbanks, Alaska.

It has a steerable mount, the large ring-like structure, which enables the antenna to track satellites from horizon-to-horizon, including the period when they are almost overhead, without encountering the difficulty commonly known as the gimbal lock.

It may be that later Nimbus operational stations may need radomes. This is being investigated, so that maintenance throughout the year in bad weather conditions can be carried on satisfactorily.

I have mentioned before that more than one data acquisition station is needed for Nimbus. If we could put a station, let's say directly at the Pole, either the North or the South Pole, of course, a polar orbiting satellite will come over it on each orbit and we will be able to collect data each time. The best we can do at the moment is to go to Alaska, fairly close to the Pole, pick a location which is supportable from the point of view of our operations, getting people there, and getting communications lines back, and we find that roughly 11 out of 14 orbits a day can be covered from a single station in Alaska. Sometimes it may drop to 9½ or 10 orbits, but basically certainly less than a full day's coverage. It is for this reason that we feel that the second station on the east coast is a necessity for the Nimbus system.

The Congress appropriated $48 million to the Weather Bureau in fiscal year 1962 for the initiation of a meteorological satellite system. This system is to be based on the Nimbus program and is to be ultimately capable of continuous observations.

NASA and the Weather Bureau have drawn up an agreement covering the responsibilities of the two agencies and have initiated what is called a project development plan for the Nimbus operational system. The agreement is outlined in the next chart (fig. 513).

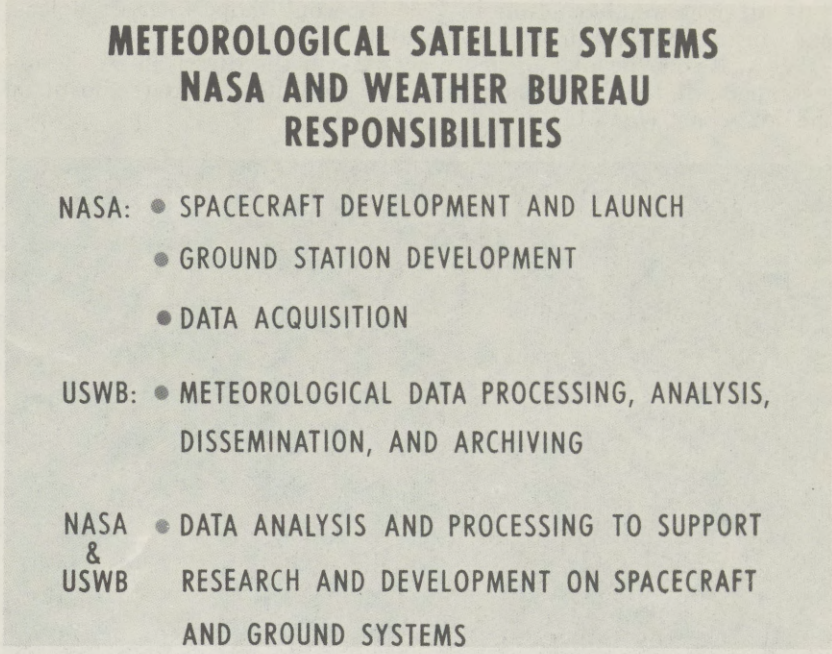

FIGURE 513

NASA will be responsible for spacecraft development and launching, for ground station development, and for data acquisition. The Weather Bureau will be responsible for the meteorological data processing, analysis and dissemination of the data, and for the archive work on the data.

Both NASA and the Weather Bureau share responsibility for data analysis and process to support research and development on both spacecraft and ground systems so that we can improve the system as we go.

From an engineering point of view our major interest will be improvement of the sensory units in the spacecraft, spacecraft itself, and data acquisition facilities. The Weather Bureau will be concerned with such items as data-processing techniques and integration of the data into meteorological operations which already exist so that they flow with the greatest speed and effectiveness into their existing networks.

The Weather Bureau will also consolidate all weather data users' requirements and specify the needs for particular types of observa-

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tions to the spacecraft systems designs so that the spacecraft will be able to carry out the types of operations that the Weather Bureau thinks will be of optimum value for its purpose.

With the Nimbus development program already underway and the assembly of the prototype moving along, the addition of the Weather Bureau's funding will result in the procurement of hardware for additional Nimbus satellites of the basic design that I have already shown. We then plan to be prepared to launch Nimbus units about twice as frequently as when the original research effort was scheduled.

If all goes well, sometime in 1963 we would hope to have at least one working Nimbus in orbit nearly all the time.

We will soon be placing more activity in the direction of the development of the Aeros meteorological satellite. This is shown on the next chart (fig. 514).

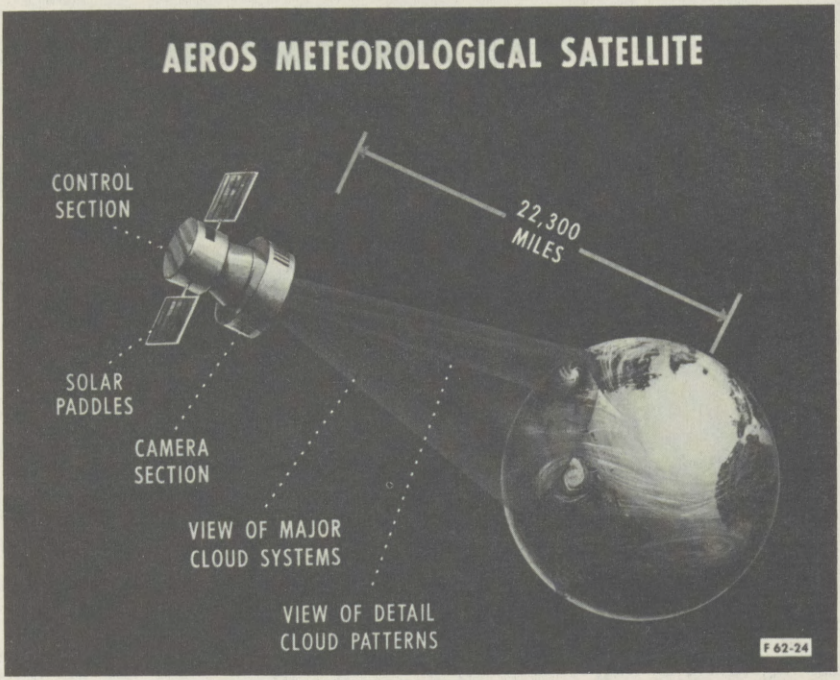

FIGURE 514

Aeros is conceived of as a satellite which will be placed in equatorial orbit at an altitude of 22,300 miles. This will result in its remainng stationary at a given location over the Equator from which it can view tropical and temperate latitudes. Aeros will carry, in much the same way as Nimbus, solar cell paddles for power, a control section, and a camera section at the bottom which will collect the data.

Aeros is unique in that it has a stationary position with respect to the Earth and continuously observes the same area. It should be able to see about one-quarter to one-third of the Earth's surface. We will then have a capability in Aeros to track a particular storm as

it moves over the surface of the Earth. This is the intent of this development.

The chart indicates the two TV patterns considered at the present time for Aeros. One is obtained with a relatively wide-angle type of camera which records and transmits pictures of all major cloud systems. In actuality the camera will have a viewing angle much like that of the conventional home movie camera and the overall view should then be fairly similar to and readily correlated with a mosaic made up of successive Nimbus photogaphs. The other Aeros camera will be one of relatively high resolution, and very narrow angle of view, compared to the one which covers the total hemisphere. The actual resolution will be comparable to that of Nimbus but in this case the camera will be directable on command so that any selected area can be brought into the field of view at any time. The areas will be chosen from the wide coverage data. A special lens and pointing mechanism wil be required for this camera.

We will start this spring in working on details of these components. The question can readily come up as to why would we want to have another meteorological satellite at such a high altitude when Nimbus will give us effectively 100-percent coverage of the Earth's surface? Our calculations indicate that 14 orbits elapse before Nimbus returns and passes in daylight over about the same area of the Earth as it did in its first orbit. Roughly, the same area is covered, but in a pass in the opposite direction and at night, every seven orbits. This means that about every 12 hours we get another observation of a given spot on the Earth's surface, but are limited on alternate passages to infrared sensors rather than TV cameras, until we lick the problem of having a satisfactory infrared TV camera.

The next chart (fig. 515) serves to give an indication of why we are interested in more frequent coverage of the same area on the Earth. This chart indicates the typical lifetime of certain common weather systems, tornadoes, thunderstorm cells, hurricanes, and cyclonic storms. You also note that it indicates the typical size of these weather systems at the same time.

You see they tend to go up in sort of a straight-line relation, the larger ones having a longer life. We have indicated on the chart the time at which one Nimbus satellite in orbit would come back and take another look at the same area. This is about 12 hours as I have just mentioned.

You can see that we have a chance here of tracking a hurricane and getting some successive pieces of information on that happening because its lifetime is greater than 12 hours, but we have little chance of following thunderstorm complexes or cells and probably absolutely no chance, except by luck, of spotting tornadoes, as such.

We hope that the Aeros type of operation, with its ability to track a storm in a continuous sense will enable us to keep up with the short-lived weather phenomena and assist the meteorologists in this area.

I would like to mention now very briefly the meteorological rocket program. These are the sounding rockets I made some mention of at the beginning. The chart (fig. 516) indicates the grenade-sounding techniques which are used in meteorological sounding rockets and in these tests, a series of small explosions at a number of altitudes by ejecting what we call grenades from a sounding rocket. These grenades are essentially noise producers. Shock-wave blasts and the

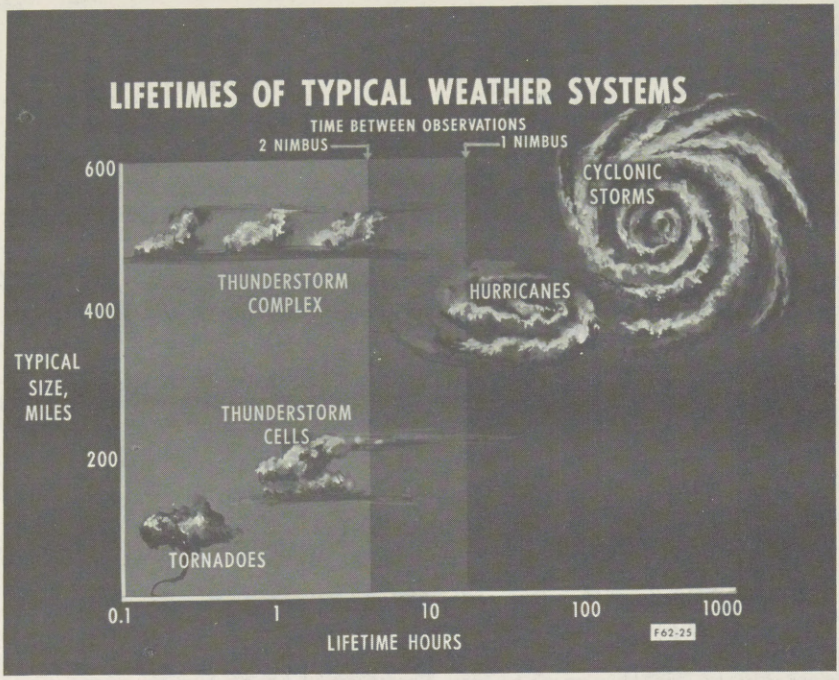

FIGURE 515

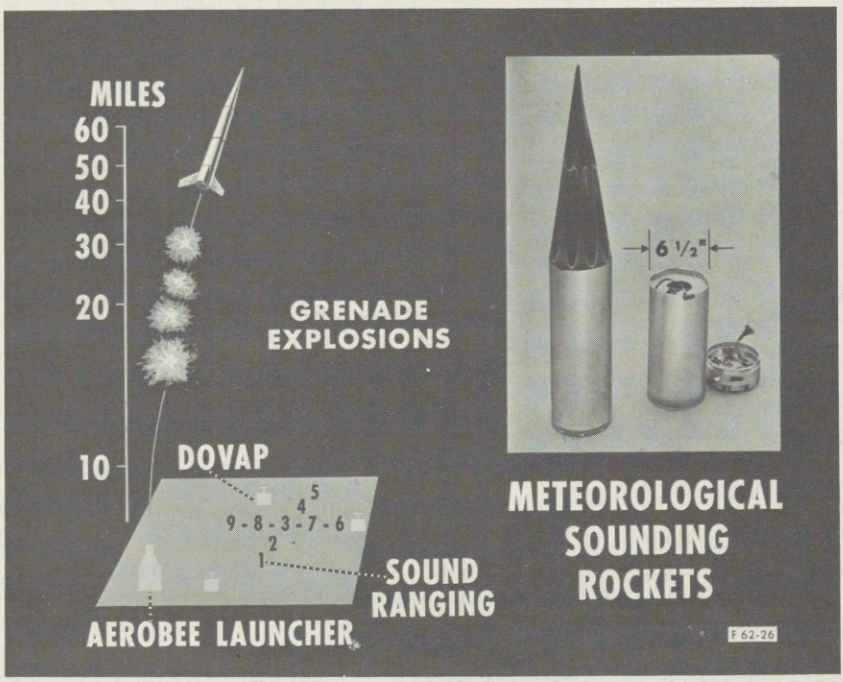

FIGURE 516

time of arrival of the sound wave from each explosion are measured at a group of microphone stations down at the ground. These are indicated at the bottom of the chart.

The Dovap stations are stations which are provided to tell where the rocket is. These are radio-type stations which track the rocket and enable us to determine the trajectory.

By using the data from the Dovap and the microphones we can work up the wind and temperature in the upper atmosphere in the layers between successive explosions. The insert on the chart shows a typical grenade head for meteorological sounding rockets of this type. The marks on the head show where the grenades are ejected, smaller grenade heads are on the outside for the lower altitude firings and the larger grenades come out near the point of the rocket. The two remaining elements of the rocket are the power supply and timing device that are used to eject the rockets in a programed manner on the way up.

The next chart (fig. 517) shows some typical data achieved with these meteorological sounding rockets. On one edge of the chart you see the rough limits of balloon radiosonde data for temperature and winds. The remainder of the chart shows where the rocket grenade data comes from.

It is interesting to note the variation in the winds, that is that the winter winds are chiefly to the west, west winds, while summer winds are easterlies. This is at Fort Churchill near Hudson Bay where the data was collected.

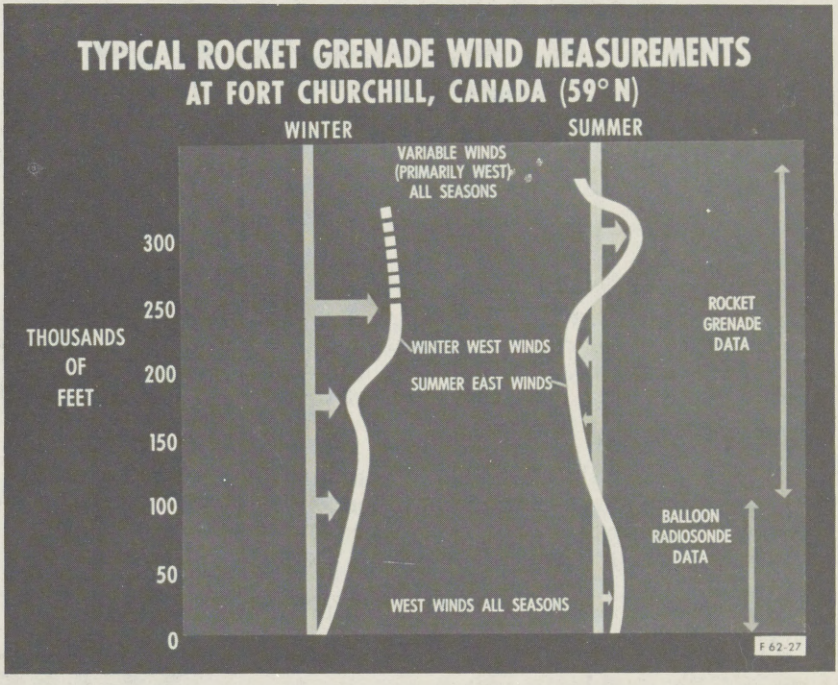

FIGURE 517

This data could not have been obtained with balloon soundings because the balloons have just hit their limit at the point at which this transition tends to take place for the wind direction.

Satellites also cannot give us this data, as I mentioned before, because we have no way of putting instrumentation aboard the satellite at this time which will enable it to probe into this layer below 100 miles and above 20 miles.

We have an international aspect, of course, to our meteorological systems activities and this is shown on our next chart (fig. 518).

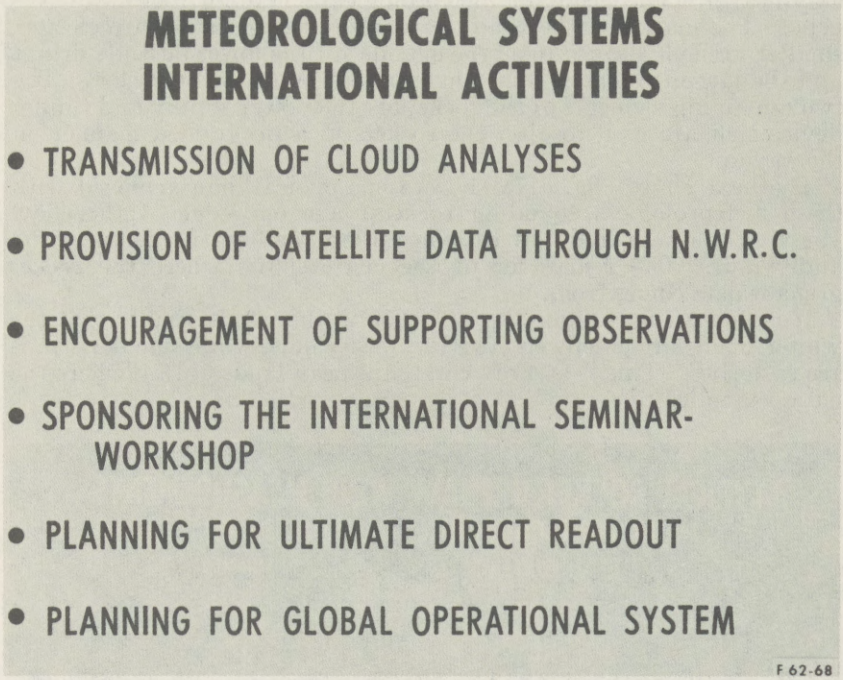

FIGURE 518

We transmit the satellite cloud analyses to foreign countries for their usage in their meteorological systems. We make our basic satellite data available to all countries through the National Weather Records Center. We encourage supporting meteorological observations in other countries in connection with the satellite passage over their territory.

We have sponsored an international seminar-workshop in satellite meteorology. We have encouraged other countries to undertake long-range planning for ultimate direct readout and for international participation in a unified global operational meteorological satellite system.

All these activities have been undertaken, of course, in conjunction with the U.S. Weather Bureau, which has a major meteorological responsibility for this type of work.

Now the next chart (fig. 519) shows in summary the meteorological satellite launch schedule. TIROS is shown, four satellites which have already been launched and the satellites for 1962 which will

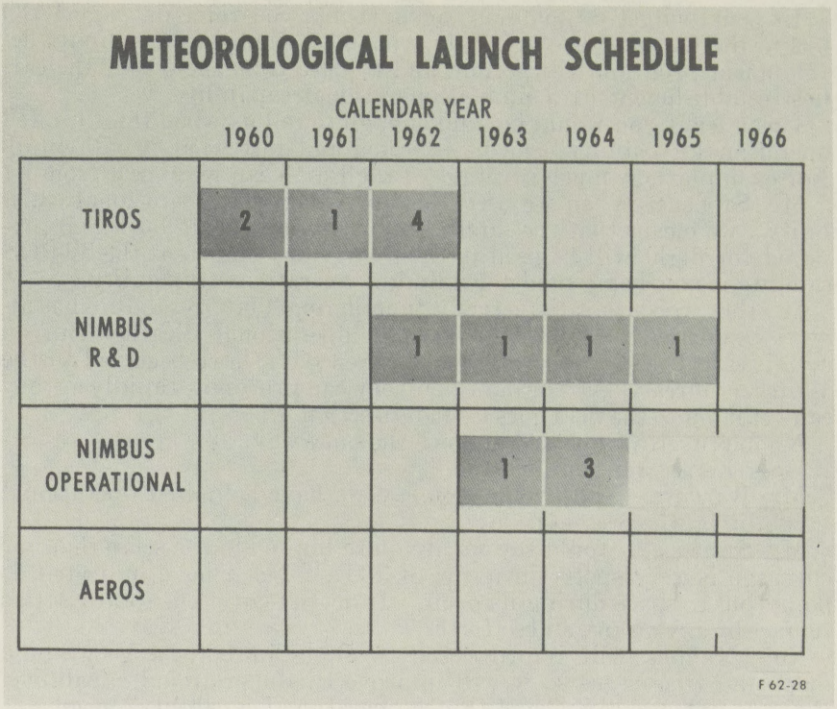

FIGURE 519

follow the one already up and which will overlap the Nimbus. We have shown the Nimbus R. & D. satellites at a one-a-year rate, and the Nimbus operational satellites which are funded by the Weather Bureau funds which will overlap and interleave, in the sense of their launchings, with the Nimbus R. & D. activities.

The Aeros and the last of the operational Nimbus satellites are shown in a different shading to indicate that they are not funded nor are there requests for funds included in this budget, but just to indicate the level of project activity that we think will take place in the future.

The next area that I would like to go into is communications systems.

Mr. HECHLER. May I interrupt?

Mr. STOLLER. Certainly.

Mr. HECHLER. From the standpoint of continuity it might be better for you to pause and allow us to ask a few questions on the meteorological satellites.

If it is agreeable with you I think this might be a good point, since we have reached the end of your formal testimony on meteorological satellites, to pause for staff questioning.

Mr. STOLLER. Fine.

Mr. WILCOVE. Mr. Stoller, at this point I would like to discuss with you briefly your operational goals, your arrangements with the Weather Bureau, and cooperation between the military and civilian authorities on the meteorological satellite program.

In your budget estimate or backup book, you refer on page RDO 6–2 to the fact that the presently scheduled Nimbus research and development program will permit, and I quote from the book, "the earliest establishment of a limited operational capability."

I wonder if you would be kind enough to tell us when this "limited operational capability" can be expected and just what it will entail. For example, how much coverage of the Earth can we expect from it?

Mr. STOLLER. When we used the words "limited operational capability," we meant that the satellites that are now being built and prepared for flight will be used in their early days much as the TIROS satellite is now being used for a limited operational capability.

In other words, a satisfactorily functioning TIROS satellite has always been used in a limited sense for operational Weather Bureau activities. The TV records, the infrared data, have been fed to the Weather Bureau. All the data that they can process as rapidly as they can get it out to the field goes in that direction.

Nimbus itself will be tied in much the same way.

Does this answer your question?

Mr. WILCOVE. Well, would you say we have a limited operational capability at the present time?

Mr. STOLLER. I would say we are quite limited in the sense that our coverage is very spotty in terms of TIROS: as I have indicated, it points out to space during its orbit. It doesn't cover the total Earth's surface by any means, and so forth.

Now Nimbus will improve the coverage in both a geographic sense and time sense so it will improve this operational capability. Perhaps I should say what I think "operational capability" means.

Mr. WILCOVE. Please do.

Mr. STOLLER. Maybe this would help define "limited operational capability." When I say "operational capability" I think of a system in which there is always a satellite functioning with great reliability in the sense that any day at any time data is being transmitted that can be fed directly into the meteorological data processing network.

The Nimbus system at this point has not yet been flown. The first satellites obviously will carry out the proving of an R. & D. activity. We expect them to work quite well. Our tests are going to be very thorough and we will integrate these R. & D. satellites as rapidly as we can into an operational system.

But it would be somewhat optimistic to say that the first R. & D. satellites would be the operational system.

Mr. WILCOVE. We could say, then, that your limited operational capability is limited due to the fact that (1) the TIROS satellite doesn't cover the entire Earth's surface, and (2) it is not operating at all times.

Mr. STOLLER. I would say this is right, yes.

Mr. WILCOVE. In another passage in the backup book you say that the establishment of a—

> fully effective operational meteorological satellite system is dependent upon the completion of the improvements displayed in the presently scheduled Nimbus research and development program.

When do you anticipate this will occur and what will it entail?

For example, how many Nimbus satellites will have to be employed to provide a fully effective system? Can you give us some idea of your time schedule?

Mr. STOLLER. I am just estimating here at the moment, because we haven't had, as I said before, our first experience with Nimbus, but my estimate is that it will be about the 1965 or 1966 period.

Mr. WILCOVE. Calendar year?

Mr. STOLLER. Calendar year—for a full system in that sense. In other words, this gives us a chance to have flown some four developmental satellites in which there will be certain changes to develop new instrumentation and four or more of the Weather Bureau operational types.

Mr. WILCOVE. In other words, beginning in 1965 or 1966, if present plans go through all right, you will have the capability of covering the entire Earth at all times; you will have a satellite in orbit that will be accomplishing that at all times?

Mr. STOLLER. We would hope so, yes.

Mr. WILCOVE. Of course, any time you have a lapse it is no longer operational.

Mr. STOLLER. Yes. We will have a planning, scheduling situation to meet along this line, which will be whether or not we maintain a satellite in readiness for launch should one fail. I guess you realize this.

In other words, if we put up a satellite for continuous observation, do we keep one, in effect, in reserve at all times so that if one should fail we can make a launch on extremely short notice so as to supplement the system?

Mr. WILCOVE. I would assume that to have a truly operational system you would be prepared to do that.

Mr. STOLLER. I have a feeling that we may actually carry out this operation by having more than one satellite for the system in orbit at all times, so there will be at least one available for data collection.

Mr. WILCOVE. Is it your thinking to have in orbit one Nimbus at a time and another in reserve?

Mr. STOLLER. Our thinking for the present is one at a time because we are still in the early phases. The later thinking says more than one at a time in orbit.

Mr. WILCOVE. About how many would you need to make it truly effective?

Mr. STOLLER. I think we feel that at least two and beyond that point I am not prepared to say at this point.

Mr. WILCOVE. Now you discussed your arrangement with the Weather Bureau on the R. & D. phase of the meteorological program when the system becomes operational.

Do you have a hard and fast agreement on that, or do you just have an understanding on what the Weather Bureau will do and just what you will do during the R. & D. phase and during the operational program?

Mr. STOLLER. We have a joint agreement with the Weather Bureau which I can submit for the record if you choose.

Mr. WILCOVE. Would you do that?

Mr. STOLLER. For what we call the Nimbus operational system at this point. It is this limited operational sense that is covered. It covers the scheduled time that was indicated on the schedule chart.

Mr. WILCOVE. May we have that, Mr. Chairman?

Mr. HECHLER. Without objection.

(The matter referred to follows:)

JANUARY 1962.

AGREEMENT BETWEEN NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AND DEPARTMENT OF COMMERCE-U.S. WEATHER BUREAU CONCERNING IMPLEMENTATION OF NIMBUS OPERATIONAL SYSTEM (NOS)

The supplemental appropriation act, 1962, provides the first increment of funds to the Department of Commerce-U.S. Weather Bureau for the joint NASA–USWB implementation of the first phase of a national operational meteorological satellite system.

This phase is to be designated as the Nimbus operational system (NOS), and will correspond to the time period coincident with the NASA Nimbus R. & D. program, and thus is expected to extend approximately through 1965.

It is the purpose of this joint agreement to set forth the functional responsibilities and operating procedures under which NASA and USWB will conduct their respective parts of the NOS program.

A. RESPONSIBILITIES

The functional responsibilities of the USWB and the NASA under NOS will be as follows:

1. U.S. Weather Bureau:
   (*a*) Determination of the overall meteorological requirements;
   (*b*) Specification of quantities to be measured by the satellite meteorological instruments;
   (*c*) Processing of data for operational meteorological purposes;
   (*d*) Integration of data into weather analyses;
   (*e*) Use of data and analyses for forecasts;
   (*f*) Dissemination of data, analyses, and forecasts;
   (*g*) Archives (processing, storage, retrieval);
   (*h*) Research and climatological use of data.
2. National Aeronautics and Space Administration:
   (*a*) Design, fabrication, and test of the spacecraft;
   (*b*) Procurement of the launch vehicle;
   (*c*) Maintenance of launch sites;
   (*d*) Construction of command and data acquisition stations;
   (*e*) Prelaunch preparation of spacecraft and vehicle;
   (*f*) Launch operations, including scheduling;
   (*g*) Tracking and orbit determination;
   (*h*) Programing and command to satellite;
   (*i*) Data recovery at command and data acquisition stations;
   (*j*) Communication of data to meteorological satellite activities organization.

B. EXECUTION OF THE NOS PROJECT

NASA has assigned the responsibility for the execution of its part of the NOS program to the Goddard Space Flight Center, Greenbelt, Md., which will conduct the effort in conjunction with its research and development project for Nimbus. The Goddard Space Flight Center will manage, direct, and coordinate its efforts through and by the Nimbus Project Office of the Aeronomy and Meteorology Division. The USWB shall assign one of its staff to the Nimbus Project Office as data utilization systems manager.

The USWB has assigned the responsibility for the execution of its part of the NOS program to the meteorological satellite activities organization.

C. FUNDING

Funds required for the implementation of NASA responsibilities under this program will be made available by the USWB to NASA on a reimbursable order in accordance with the financial operating plan attached hereto and any amendments subsequently approved by NASA and the USWB. NASA will apply these funds in accordance with the provisions stated in said plan and more specifically in the Nimbus operational system project development plan. Accountability and reporting will be in accordance with the provisions of the NOS project funding agreement attached hereto.

D. BUDGET PREPARATION

Budget preparation, submission, and justification shall be conducted in a coordinated manner. Based on the meteorological requirements and any financial constraints stated by the USWB, NASA, and the USWB will each year jointly

agree on a single set of program assumptions. NASA then, on the basis of these agreed assumptions, will prepare and provide to the USWB an estimate of funds required for the execution of its responsibilities under this agreement. Such information shall be provided in the degree of detail, including necessary narrative and explanatory material, in which the USWB is required to submit its budget requests to the Bureau of the Budget and the Congress. Incompatibilities between requirements and financial constraints will be resolved by discussion and mutual agreement. While the primary responsibility for the further submission and defense of the NOS budget will be that of the USWB, NASA will, if requested, assist the USWB in defending, before the Bureau of the Budget and the Congress, those budget items pertinent to its areas of responsibility as defined in this agreement.

E. AMENDMENTS

This agreement shall be subject to amendment at any time by the mutual agreement of both parties. Addenda may be added to cover areas not adequately covered in this basic agreement.

F. RELEASE OF PUBLIC INFORMATION

Release of public information shall be in accordance with the policy guidance agreement executed by the USWB and NASA on October 20, 1961, including any amendments thereto.

G. RESOLUTION OF QUESTIONS

USWB and NASA will exercise regular coordination and review of the project by means of a Nimbus Steering Committee composed of the following two members:

Chief, Aeronomy and Meteorology Division, GSFC.
Deputy Director of Meteorological Satellite Activities, USWB.

Policy differences which cannot be resolved within the project framework or the Steering Committee will be referred to the Director of MSA, USWB, and the Director of Meteorological Systems Office of Applications, NASA.

JAMES C. WEBB,
Administrator, National Aeronautics and Space Administration.
LUTHER H. HODGES,
Secretary of Commerce.

[Addendum to NASA/WB agreement]

FUNDING AGREEMENT NASA–USWB

In accordance with the provisions of the NASA-Department of Commerce-U.S. Weather Bureau agreement for the implementation of the NOS project, dated _____, the following funding arrangements are established.

A. METHOD OF FUNDING

1. The Weather Bureau will issue a reimbursable Government order to NASA in accordance with the NASA operating plan estimate approved by NASA and the Weather Bureau.

B. METHOD OF COSTING

1. Where possible, the requirements for flight hardware and ground equipment in support of operational spacecraft will be included in existing NASA contracts for "flight hardware." In order to provide for equitable distribution of cost between R. & D. and operational spacecraft and ground equipment, the total cost of these items will be apportioned between NASA and U.S. Weather Bureau on a pro rata basis, based on the number of R. & D. versus operational flight models in each contract as reflected in the financial operating plan. Costs of the prototype spacecraft development will be borne by the R. & D. project.

2. Personnel services cost included in "direct management" will be based on timecard records of personnel assigned to management of the projects and prorated where applicable between R. & D. and operational effort. Other direct management cost will be charged on an actual cost incurred basis.

3. A companion job order system will be established within the GSFC accounting system to accumulate all pro rata and specifically identifiable costs of the NOS program.

C. FINANCIAL REPORTING

1. NASA will provide a monthly report to U.S. Weather Bureau of commitments, obligations, and expenditures incurred on NASA books against the reimbursable order. This report will be in the detail necessary to provide entries required by the Weather Bureau accounting system and mutually agreed to by the Weather Bureau and NASA.

D. REVIEW OF BUDGETARY REQUIREMENTS

1. NASA will conduct a continuing analysis of contractor cost requirements under this program in the same manner in which the R. & D. project is analyzed. The results of this analysis will be made available to the U.S. Weather Bureau whenever any significant variance from the operating plan is indicated, but no less frequently than semiannually. The Weather Bureau may assign a financial liaison representative to the project.

E. PROPERTY ACCOUNTABILITY

1. Flight hardware and other items of supplies, materials, and equipment with an initial cost of less than $100 will be considered expendable material for which property records are not required.
2. Ground station equipment and other items of a capital nature with initial cost in excess of $100 will be identified and accounted for in accordance with existing NASA regulations. Title to this equipment will be held by NASA, subject to agreement between the two agencies as to its final disposition.

Operating plan, Nos. —, NASA funding requirements, Nos. —

[In thousands of dollars]

	Fiscal year 1962	Proposed fiscal year 1963
Spacecraft	20,000	18,800
Launch vehicle	13,000	13,000
Command and data acquisition sites:		
Fairbanks	5,840	2,805
Newfoundland	6,260	2,685
Communications:		
Fairbanks	----------	775
Newfoundland	----------	400
Programing and computing	----------	1,000
Technical management	570	1,135
Total	45,670	40,600

Mr. STOLLER. We have no agreements at the present time for what will follow. When we have gone through this phase of the activities then we will establish a new agreement and operational method.

Mr. WILCOVE. Your agreement covers now the TIROS satellite system?

Mr. STOLLER. No, it covers the Nimbus system.

Mr. WILCOVE. Just the Nimbus?

Mr. STOLLER. It covers the Nimbus limited operational system I would call it.

Mr. WILCOVE. But not the fully operational system?

Mr. STOLLER. Not the fully operational system.

Mr. WILCOVE. You anticipate you would draw up a new agreement?

Mr. STOLLER. We would draw up a new agreement after this first phase is completed.

Mr. WILCOVE. Is there considerable cooperation now between the military and civilian authorities in the development of the meteorological satellite system?

Mr. STOLLER. I think there is. The major cooperation is in the meteorological side of it, data handling and making use of the data. But there is a coordinating committee which Dr. Tepper is a member of, and if you wish Dr. Tepper could tell you more about the various coordinations with the military. There are a number of contacts and ways in which military, Weather Bureau, and NASA get together to see that the requirements of all are incorporated in the meteorological satellite system.

Mr. WILCOVE. Is it planned that the military will utilize the civilian system or will it set up its own?

Mr. STOLLER. At the present time so far as I know they are actually acquiring data from the system, the TIROS material. They will acquire data from the Nimbus system and will continue to do so.

Mr. WILCOVE. There is no plan by the military to set up a separate system?

Mr. STOLLER. We haven't been informed of one as such at this time.

Mr. WILCOVE. Thank you, Mr. Stoller.

Mr. HECHLER. Mr. Stoller, looking forward now to 1965 or 1966 when you have a fully effective operational system, just what is this going to mean in down to earth terms so far as improvement of our weather forecasting is concerned, over the present? Just what is this going to mean?

Mr. STOLLER. Well, I would rather have Dr. Tepper answer that if I could because he is a meteorologist and I am not.

Mr. HECHLER. All right.

Dr. TEPPER. Thank you, Mr. Stoller.

One really has to give a lecture in weather analysis and forecasting to answer the question adequately.

All weather forecasting is based on observations and the more observations you have and the more complete they are, and the more frequent they are, the greater the knowledge you have of what is going on, not only in your immediate locality, which affects your weather immediately, but also in areas not so close by and even further away which would affect the weather in your locality some days later and perhaps even more than days.

At present we are limited in our observational capability as you know by observations where people live. We don't have observations regularly from the midoceans, from the Arctic regions, desert areas, things of that sort. The atmosphere doesn't know really where we live, it just keeps going around the Earth in response to various external forces, and things may develop in regions that aren't inhabited, like the eastern Atlantic, where Mr. Stoller showed you Hurricane Esther developed.

A storm may develop there and move out and be upon us before we know it.

This is a dramatic illustration for nonmeteorologists. Meteorologists are concerned with lesser dramatic things that affect our weather situation. So to get back to your question, what would a system of this sort do? A system of this sort would provide a continuous weather watch, a global, continuous weather watch. That means that at all times the meteorologist will have a very good idea of what is happening practically everywhere in the world from a meteorological point of view. Thus he will be in a much better position, by perhaps an order of magnitude, from a technical point of view. He would be

in a much better position to determine the types of weather that will affect his locality or our locality in not only the immediate future but perhaps, in an extended manner, in terms of a few days or a week much better than he is able to do today.

After the research and development program has continued over a period of a few years and we have extracted more information from the satellite, I am confident that we will learn more about the effect of the Sun's influence on us, on the weather.

Now this is important because it gives us a clue to longer period weather, seasonal type variations, perhaps. The solar influence over the globe might be linked into seasonal influences. You notice I didn't say seasonal forecasting. I don't think that through this information, on January 1, we will be able to predict exactly what is going to happen on opening day of the baseball season. But we might be able to get a better clue what to expect during the summer. That is about the best we can do.

Mr. HECHLER. Mr. Roush.

Mr. ROUSH. Do you think the day will come when my Indiana farmer, contractor, construction worker, and sportsman will be able to have definite and certain knowledge on Sunday as to whether it is going to rain on Wednesday?

Dr. TEPPER. Now who are these people again you are referring to?

Mr. ROUSH. Well, I am thinking of general groups of people who are most interested in weather prediction and who at the present time do not have a dependable intelligence system going, the farmer, the contractor, the construction worker, and the sportsman.

Dr. TEPPER. The reason I asked wasn't just to be facetious, but I want to get an idea of what type of area you had in mind.

Incidentally, I should say that the better people to answer this question would be the Weather Bureau meteorologists who are working with this every day, but I will be glad to try to answer this.

I seriously doubt that the individual farmer having his own acreage of a certain size or the sportsman who is concerned with the Griffith Stadium or the new Washington Stadium or any small area of this sort we will know within a few years, say the next 5 years, with confidence on Sunday whether his individual area will be affected at a certain time on Wednesday. This is a pretty difficult scientific problem that is being asked of the meteorologist.

However, I think in terms of probability he will be able to get fairly good answers. In other words, a numerical probability in terms of 70, 80, or 90 percent. You said with 100 percent—you said with assuredness. But from a lesser probability the meteorologist would be able to provide that, and the probability would increase as the area involved would grow.

In other words, if you are interested in rain over the Metropolitan Washington area, I think the chances of knowing on Sunday whether it is going to rain on Wednesday over Washington will be very good. Whether it will rain over the New House Office Building on Wednesday, to know that on Sunday I think would be much more difficult, if not impossible in a few years. To state with assuredness every time, that is. You see, sometimes you have a rain situation which is so widespread, and you are sure it is coming in, that not only is it going to rain over the House Office Building, but it is also going to rain over Wheaton, Arlington, every place else around here.

So you can say your assuredness would be better. But if you try to localize it, that it will rain only in a small area, this would be difficult.

Mr. ROUSH. Thank you.

Mr. DAVIS. May I interject this thought? Isn't it roughly comparable to this: that a life insurance actuary could tell you, as a parallel example, that a certain percent of 70-year-old men will die in a given year, but he could not begin to tell you which ones out of that group would die? He could give you simply a percentage.

Isn't that the problem that you are up against? If you want to know what the weather will be over the House Office Building, it is going to be extremely difficult to pick out exactly which given area will be clear and which cloudy, even though you might be able to say accurately a certain percentage will or will not?

Dr. TEPPER. This is the difficulty with the words "scattered showers" in the summertime. You know the scattered showers where in your particular area it may be absolutely clear, while in another part of Washington scattered showers might be a heavy thunderstorm that just practically floods the basements. Both people are unhappy. They say this is a poor forecast. In the one place he says: "I got no rain," and in the other: "We got a deluge." But if you look at that over the entire area it might have been very well a scattered shower. I don't know how else you would describe it, if you had a few of these over a wide area, but "scattered showers."

Mr. HECHLER. Mrs. Weis.

Mrs. WEIS. I would like to ask Mr. Stoller a question just to clear something up in my own mind. This has nothing to do with this budget.

As I understand it, the TIROS is more or less a first generation satellite, eventually will be obsolete, and you won't use it after that.

Mr. STOLLER. That is correct.

Mrs. WEIS. Then the second one——

Mr. STOLLER. Nimbus.

Mrs. WEIS. Nimbus comes along and that will become obsolete. Aeros is your ultimate weapon, shall we say?

Mr. STOLLER. No, this is not correct in the sense, that it is probable that Aeros will supplement Nimbus rather than replace it.

Now something may replace Nimbus in the sense that at some point or another a completely different satellite structure and set of sensors, power supply, and so forth and so on may be technically more reasonable to use than the basic Nimbus structure as we see it. I think the Nimbus job will be continued and we will supplement it with Aeros.

Mrs. WEIS. When you finish with your R. & D. on Nimbus, it becomes operational. Then it becomes just a question of turning it out. Is it turned over to the Meteorological Division to run? Who is going to actually run that system when it becomes operational?

Mr. STOLLER. The probabilities are that the NASA will continue to be responsible for the spacecraft as such and the data acquisition because this is where the people with that background happen to be located at this time and they have the benefit of working with all the rest of the people in the same area in spacecraft design and improvement. The Weather Bureau people will continue to set requirements for the system, and so forth. Even when the operational

system came along it is quite probable we would turn over the production of the routine satellite to a specific group in NASA charged with just turning out satellites for the Weather Bureau.

Mrs. WEIS. Are there any potential income-producing factors in this system when it does become operational? Is there any way that you can sell this service to the people, such as weather forecasting, so that there might be some financial recovery from manufacturing these and operating this system?

Mr. STOLLER. This is an area in which NASA hasn't been at all involved in meteorology. Does the Weather Bureau sell services?

Dr. TEPPER. No. By statute I think the Government has given the Weather Bureau the responsibility of providing a service to the country. The Weather Bureau would in a sense continue to provide this type of service.

Mrs. WEIS. Then this would be a continuing expense on the Government, as long as we had this system in operation.

Dr. TEPPER. Yes.

Mrs. WEIS. Thank you.

Mr. HECHLER. Do I gather from your response to Mrs. Weis' questions that on the Aeros you are not sure at the present time whether it is going to be a fully operational system?

Mr. STOLLER. No.

Mr. HECHLER. I wasn't exactly sure.

Mr. STOLLER. What we are saying is that Aeros is a system which is reasonably far in the future and has to go through all the various R. & D. phases, systems, components design, prototype and at some point it will come through an R. & D. phase and hopefully it will be a supplement to Nimbus.

Mr. HECHLER. I have gotten the hint, perhaps, that something else might develop that would cause you to move on to something else beyond Aeros.

Mr. Waggonner.

Mr. WAGGONNER. The Nimbus satellite, of which none is operational at this point, is intended to operate at what orbital speed and what altitude in its polar orbit?

Mr. STOLLER. The altitude is 500 to 600 miles depending on the actual weight that the satellite will come out with.

Mr. WAGGONNER. What is the estimated weight?

Mr. STOLLER. The estimated weight now is 680 pounds.

Dr. TEPPER. Around that.

Mr. STOLLER. About 680 pounds.

Mr. WAGGONNER. About 10 times that of the TIROS?

Mr. STOLLER. No, TIROS is close to 300 pounds.

Mr. WAGGONNER. Is it that big?

Mr. STOLLER. It is something more than twice.

Mr. WAGGONNER. What is the orbital speed for a full polar orbit? What is the time involved there?

Mr. STOLLER. It is 100 minutes, about 100 minutes once around.

Mr. WAGGONNER. What is the estimated orbital time and altitude of the Aeros in its equatorial orbit?

Mr. STOLLER. Aeros will be at 22,300 miles. This makes it a stationary satellite, so in effect it goes around the earth once a day, takes 24 hours to go around, at the same rate at which the earth turns, so that in effect it always sees a point on the earth beneath it.

Mr. WAGGONNER. I was getting at the same thing. It being stationary and the other being in polar orbit once every 100 minutes, to have a fully operational system it would require in all probability a combination of the two, would it not?

Mr. STOLLER. That is right.

Mr. WAGGONNER. But now the fine point that you will never be able to detect is the tornado.

Mr. STOLLER. Well the Aeros system with its ability to direct a high-resolution lens at a given point beneath it will enable you to chase specific weather systems once they have been identified on the general map as occurring.

Now to cover the total of the earth in such a technique would require at least three such stationary satellites.

Mr. WAGGONNER. Three of them?

Mr. STOLLER. And actually would require somewhat more. Because if you take one such satellite on the Equator it doesn't cover polar regions very well because the view is so glancing over the top and you would have to do something about covering those regions if you wanted to get 100-percent coverage.

Mr. WAGGONNER. Then if you had three Aeros satellites in orbit and you developed the infrared sensor to the point where you would have a full 24-hour coverage, theoretically you would be able to pinpoint any tornado?

Dr. TEPPER. Well, the answer is, theoretically it is correct. Whether you will be able to see a tornado from above is a problem. We don't know—for example, aircraft that fly over the tornado region do not report very frequently that they see a tornado.

Mr. WAGGONNER. That is right, from our observation now we see the black bottom——

Dr. TEPPER. That is right, so we don't know how we will identify these as yet from the top. We might, of course, identify the system in which a tornado forms. I don't have it with me, but TIROS I identified one such system where we had a very, very bright and marked isolated cloud mass which was different than what was around and it turned out there was a tornado, many tornadoes in that system, but this was 50 miles by 50 miles or so, much bigger than the tornado which is as you know a few hundred yards.

Mr. HECHLER. Mr. Davis.

Mr. DAVIS. I would like to ask Mr. Stoller one question in connection with the question Mr. Wilcove asked earlier.

Mr. Wilcove asked this question: Would the Nimbus satellite keep the earth under constant observation at all times?

And the answer was "Yes." Of course that "Yes," I take it, was a qualified "Yes," was it not? You spoke of putting Nimbus in a position so that the sun would always be looking over its shoulder, therefore whatever was under it would be lit up with sunlight, of course.

But it still has to orbit and that would cut its efficiency down to about 50 percent, wouldn't it? Then the earth is still going to rotate with reference to its orbit, so that means that a given spot on the earth's surface would pass under the camera only once a day.

So the statement that Nimbus would keep the earth under constant observation requires a good bit of limiting, doesn't it?

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Mr. STOLLER. That is right, you are exactly right. You have gone right through the sequence of steps. But you would cover all the whole earth's surface once a day with the cameras because again that rectangular field shown in the chart for the three cameras makes a swath across the surface, which if you take them all and lay them down on the earth's surface they overlap just enough to give you 100 percent coverage.

Mr. WAGGONNER. What is the estimated operational life at this stage of the Nimbus satellite?

Mr. STOLLER. Well, we are pushing our design people to introduce enough tests and design things to hit what we will hope will be a minimum of 3 months and hopefully some 6 months of life.

Mr. WAGGONNER. As compared to the TIROS.

Mr. STOLLER. Well, TIROS—one was 2½, 3 months—a little over 2½ months, one was 10 months.

This business of life in orbit, of course, is very difficult. The systems are very complex many hundreds and in some cases thousands of electronic components aboard.

Mr. HECHLER. Mr. Roush.

Mr. ROUSH. Mr. Chairman.

Have you considered combining the Aeros weather satellite with the communications satellite which is planned for a 24-hour orbit also?

Mr. STOLLER. There are considerations of this that have been made and it depends upon our ability at the time that Aeros gets to be a solid flight project rather than a study and component development phase as it is now, as to where we are going with the communications satellite and whether or not we can combine them. But this is definitely a possibility to put only one satellite in orbit at the 24-hour altitude for both services.

Mr. ROUSH. Thank you.

Mr. HECHLER. It will save a lot of money.

Any further questions?

Mr. WILCOVE. Mr. Chairman.

Mr. Stoller, can foreign nations gather data in the same way we are doing from a meteorological satellite?

Mr. STOLLER. At the present time the satellites are read out by command over our data acquisition stations and our data acquisition stations have to be provided with relatively large antennas so that they can collect the signals for the nature of the communication involved. So you need a special receiving station to pick up the data and you have to be able to command the satellite to get it. The answer is they don't have free access at this time to the data as transmitted from the satellite.

Mr. WILCOVE. Could a foreign nation do that?

Mr. STOLLER. In the sense—the answer is "Yes, if they break the command code."

Mr. WILCOVE. I presume the command code is no more difficult than various other codes that were used during the war.

Mr. STOLLER. I would presume so. The best we can say is we have no evidence that anybody has been breaking the code and causing it to read out.

Dr. TEPPER. Well, we know they have not, because the present satellite has a destruct read out. That means that as you read out the data you erase it. If anybody has been reading out this data it would not

have been available to us when we commanded it. So we know nobody has been reading out this data on command—well it just hasn't been done, other than ours. And this also will be true for Nimbus.

Mr. WILCOVE. My thought was that in time of war, weather information is very important to all nations. I was wondering whether a foreign nation could set up its own ground station and obtain the information the same as we do.

Mr. STOLLER. Let me say that if you had military circumstances of that sort to consider, I would think that you might do some rework, you might say, of the electronics to provide antijam and security provisions on the data transmission. At the present time for our work with the Weather Bureau these have not been considered to be necessary.

Mr. WILCOVE. Is the information we are receiving now transmitted to all nations?

Mr. STOLLER. Transmitted through the Weather Bureau device to other nations.

Mr. WILCOVE. Does the information go to Russia, among others?

Mr. STOLLER. As far as I know, it does.

Dr. TEPPER. Yes.

Mr. STOLLER. In the same way ground observations are transmitted to the other nations. All nations in the world cooperate in the meteorological sense.

Mr. WILCOVE. Thank you.

Mr. HECHLER. Mr. Hines.

Mr. HINES. Referring to the budget book, I notice you have procured most of your launch vehicles in fiscal 1962; is that correct? Thor-Delta vehicles, for TIROS, 567?

Mr. STOLLER. Yes; you are talking about page RDO 6–5?

Mr. HINES. That is right.

Mr. STOLLER. Yes.

Mr. HINES. Then going over to the Nimbus funding, I note that in fiscal year 1962 you requested $6,817,000 for the Nimbus launch vehicles.

Mr. STOLLER. Yes.

Mr. HINES. Have they been delivered yet. Do you have those off the line?

Mr. STOLLER. No; we incrementally fund our vehicles, particularly vehicles of the larger sizes like Thor-Agena, Atlas-Agena, and so forth. So we make a payment in effect for the vehicle quite a bit ahead of time and we make successive payments as they are being built, and eventually when they get to us the payments that remain to be made are finish costs at that point, plus launching costs, fueling costs. That is why the dollars are so spread.

Mr. HINES. That would explain why in 1963 you are asking for $4 million more. That is further in the future for the Nimbus program. Does that money include any rework that may be involved with future vehicles in your R. & D. program, or with the spacecraft? If the vehicles require rework at the upper end, would this money cover that, or would new money be needed?

Mr. STOLLER. I don't know whether there is any specific provision for that. I would not anticipate much of that, because the vehicle and spacecraft interface is defined at as early a date as we can get

the engineers to commit themselves, and from then both work toward that definition so as to not produce these reworks that you are talking about.

Mr. WILCOVE. I would like to discuss with you your funding of the two programs, TIROS and Nimbus. First, for the record, can you tell us the contractors for the two programs?

Mr. STOLLER. TIROS system is handled by the RCA. They have built the satellite system for us, tested it, and so forth, and so on—turned it over to us for launching.

For the Nimbus system, the major contractor is General Electric Co. Nimbus is being bought in somewhat a different manner than Tiros is, where we have a major contractor, RCA, handling almost the whole job with some Government-furnished equipment going aboard.

But Nimbus is being procured in a somewhat different manner in that there are a large number of contractors involved—and I can submit the list for the record for you, if you care to have it—the major contractor being the General Electric Co., which is responsible for integration and test of the system. This really includes building the structure in which all the subsystems go. General Electric is also the contractor for the controls, the subsystem itself. RCA builds the TV systems and solar paddles as well.

Dr. TEPPER. That is right.

Mr. STOLLER. And other contractors provide telemetry, infrared sensors, and other components. I think at least, if I remember correctly, some 18 contractors are involved in the Nimbus system in the major sense.

Mr. WILCOVE. Mr. Chairman, could we have placed in the record the names of all the contractors for the Nimbus system?

Mr. HECHLER. Without objection.

(The matter referred to follows:)

Nimbus contractors

Contract No.	Subsystem	Contractor and location
NAS 5-978	Spacecraft integration and test	General Electric, MSVD (Philadelphia, Valley Forge, Pa.).
746	Controls and stabilization (prototype)	Do.
1347	Controls and stabilization (flight units).	Do.
943	Solar power	RCA, AED (Hightstown, N.J.).
1118	Clock receivers	Do.
877	HRIR tape recorder	Do.
667	Advanced Vidicon camera systems	Do.
877		
902	PCM telemetry	Radiation, Inc. (Melbourne, Fla.).
1167	PCM/AM XMTR	Hughes Aircraft (Culver City, Calif.).
878	Clock command	California Computers (Downey, Calif.).
567	"S" band XMTR	General Electronics (Silver Spring, Md.).
757	MRIR	Santa Barbara Research Center (Goleta, Calif.).
1074	MRIR/FM XMTR	Texas Instruments (Dallas, Tex.).
1125	PCM and MRIR tape recorders	Raymond Engineering (Middletown, Conn.).
1262	MRIR Electronics	Aero Geo Astro (Alexandria, Va.).
668	HRIR	ITT (Fort Wayne, Ind.).
1882	Data utilization studies	Stanford Research Institute, (Menlo Park, Calif.).
1016	LRIR	Barnes Engineering (Stamford, Conn.).
	HRIR ground presentation equipment.	To be selected.
	Reliability	Do.
	Ground station integration	Do.
	Data utilization equipment	Do.
Completed	Antenna design studies	New Mexico State University (University Park, N. Mex.).

Mr. WILCOVE. Now what about the advanced Nimbus? Will you have the same contractors?

Mr. STOLLER. The advanced Nimbus, I would think, for the major systems that make up the spacecraft, may well use the same people because they have already the techniques. There will be changes in systems which will be incorporated in the advanced systems and these will be procured by the normal procedure of asking for proposals and reviewing proposals made and new contracts placed.

Mr. WILCOVE. I believe that for the funding of the TIROS the authorization you are requesting for this fiscal year would complete the program, would it not?

Mr. STOLLER. It should. Unless there is a truly extended life on the last TIROS, which could happen since we have three TIROS to go. The possibility of difficulty with Nimbus must always be considered in planning, we have to plan both for success and failure in this type of business.

If there were an additional TIROS that would have to be flown in the future to keep meteorological data coming while we were meeting problems with Nimbus, then we would have to come back, in effect, in the next fiscal year and say we have to fund another TIROS and we certainly will have to fund at that time data processing if we have an extended life for the last of this particular chain. But I would say in the main we have completed the funding for TIROS with this request.

Mr. WILCOVE. Now in your funding for Nimbus you have $34,914,000 requested for the program for 1963. Your planned satellite flight schedule continues through 1965. Would you give the committee your estimate of how much funding will be needed to carry out the program through 1965?

Mr. STOLLER. I don't think I have that with me. Can I submit that for the record?

Mr. HECHLER. Supply it for the record.

Mr. STOLLER. I will supply it for the record.

(The matter referred to follows:)

Nimbus research and development funding requirements

[Costs in thousands of dollars]

Fiscal year	Total	Cumulative
1960	1,802	
1961	12,722	14,524
1962	26,902	41,426
1963	34,914	76,340
1964	26,100	102,440
1965	5,800	108,240

Mr. HECHLER. Any further questions?

If not, we want to thank you, Mr. Stoller and Dr. Tepper for this illuminating testimony.

We will, without objection, insert the complete text of your statement on the meteorological satellites in the record at this point.

(The document referred to is as follows:)

STATEMENT OF MORTON J. STOLLER, DIRECTOR, OFFICE OF APPLICATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and members of the subcommittee, I am pleased to have this opportunity to outline to you the fiscal year 1963 program of the Office of Applications. Dr. Seamans has already indicated in his review of the NASA organization the position of the Office of Applications in NASA's overall operations. On my first chart (fig. 493) I have shown the functional areas of the Office of Applications.

The first of the program elements that I will discuss is meteorological systems. Here we are essentially concerned with the development and application of meteorological satellites and the associated command and data acquisition stations which are needed to establish a meteorological satellite system. These facilities will be used to obtain a better understanding of the weather and how to forecast it. The NASA staff works closely with the Weather Bureau, the weather services of the Armed Forces, and the international meteorological community in formulating the program.

The second program area indicated on the chart is that of communication systems. This segment of the overall program of the Office of Applications includes our activities relating to satellites and ground facilities for communication satellite systems. This program area also has its international aspects, as the relations between NASA and its counterpart agencies in other countries, in establishing plans for satellite communications, play an important role in our overall program.

The future applications program area was established at the time of the reorganization last November. Here the effort is directed to the identification of other promising applications of spacecraft and the rapid dissemination of information on the technological developments resulting from NASA research and development activities which appear to be useful for general industrial application.

Consider now NASA's meteorological systems activity. I am sure you are already familiar with the TIROS meterological satellite, and you have most probably heard in previous presentations of our plans for the Nimbus satellite. Because an appropriately designed satellite gives a capability to observe the weather from above, it is possible as the result of applying space technology, to furnish the meteorologist in a timely manner with maplike pictures of cloud systems over most of the world's surface. With Nimbus, we will be able to do this over the entire Earth, including especially the areas from which meteorological data are now nearly nonexistent. The ability to determine just where cloud systems are located, to determine the specific nature of the cloud patterns, and to estimate from successive observations approximately how fast storm systems are moving, and in what manner they are changing, has already been turned into a valuable operational tool by the meteorological services. The meteorological satellite has made it possible for the weather forecaster to be furnished with much more extensive information as to the conditions prevailing over very large areas. This has improved the meteorologist's ability to detect severe weather systems of certain types and has made it possible for certain military and naval operations to be conducted in a much more effective manner.

Because of the tremendous gain which obviously will be realized from our ability to feed worldwide cloud cover and other meteorological information into the meteorological forecasting procedures, we are proceeding as rapidly as possible, in conjunction with the Weather Bureau, to develop a meteorological satellite system which will provide satellite observations for the meteorologist to use in his routine daily operations. Our meteorological systems program objectives reflect these considerations and are shown on the next chart (fig. 494).

In the first phase of the program we are undertaking the development of the equipment and techniques required for the establishment of an operational meteorological satellite system and for the general support of meteorological research. These two end uses may, of course, lead to somewhat different satellite configurations; for example, the operational systems will require equipment with a very high degree of reliability. As the satellite must operate dependably day after day in support of meteorological forecasting, it is probable that successive operational units will have the same configuration so that the performance can be improved by repetitive use of the same system elements. On the other hand, equipment for the meteorological research satellite is necessarily somewhat more experimental in nature and will be flown in various configurations in the course of development as it is being proven out for operational applications.

In the second phase of the program, there are satellite launchings for the continued development of sensors, spacecraft, and systems. By sensors we mean the devices which detect the physical phenomena of interest to the meteorologist; for example, the television cameras, and the infrared detectors, whose value has already been demonstrated and the radars or lightning discharge detectors which may eventually be of value. The term "spacecraft," which you will hear many times in these presentations, refers to the satellite or probe unit containing the specialized devices required to carry out a mission. The spacecraft is placed in orbit or started on its trajectory, by the rocket launch vehicle. In the case of meteorological systems, with the exception of our sounding rockets, our spacecraft are satellites. By "systems" we mean the overall arrangement in which the satellite, its telemetry, the tracking devices, and the ground data acquisition stations and the data processing units are all fitted together properly. We expect that these developmental launchings will continue to support the interim operational use of the cloud coverage pictures by the weather services, which was started with the TIROS data. In fact, the initial Nimbus research and development satellites will be integrated into the interim operational system.

The third phase of the program calls for the establishment, with the Weather Bureau, of an operational meteorological satellite system. This system will eventually make it possible for the Weather Bureau and other weather data users to use satellite observations much as they now use ground and balloon observations. Finally, we have an interest in those specialized sounding rocket techniques which are directly adapted to meteorology. Our interest here includes the development of specialized meteorological sensors which can be used in small sounding rockets in regular support of meteorological activities. In the development of this particular phase of our program we are, of course, working closely with the NASA, Weather Bureau, and DOD groups doing research in the upper atmosphere and in aeronomy.

The next chart (fig. 495) shows the three meteorological satellites with which we are currently concerned. Four TIROS satellites, of the design shown on the left, have already been orbited. TIROS was our initial effort in the design and development of meteorological satellites. The Nimbus, in the center, is the meteorological satellite with much improved capabilities, which we now have under development and construction. The first Nimbus should be launched about a year from now. The Aeros satellite is shown in a conceptual form on the right, as we have not yet initiated a flight program for this satellite. We are now chiefly concerned with design studies and research and development efforts on components for eventual incorporation in Aeros. I will discuss each of these satellites and some of their system elements in somewhat more detail in what follows.

The next chart (fig. 496) lists the four TIROS launches that have taken place to date. You will notice that, since April 1960, we have launched four TIROS, and their useful life has been from 2½ months to 10 months. We added two infrared radiation sensing systems to TIROS II and increased this to three systems in TIROS III.

Let me take a moment here to point out on this chart (fig. 497) the types of sensors used in TIROS. The primary sensor is the TV which, with the wide-angle lens used in all TIROS satellites, covers an area on the ground about 800 to 1,000 miles across when looking straight down from the orbital altitude of 450 miles. The area increases somewhat when the satellite is tipped and the camera looks down at an angle. One set of infrared radiation sensors which are incorporated into an instrument called a multichannel scanning radiometer, scan the Earth and atmosphere as a result of the rotation and orbital motion of the satellite. The channels of this instrument are so designed that data are obtained corresponding to—

(*a*) The temperature of the uppermost layers of water vapor in the atmosphere.
(*b*) Night cloud temperatures.
(*c*) The total amount of reflected sunshine.
(*d*) The total amount of heat emitted from the atmosphere.
(*e*) Low resolution cloud coverage.

The second of these channels, which measures the night cloud top temperatures, can be used for rough nighttime cloud cover mapping, as I will show on a later chart. It must be remembered though, that these sensors do not produce a direct TV-like picture when collecting the data. Many independent scans, each containing the data on the temperature variation along one line

drawn across the surface of the Earth, are recorded. This information, after machine processing, is assembled into a radiation or a temperature map. From this, cloud cover or energy exchange estimates are developed. This is a rather lengthy procedure as yet and additional study and development on high speed data processing methods are required before routine inclusion of such infrared data in daily forecasting takes place. Of the possible applications of the infrared data, only the cloud cover and temperature studies have been investigated. Yet it is entirely possible that infrared radiation data may ultimately turn out to be even more valuable to the meteorologist than the cloud pictures.

TIROS also carries two additional sets of radiometers. Their major difference is the size of the area viewed at any instant. One sees an area about 400 miles on a side. While the other can see the entire area from horizon to horizon, it is particularly sensitive to energy in a circle about 1,000 miles in diameter centered just below the satellite. Each set contains both a white and a black sensor. The white sensor measures total emitted or outgoing radiation—in a sense, the exhaust of the atmospheric engine. The black sensor measures this plus that part of the incoming solar energy reflected by the Earth, the sea, and especially clouds. By subtraction, we can separate the reflected energy and, by again subtracting this from the energy known to be coming from the Sun, we can determine how much solar energy was retained to drive the atmosphere and create the weather. It is hoped that meteorologists can in time use these data to develop improved longer range forecasting techniques.

On the next chart (fig. 498) we have a breakaway drawing of the TIROS satellite. TIROS has been referred to as a satellite with a hatbox configuration. It is approximately 42 inches in diameter, 19 inches in height, and weighs almost 300 pounds. The version shown in the chart was flown as TIROS III. It closely resembles TIROS IV which is now orbiting the Earth and transmitting cloud cover and infrared data. The satellite carries the sensors I have just reviewed, the associated tape recorders and electronic systems for recording the meteorological and engineering information and the telemetry system for transmission of the data to the ground when recorder playback is commanded. There is one TV camera shown in the front of the drawing; a second similar TV camera is installed so as to provide a backup or alternate television channel. This was found to be particularly valuable in TIROS III, where one camera system had a relatively short life, and the second camera enabled us to obtain most of the data we set out to get. The infrared systems' electronics are located at this point on the diagram. And here is one of the nonscanning radiation sensors—the one with the horizon-to-horizon coverage.

TIROS is covered on the upper and side surfaces with solar cells for recharging the storage batteries which are carried aboard. It is furnished with a number of other technical devices, of which I think two are worth pointing out to you as evidence of the engineering techniques which must be used to accomplish a satisfactory satellite operation. TIROS is a spin-stabilized satellite; this means that the whole satellite revolves in space, in this case about an axis lined up with the receiving antenna. The technique of rotating the satellite, to keep it in a fixed attitude in space, is used in many satellite projects. To keep the rotational or spin rate at an appropriate value in order to maintain stability, TIROS has a number of small rockets mounted near its lower edge. These can be fired on command when the satellite spin slows down, and this operation has been demonstrated a number of times in the course of normal operations. In TIROS III, one pair was successfully fired after 10 months in space.

During the flight of TIROS I, it became apparent that, while the satellite axis had been expected to point continuously in one direction in space, it was actually slowly drifting and changing direction. Fortunately, it did so in a favorable sense. After testing various hypotheses as to why the axis should be drifting, it was determined that it was probably due to the interaction of the magnetic field of the satellite, created because of its internal electrical currents, with the magnetic field of the Earth.

In the second and subsequent TIROS, advantage was taken of this analysis. A current carrying coil, called a magnetic orientation coil, was designed and installed in the satellite. This coil is used to cause the spin axis to drift slowly in a desired direction in the course of the life of the satellite. A current control device, commanded from the ground, was also added so that magnetic fields of controlled intensity could be generated in the satellite. Therefore, there could be a deliberate interaction of a selected intensity, with the Earth's field. Experience in operating this device has indicated that in general the satellite axis

will drift in the predicted direction but not more rapidly than 15 degrees per day. This makes it possible for the satellite operations programer to keep TIROS so oriented that the satellite will be looking down at the Earth when it is favorably located on the sunlit side. This makes the overall data collection coverage of the satellite appreciably better, but we still cannot keep the cameras pointed at the Earth more than about one-third of the time on each orbit.

This chart (fig. 499) indicates a typical orbital path of a TIROS satellite, TIROS is injected into an inclined orbit. The chart indicates the maximum limits of latitude (about 50° north and south) to which TIROS normally can provide observations because of the inclination of the orbit. As I have already mentioned, the satellite itself is spun about its axis; it consequently reacts like a gyroscope, in that its axis will usually maintain over a period of the order of a day or so a fairly fixed space orientation. Accordingly, the satellite can be initially so oriented as to properly observe the North American Continent and other parts of the northern hemisphere, as is shown on this chart, with the TV camera pointing down toward the Earth in the northerly latitudes. However, when it gets to the other portion of its orbit in the southern hemisphere, the camera will be pointing out into space and there will be no southern hemisphere coverage at all. The motion of the spin axis because of the magnetic interactions, as I have already mentioned, is not rapid enough to rotate the satellite so as to see the southern hemisphere in the time of one orbit. Only slow movements of the axis can be corrected and controlled.

TIROS has enabled us to make specialized observations of storms and hurricanes. Here is a photograph of Hurricane Betsy which was picked up by TIROS in the western Atlantic Ocean last September (fig. 500). This satellite photograph of the hurricane is, of course, an almost classic one, corresponding to hurricane pattern as seen on radar and to a plotting symbol the meteorologists have used for many years. The ability to identify hurricane cloud patterns, to locate them with respect to land masses, and to follow their motions, is one of the major benefits of the meteorological satellite.

The next chart (fig. 501) shows in a very abbreviated form the TIROS global cloud analysis for September 11, 1961. We have here a map of the world looking down on the North Pole. The various areas that are outlined on the chart are assemblages of data from many TIROS cloud cover pictures all taken on this one day. Each finger-shaped area shows in a very condensed way the cloud information from a sequence of TIROS photographs. The white represents the clouds and the blue the clear areas as seen by the satellite. For this type of work the photographs are converted to a graphical notation by meteorologists at the data read-out stations and the cloud cover maps are sent by wirephoto to U.S. Weather Bureau's National Meteorological Center at Suitland. At that center they are combined on maps such as this one and further distributed to weather stations all over the world. On the chart there are indicated the major storm and hurricane centers which could be identified in this global analysis. You will notice that we have indicated by the three-legged symbols six distinct tropical storm centers, which were located by the detailed analysis of the data used to make this map. One center which is the remnant of Hurricane Betsy and a second, which never grew enough to acquire a name, are also shown.

The next chart (fig. 501) shows some of the details of the world chart with particular attention paid to Carla as it hit the Texas coast. I have deliberately retained on this chart many of the details of the cloud analysis as they are presented in a graphical form for transmission over the facsimile (or wirephoto) network that the Weather Bureau and the military weather services maintain. The various letter symbols and the specific details of the lines of the cloud formations convey a good deal of information to the trained user of these charts. Hurricanes Debbie and Esther are also on this chart. This was the day TIROS III discovered Esther—at least 2 days before it would have been likely to have been spotted by aircraft or other techniques. These cloud analysis charts show the extent to which meteorologists can derive information on large-scale weather conditions from a satellite such as TIROS.

The next chart (fig. 503) indicates one type of data that the meteorologist derives from TIROS infrared observations. The upper chart shows temperature contours; each line represents a condition of constant temperature as observed by the particular infrared sensor in the TIROS satellite, which gives cloud top and earth surface temperatures. The letters "W" and "C" are placed to show warm and cold locations respectively. Below these is shown for correlation the cloud cover information for the same period of time at which the infrared data were recorded. In this case this cloud data came from conventional ground

observations. The lines here show the altitudes, in thousands of feet, at which the cloud layers were located. Note how the cold areas in the upper chart correspond to the cloud (shaded) areas in the bottom one, while the warm areas are clear. Also, the coldest areas are those where the clouds extend to the highest altitudes. This correspondence shows how we could use such data to observe general cloud coverage at night when we are able to process the data without delay.

The next chart (fig. 504) indicates the way in which the cloud picture data collected from the TIROS satellite flows to the users. TIROS requires a pair of data acquisition stations, one of them is located on San Nicolas Island (a part of PMR), not far from Los Angeles, Calif., and one at NASA's Wallops Station located on the east coast of Virginia, not far from the Maryland border. The data are analyzed, processed, and transmitted in "real time" to the National Meteorological Center and are finally sent to the forecasters and the meteorological services over the world. These same data but in the form of copies of the recordings made at the acquisition stations are later provided through the National Weather Records Center to meteorologists and others desiring them for research and climatological studies. The infrared data are reduced and processed to usable forms and are then also made available through NWRC. All these uses of the data require information on the location in its orbit of the satellite at the time the observations were made and these are obtained from the reduction at the Goddard Space Flight Center of observations made by NASA's minitrack network.

If the committee wishes, additional material on the success and meteorological output of TIROS can be made available for the record. Dr. Morris Tepper, Director of Meteorological Systems in the Office of Applications, has prepared a summary of TIROS experience which you may wish to have included in the record. This summary is based in part on information provided by the U.S. Weather Bureau and the Air Weather Service.

TIROS is a satellite system of a developmental nature which already has shown in its first three flights and in the first weeks of the fourth, its great usefulness to the weather forecaster. Accordingly, our program calls for three additional TIROS launchings at approximately 4-month intervals so that we can continue to supply cloud-cover pictures and infrared data to meteorologists both here and in foreign countries. The cloud pictures can be used for support of regular meteorological operations while both types of data will be available for meteorological research investigations. These TIROS satellite launchings are scheduled to continue until the time when the first Nimbus satellite is expected to be ready to support meteorological operations.

I have already indicated with the use of the chart showing the TIROS orbit and in the discussion of TIROS as a spin-stabilized satellite that TIROS cannot provide cloud-cover data for the entire earth's surface on a daily basis because of limitations arising from our use of the inclined orbit, the space-stabilized pointing of the camera, and the relation of these to the illumination from the sun. The previous chart (fig. 499) showing TIROS is repeated on the left of this chart (fig. 505) which compares TIROS and Nimbus.

The Nimbus system is specifically designed to overcome this difficulty. In view of the limited coverage of TIROS, it was apparent at the start of that program that the next step forward would be a satellite whose viewing axis was stabilized with respect to the Earth. By this I mean stabilized in such a manner that the various sensing systems, especially the TV camera, always point toward the Earth. Furthermore, to provide full global coverage, we will use a nearly polar orbit. It is helpful also to always have the observations made at the same time of day (at noon for example) when the satellite is on the illuminated side of the Earth where the present TV's can work. Fortunately, analysis shows it is possible to do this. How well such a condition can be maintained for an extended period will be determined by the accuracy of the Nimbus launching. With the expected accuracy, we should be able to stay reasonably close to this condition for the estimated useful satellite lifetime.

In this chart (fig. 506) which enlarges the right side of the previous chart (fig. 505) we show Nimbus in near polar orbit. We have indicated also the fact that because Nimbus is Earth stabilized rather than space stabilized, the TV which is mounted on the bottom ring will always be looking at the Earth. As a full hemisphere is always illuminated by the Sun, with a properly selected initial orbital injection time we can always view the subsatellite point over half an orbital period without difficulty. It is presently planned that this be the northward moving half of the orbit for Nimbus. Notice that to keep the

cameras pointed at the Earth, and the paddles pointed at the Sun, it is necessary to provide for paddle rotation as the satellite travels in its orbit. Also indicated on the chart are the two control and data acquisition station locations. One station is planned for Alsaka. The location of the second has not yet been determined, but it preferably would be on the east coast of North America as far north in latitude and east in longitude as feasible. Arrangements for collecting data from successive orbits of Nimbus without incurring limitations imposed by present transoceanic communications systems will be discussed a bit later.

Now to the Nimbus itself—on this chart (fig. 507) we see that the satellite has these large solar cell paddles; there is an upper section which houses the controls; attached to this control housing are the horizon scanners. The horizon scanners are used to activate the controls which maintain the axis of the satellite pointing toward the center of the Earth. These instruments continuously sweep over the Earth's horizon and if they should detect that the satellite is not symetrically located with respect to the horizon, control signals are developed calling for angular changes in satellite position. The control system achieves this by turning flywheels, which are known as inertia wheels, with small electric motors. Should these inertia wheels reach the end of their control range (that is, if their maximum speed is reached) there are gas jets attached to the control section which come into play. These gas jets are used to keep the satellite stabilized while the wheels are slowed down. They are also used to attain the proper initial position when the Nimbus is injected into orbit or if the satellite should be forced too far from its proper position by some external force. The conical structure above the control section is simply the upper portion of the command antenna. The straight tubular structure below the control section connects it to the sensor ring; a satellite configuration with such a separation uses certain properties of the Earth's gravity field to help realize the desired Earth-oriented stabilization. The circular tubes are also a part of the antenna. The sensor ring is so constructed that a large number of electronic modules of standardized sizes can be accommodated. These modules contain most of the electronics circuits, the storage batteries for the TV cameras, the tape recorders, the telemetry transmitters, and the like.

Down at the bottom of the ring we see the two units containing the infrared scanners and a bank of three TV cameras which are arranged to produce a field of view approximately as shown on the ground below. The three cameras cover a ribbon-like swath on the ground from pole to pole, as the satellite moves along its orbit. Successive orbit-to-orbit strips completely cover the higher latitudes with an appreciable overlap, since each strip covers an east-west distance about 1,500 miles in width. At the Equator these ribbons just barely overlap. The infrared scanners will cover a similar strip, actually looking from horizon to horizon.

The design of Nimbus started over 2 years ago, and most of the major contracts have been underway now for 12 or more months. The prototype spacecraft is now being assembled. This photograph shows a mockup of the prototype satellite (fig. 508). The model gives you an idea of the large size of the satellite. It shows the large solar paddles, the lower structure which will contain the sensors, and the upper structure containing the stabilization and control system, which also keeps the paddles facing the Sun.

Several people have already asked about the cutouts on the corners of the solar paddles, as they show up on all the photos and drawings. To launch the Nimbus, it is necessary to fold the paddles in toward the main structure so that it will have a small enough overall diameter to fit within the shroud of the Agena launching vehicle. When the paddles are folded in and rotated around to the prelaunch, stowed position, these notches are found to be necessary to clear the sensor ring at the bottom. This photograph (fig. 509) shows the developmental control system under test. The complexity of the control system is a result of the need for Earth stabilization. We have as yet been unable to come up with a system for Earth stabilization which does not have a fairly large number of active mechanical and electronic elements, all of which are required to carry out the stabilization with adequate precision over the long period the satellite is expected to function. I will mention later, in discussing communications satellites, NASA's intent to investigate in greater detail, stabilization systems which have appreciably less complexity. We expect that the investigations undertaken for the improvement of communication satellites will result in a direct benefit to the meteorological satellite program as well.

In developing Nimbus, we are making an effort to design the spacecraft so that future spacecraft, whether for the purpose of either research and development or for routine operational use, can be assembled rapidly with a minimum of modifications to the basic structure although completely new sensory subsystems may be added. This is illustrated on the next chart (fig. 510) where on the left we have shown the basic Nimbus system with its fundamental elements of power supply, controls, and sensory package. In the center it is shown as it might be modified, if in the course of the development activity a decision were made to test fly a rainfall radar system. In this case we would undertake to mount the antenna on the sensory package structure and would mount the electronic components of the radar in the space provided in the sensory package for electronic modules. The TV cameras could look through small holes in the radar antenna. If a special infrared spectrometer, now being developed by the U.S. Weather Bureau to measure the vertical temperature profile of the atmosphere, were desired, we might mount this in the center of the sensory package ring, where the TV cameras are now located. The spectrometer package is indicated in outline form in the sketch on the right.

A specialized data acquisition and processing system will come into being for the support of the Nimbus project. Its general organization is indicated in abbreviated form on this chart (fig. 511). As you can see there will be a complex consisting of command and data acquisition stations, data transmission channels to and from these stations and data processing facilities in the Washington area at the Weather Bureau's National Meteorological Center, and at NASA's Goddard Space Flight Center. Both centers are concerned with data processing as each has responsibilities for specific phases of the operation. The Weather Bureau will be responsible for the dissemination of weather data from Nimbus to national and international users, and for research and climatological purposes.

The typical data acquisition antenna required at the Nimbus stations is shown in this photograph (fig. 512). Here we see the first of the antennas for the acquisition of data from polar orbiting satellites which NASA is installing. This unit is installed at the Fairbanks, Alaska, site. It is a part of NASA's network of tracking and data acquisition stations, which will be discussed in another presentation. The antenna reflector which collects the signals is 85 feet in diameter. It is mounted on this steerable mount which will permit it to track satellites from horizon to horizon, including the period when they are almost overhead, without encountering the difficulty commonly known as gimbal lock. As an operational system must of course function continuously and with minimum time outs, should an interruption occur, the antennas for the Nimbus operational system may be installed in radomes, so as to permit maintenance operations to take place in severe storm weather.

The need for several data acquisition stations for the Nimbus system has already been mentioned. At whatever altitude a satellite orbits, it must be visible at a sufficient height above the horizon for data acquisition to take place. An examination of the geometric conditions that are set by the Nimbus orbital requirements, leads to the conclusion that only by placing a station extremely close to the pole, could we cover all of the regular daily orbits and so realize global coverage. Alaska is a practical location, which can be used, which is fairly close to the pole. To complete the coverage, a station diametrically opposite to Alaska at the other side of the pole would satisfy the simple geometrical condition. Such a location would be impractical in an engineering sense, even if it were available politically, as there are no reasonable cost communication channels available for the transmission of the data to the central data processing location. For this reason, a second station, on the east coast of the American Continent and as far north as it is practicable to provide the necessary communications is being considered.

The Congress appropriated $48 million to the Weather Bureau in fiscal year 1962 for the initiation of a meteorological satellite system, based on the Nimbus program, which is to be ultimately capable of continuous observation. NASA and the Weather Bureau have since that time drawn up an agreement covering the responsibilities of the two agencies and have initiated a project development plan for the Nimbus operational system. This agreement is outlined in the accompanying chart (fig. 513). The agreement states that NASA will be responsible for spacecraft development and launching, for the development of the ground command and data acquisition stations, and for data acquisition from the satellite. The Weather Bureau will be responsible for data processing for meteorological purposes, for the analysis and dissemination of the data, and for

the maintenance of the data archives. Both NASA and the Weather Bureau will undertake data analysis and processing to support a continued program of research and development on the spacecraft and on the ground systems. From the engineering point of view, NASA's major interests will be in the improvement of the sensory units in the spacecraft, the spacecraft itself, and the data acquisition facilities. The Weather Bureau's major interests will be in the adaptation of improved data processing techniques to the data which will be available from the Nimbus spacecraft, and in the integration of the satellite system's data into the existing meteorological operations with the greatest speed and effectiveness. The Weather Bureau will consolidate all weather data users' requirements and specify the needs for particular types of observations to the spacecraft systems designers, so that the spacecraft itself will be able to carry out the types of observations that the Weather Bureau thinks will be of optimum value for its purposes.

With the Nimbus development program already underway and the assembly of the prototype moving along, the addition of the Weather Bureau's funding will result in the procurement of hardware for additional Nimbus satellites of the basic design you have seen here. We then plan to be prepared to launch the Nimbus units about twice as frequently as when the original research effort was scheduled. If all goes well, starting some time in 1963 we would hope to have at least one working Nimbus in orbit nearly all the time.

We will soon be placing greater emphasis on the development of the Aeros meteorological satellite. The Aeros concept is illustrated in the chart shown here (fig. 514). Aeros is conceived as a satellite which will be placed in equatorial orbit at an altitude of 22,300 miles. This will result in its remaining stationary at a given location over the equator from which it can view tropical and temperate latitudes. Aeros will carry, in much the same way as Nimbus, solar cell paddles for power, a controls section and a camera section. The unusual features of the Aeros system are associated with its stationary position with respect to the earth. With this satellite, it is planned to undertake continuous surveillance of the weather systems on the one-fourth to one-third of the Earth visible below the satellite. Thus we will have a capability for the continuous tracking of a particular storm as it moves over the surface of the Earth. The chart indicates the two TV patterns considered for Aeros. One is obtained with a relatively wide angle type of camera which records and transmits pictures of all major cloud systems. In actuality, this camera will have a viewing angle much like that of a conventional home movie camera. This overall view should then be fairly similar to and readily correlated with a mosaic made up of successive Nimbus photographs. The other Aeros camera will be one of relatively high resolution, and very narrow angle of view, compared to the one which covers the total hemisphere. The actual resolution will be comparable to that of Nimbus but in this case the camera will be directable on command so that any selected area can be brought into the field of view at any time. The areas will be chosen from the wide coverage data. A special lens and pointing mechanism will be required for this camera. Preliminary design studies, to be initiated this spring, will consider, among other details, whether a single camera with an adjustable lens system will offer advantages over a multiple camera arrangement for this purpose.

Why is it that we wish to have another meteorological satellite at such a high altitude, when the Nimbus satellite should give us 100 percent coverage of the Earth's surface? Our calculations indicate that 14 orbits elapse before Nimbus returns and passes in daylight over about the same area of the Earth as it did in its first orbit. Roughly, the same area is covered, but in a pass in the opposite direction and at night, every seven orbits. This means that about every 12 hours we get another observation of a given spot on the Earth's surface, but are limited on alternate passages to the use of the infrared techniques, until we can develop a TV camera that can see clouds at night.

The importance of more frequent or continuous observations is illustrated in the next chart (fig. 515). Here we have shown the typical lifetime of certain common weather systems: tornadoes, thunderstorm cells, hurricanes, and major cyclonic storms. The chart shows the general relation which exists between the lifetime of these systems and their typical size. We have also shown the time between observations (about 12 hours) which will result if one Nimbus satellite is up and the time between observations which would result if we eventually operate a system which continuously maintains two Nimbus satellites in orbit. In both cases we are assuming we are using the nighttime as well

as the daytime observations. With one Nimbus in orbit, about half a day passes before we again see the same area. This will be a reasonably satisfactory time for the observation of such systems as cyclonic storms and hurricanes whose normal life is considerably greater than 12 hours. But, if we attempt to observe thunderstorm cells or tornadoes, systems whose life is appreciably less than 12 hours and often less than 6 hours, will usually form, move, and die out without ever being detected. It is for this reason that the Aeros satellite, with its capability for focusing on small short-lived storm systems and tracking them continuously, is considered to be an integral component of the eventual operational system. While Aeros will not be able to see into the polar regions, there the Nimbus orbits overlap and provide rather frequent coverage.

Another aspect of the research and development program is reflected in the effort devoted to the continuous improvement of meteorological sensors, electronic and mechanical components, and systems configurations. These activities are coordinated with similar program studies arising in other areas of interest in order to so direct the work that more than one flight-development program can benefit. The objective of these studies is the improvement of subsystems elements which will be eventually incorporated in the satellite flight program. New types of infrared sensors for the measurement of quantities of meteorological interest, and new data storage devices for use in the satellites are typical of the items covered in the advanced research program.

To complete this review of the meteorological systems program I wish to mention briefly the meteorological observations made with sounding rockets, which supplement standard ground station observations, balloon sounding, and the satellite data. NASA's meteorological systems program includes the development of improved sounding rocket techniques. In particular, we have been working wtih a method known as grenade sounding. In these tests, a series of small explosions is produced at a number of altitudes by ejecting grenades from a sounding rocket. The time of arrival of the sound wave from each explosion is measured at a group of microphone stations on the ground. The location of the grenade at the time of firing is also determined with radar and/or optical instruments. The use of appropriate data reduction procedures then enables us to determine both the winds and the temperature in the upper atmosphere up to the altitudes at which the last grenade was exploded. The chart (fig. 516) shows the general arrangement for such a sounding. The facilities include a launcher for the sounding rocket, the "Dovap" system, which tracks the rocket so as to locate it in space at the instant of an explosion, and microphones, represented by the numbered locations in the vicinity of the Dovap stations. The photograph shows a typical grenade head for the sounding rocket.

On the next chart (fig. 517) are two typical results which have been extracted from data for many sounding rocket flights at Fort Churchill, Canada, at a latitude of about 59° north. Note that the winds change appreciably from the winter season to the summer season. This phenomenon could not have been determined without the rocket soundings because only the lower altitude conditions can be measured with conventional balloon soundings. Furthermore, we know of no satisfactory techniques for observing these altitudes from satellites. The transition point at which the wind direction shifts is where the balloons start to reach their limit and the data shown from 100,000 feet on up have all been acquired with sounding rockets.

I wish to point out that NASA recognizes the international nature of meteorology. Maximum benefits in a meterological program of the sort I have discussed will result from international participation and cooperation. The following international activities are typical of those already in being or in the planning stage; all have been undertaken in conjunction with the Weather Bureau (fig. 518).

1. The transmission of satellite cloud analyses to foreign countries.
2. Making our basic satellite data available to all countries through the NWRC.
3. The encouragement of supporting meteorological observations by foreign countries in connection with satellite passage over their area.
4. The sponsorship of an international seminar workshop in satellite meteorology.
5. Long-range planning for ultimate direct readout of satellite data by foreign countries.
6. Long-range planning for international participation in a unified global operational meteorological satellite system.

In summary, the flight schedule for the meteorological satellies is as shown on the following chart (fig. 519). Here we see the sequence of TIROS satellites and here the sequence of Nimbus satellites. The overlap is, as I have already mentioned, designed to provide us with continuing meteorological observations while the initial flight of the Nimbus development program takes place. In all cases, the Nimbus flights will serve both the NASA and the Weather Bureau programs as the data collected will be used to arrive at the most satisfactory design for the operational Nimbus which will eventually take the routine data for the Weather Bureau. In the initial flight phases, the Weather Bureau will utilize the NASA research and development Nimbus results for the confirmation of the requirements and design of the operational system. In addition, the data, as for TIROS, will be made available for immediate use in weather analysis and forecasting. The flights for the 1965 Nimbus operational satellites are indicated only to give an idea of the level of effort required for the support of the system, as far as we can now predict it. There is no provision of funds in either the NASA or the Weather Bureau budgets for this year for these flights. The Aeros system is also shown in phantom to indicate the approximate period in which it might become a flight reality. At the present time Aeros is scheduled only for research and development toward system design and component development.

Mr. HECHLER. The committee stands adjourned until 10 a.m. tomorrow.

(Whereupon, at 12:30 p.m. the subcommittee adjourned, to reconvene at 10 a.m., Tuesday, March 6, 1962.)

1963 NASA AUTHORIZATION

TUESDAY, MARCH 6, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON APPLICATIONS AND TRACKING
AND DATA ACQUISITION,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10 a.m., in room 214–B, New House Office Building, Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. We have again this morning Morton J. Stoller, Acting Director of the NASA Office of Applications to continue the discussion of communications satellites.

Mr. Stoller, you can proceed in your own way.

STATEMENT OF MORTON J. STOLLER, DIRECTOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, OFFICE OF APPLICATIONS

Mr. STOLLER. Thank you, Mr. Chairman. I have here a copy of a little article on TIROS that appeared in yesterday's New York Times. The committee may be interested in putting it in the record.

It is a statement by the chief weather forecaster at the Idlewild Airport as to the value of TIROS in his operations.

Mr. HECHLER. Without objection it will be placed in the record.

(The document referred to is as follows:)

[From the New York Times, Mar. 5, 1962]

TIROS PROVES HELP TO PILOT BRIEFINGS—WEATHER SATELLITES GIVE AIR FORECASTERS MORE SCOPE

(By Joseph Carter)

The weathermen at New York International Airport are finding the TIROS satellites a boon in preparing forecasts for airline pilots and operations officials.

"We can do a job nowadays we never thought we could do years ago," Silvio Simplicio, supervising forecaster of the Weather Bureau at Idlewild, said in an interview.

"With the aid of the TIROS satellites we never had it so good," he went on, "and with the Nimbus meteorological satellite, now undergoing tests, we expect even better results."

Since the National Aeronautics and Space Administration launched TIROS I on April 1, 1960, three of the high-flying weather observers have been put into orbit around the Earth. Mr. Simplicio said that only TIROS IV, launched February 8 at Cape Canaveral, Fla., was reporting through its two television cameras.

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MERCATOR PROJECTION USED

Once a day the Weather Bureau issues a Mercator projection of the Earth showing the orbit of the satellite for the next 24 hours and the areas where photographs of cloud conditions can be expected. The satellite, flying 450 to 525 miles above the Earth, can scan an area 750 miles on a side through its wide-angle lens and 450 miles on a side with its narrow-angle camera lens.

It transmits what it sees to receiving stations at Wallops Island, Va., and Point Mugu, Calif. The pictures are analyzed by highly trained meteorologists and their interpretations are sent to weather offices throughout the world.

Mr. Simplicio said, "The satellite scans areas where heretofore we had no information services; for example, in vast regions of the Pacific, Indian, and South Atlantic Oceans."

The information sent by TIROS, together with data gathered by other means, gives the airline man a more complete picture of weather conditions on a flight pattern. The pilots themselves contribute to the common pool of weather knowledge.

VARIOUS PICTURES MADE

Clouds are often the heralds of weather events, Mr. Simplicio said, and TIROS pictures them in all their forms, including the spiraling counter-clockwise drift that signals a storm center is developing.

"Up to now we haven't had adequate surface information to define these centers," he continued, "but now TIROS is helping us to locate and define them."

He said four weather briefings were transmitted to all carriers at Idlewild daily by closed-circuit television facsimile, or both. The weather bureau at Idlewild is responsible for briefings on conditions from here across the North Atlantic and into Western Europe.

The TIROS interpretation, superimposed on a map of the area for that particular picture, helps show a flight captain the route he should take or avoid.

Mr. Simplicio, 16 years a supervising forecaster, says the TIROS information used in all pilot briefings, is a great step forward in aviation safety.

Mr. HECHLER. Do you want to comment on the article?

Mr. STROLLER. Well, I think it is interesting in that this is another example of how the TIROS data does get out into the field for operational use and improves the actual day-to-day work that people are doing in preparing predictions for such things as airlines operations. It is just another example of it and I thought it would be of interest.

Mr. HECHLER. Thank you.

Mr. STOLLER. I would like to turn now to the program in communications systems. It has been obvious for some time that the communications satellite has a tremendous potential for improving our ability to communicate with the other nations of the world and for making this capability available to all. In particular, the communications satellite offers a means for establishment of transoceanic channels for TV, for telephone, and for other telecommunications services. The improvements possible in channel capacity and in cost per channel may lead to the substitution of satellites for the undersea cables on which we now depend for transoceanic telephone communications. Economic studies which have already been undertaken indicate that with the development of the communications satellite it will be possible to provide services closely comparable in performance to those of the underseas cables, at lower costs per channel than we now experience with the cables, and that we will be able to expand the system to a capacity well beyond that which would be economic with cables alone. Related studies on the number of channels that are predicted as being required for overseas communications indicate that in a decade or so, the addition of communication satellites will be almost a necessity, if we are to keep up with the demands for service to other countries.

While the usefulness of the communications satellite and its importance in worldwide communications is clear to all, it is not immediately apparent which of the technical approaches to the problem will turn out to be the most rewarding in arriving at the design of the operational systems of the future. Accordingly, NASA is endeavoring to determine, as rapidly as possible, which of the various system designs which have been proposed should be used in the establishment of operational communications satellite systems.

To do this we must first determine which technique has the greatest promise of reliability and economy of operation, so that the development of the commercial system can be pushed forward as rapidly as possible.

On this next chart (fig. 520) I have indicated the objectives of

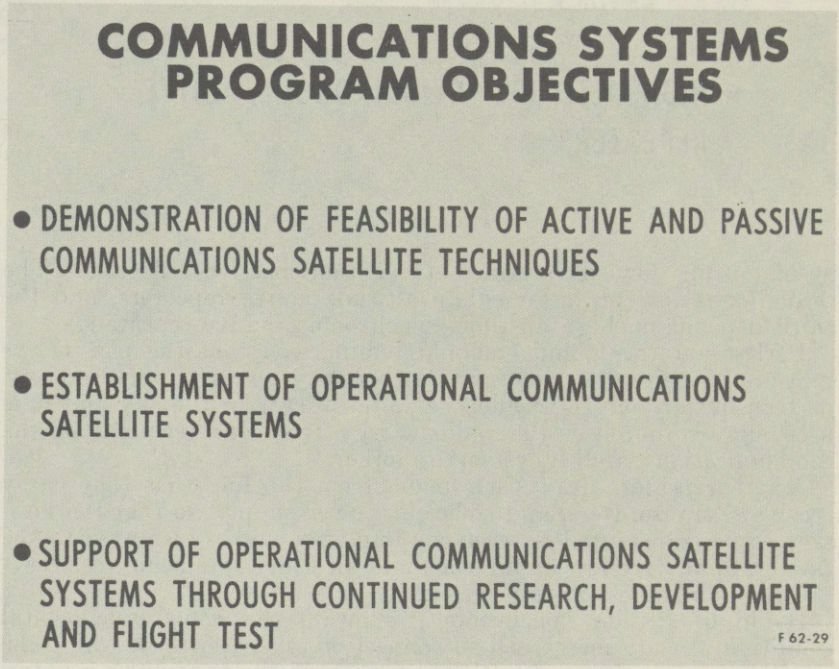

FIGURE 520

our communications systems program. The first of these is the demonstration of the feasibility of both the active and passive communications satellite techniques. The Echo experiment has already accomplished this for the passive system.

The first phase of the active satellite feasibility demonstration has been completed by the Score and Courier projects of the DOD. Our second objective is to move as rapidly as possible toward the establishment of the operational system. The third of the objectives is to support the operational communications satellite system through continued research, development, and flight tests.

On the next chart (fig. 521) there are indicated the three major communications satellite systems which offer sufficient promise to warrant continued detailed investigation. The first of these is the

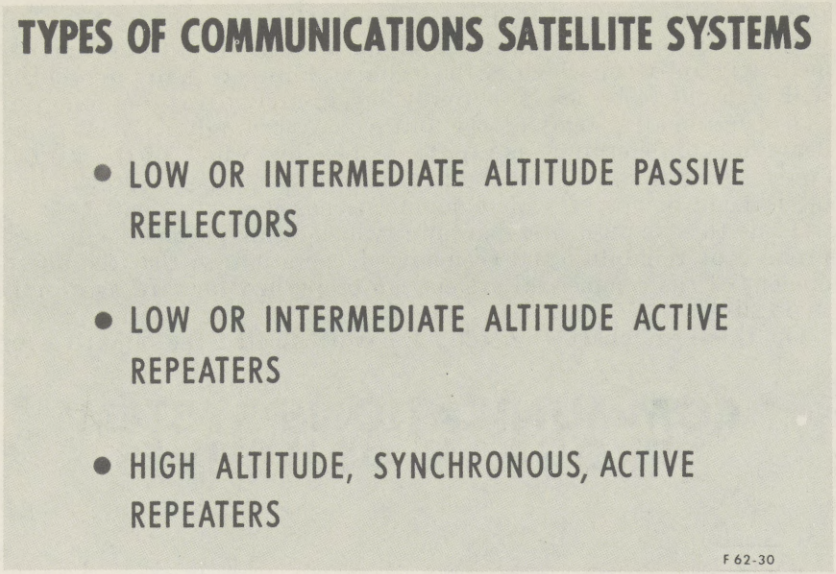

FIGURE 521

system using low or intermediate altitude passive reflectors. The second uses low or intermediate altitude active repeaters, and the third depends on high altitude, synchronous, active repeaters.

Perhaps at this point I should remind you that the passive, or reflector satellite does not carry with it any power supply receiver, or transmitter. It is, in effect, a radio mirror in the sky and it is used simply to reflect the radio energy from one terminal of the communications satellite system to another.

Active repeaters draw their name from the fact that they carry receivers, transmitters, and sufficient power supply, so that the message to be transmitted is received, amplified, and transmitted to the far terminal. By low or intermediate altitudes, we mean from several thousand miles to as much as 12,000 or so miles.

By high altitude, synchronous, is meant the 22,300-mile orbital condition already mentioned in connection with Aeros, in which the satellite apparently remains fixed over a point on the earth's equator.

The next chart (fig. 522) shows pictorially the elements of a low altitude active communications satellite system. It is characterized by terminal stations with large antennas located, for example, on the European and the American Continents, and by a number of satellites orbiting at low altitude.

The reason for the large number of satellites indicated on the chart is that the time that any one of these satellites is visible to both of the terminal stations is limited, when the satellites are in orbit at low altitude. Consequently, to get continuity of transmission between the two terminals, a number of satellites must be put into orbit, and these must be so distributed in space that at all times, at least one can be used as a communication link between the terminal stations.

A realistic appraisal indicates that unless fairly complex provisions are provided for controlling the position of the individual satellite in its orbit, it must be expected that the satellites will come after a

FIGURE 522

period of time to an essentially random set of spacings. Estimates of the number of satellites required for substantially continuous service between terminal points are therefore generally made on the assumption that the satellites are distributed in a random manner in orbit.

An example of the results of calculations on the number of satellites that are required for the maintenance of communications at several orbital altitudes is given in the next chart (fig. 523). Here we see how many satellites are needed for substantially continuous service between ground terminals located some 3,000 miles apart.

Note that if we were to orbit the satellites at an altitude of only 1,000 miles that as many as 400 randomly distributed satellites would be required. If we plan to use the 5,000-mile altitude range, then we can immediately cut the number of satellites required to 40.

Satellites are not inexpensive, and launch vehicle costs are at least comparable if not higher. Consequently, even 40 satellites in orbit will represent a considerable investment for the communications satellite system. If fewer satellites can be used, we can cut the initial costs somewhat and keep the replacement charges down.

Suppose we plan on using the 22,300-mile altitude, which is about as high as we would wish to go for reasons I will mention in a moment: 19 satellites are shown to be required by the analysis, which we must remember assumes that the satellites are randomly distributed in

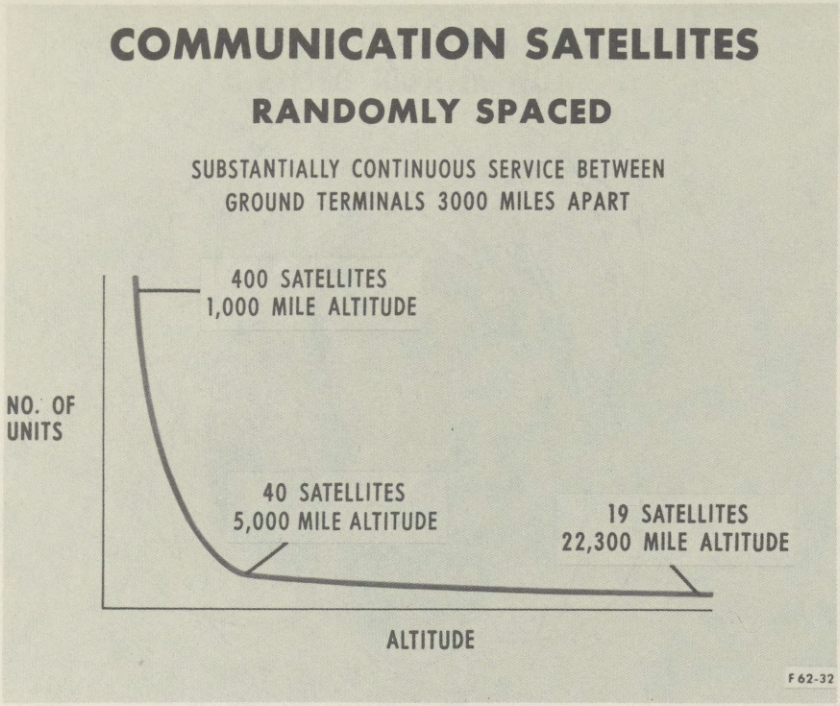

FIGURE 523

orbit. In actuality, if we were to orbit the satellites at 22,300 miles, and it were possible to exert effective precision control of their orbital velocity, we would not use randomly distributed satellites at all but would establish what is known as a synchronous satellite system.

The synchronous satellite system is illustrated on this chart (fig. 524). It is of great interest in communications work, because at the 22,300-mile altitude the spacecraft will remain fixed over a point on the Equator and it is only necessary to have three units up to provide for a basic worldwide coverage.

As I mentioned before in discussing the Aeros satellite, at this altitude a satellite will continuously see one-third or more of the Earth's surface. Consequently, if we can put a satellite up at such a longitude that it is visible to both America and Europe, continuous communications can take place between the two continents through just a single satellite.

Similarly, the establishment of another satellite further to the west will permit us to establish communications between the American Continent and Japan, Australia, and the Far East. A third satellite would round out the coverage for messages between Far East and the European and African nations. To realize this type of system, the same problems of providing a satisfactory attitude and position control system for the satellite that face the Aeros system must be met.

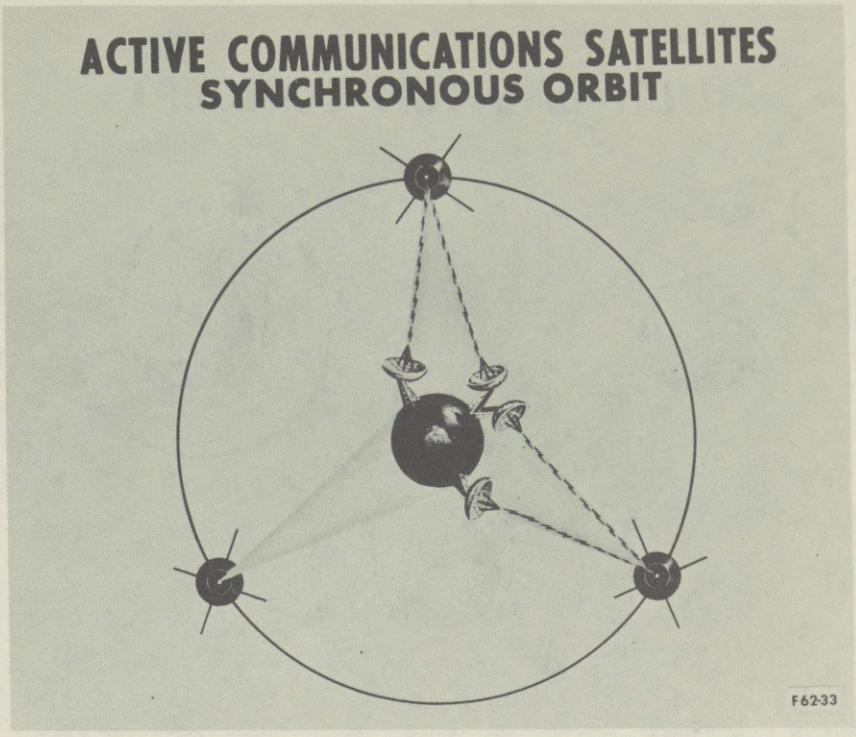

FIGURE 524

As it is by no means certain how long it will take to arrive at a control configuration of adequate reliability and precision, research on the synchronous system is being conducted parallel with that on low altitude systems. The DOD's Project Advent is directed to the development of a military communications satellite system of the synchronous orbit type.

I have already mentioned that a communications system with the satellites at low altitude will require a number of satellites in orbit simultaneously, and that spacecraft and launching costs are likely to accumulate rapidly with such a system.

We are studying techniques whereby we can launch a number of satellites into orbit from a single booster vehicle and have initiated work in this area which we expect will lead to a flight experiment within the next few years. The multilaunch concept, which is illustrated on this chart (fig. 525) calls for the insertion of a number of satellites into orbit from a single booster; the example shows three. The booster leaves the launching pad and goes into an elliptical orbit. This is on your left in this chart. This puts the spacecraft, which is carried by the launch vehicle and which has within it the three communications satellites, also into the elliptical orbit.

When the spacecraft carrying the three communications satellites reaches its apogee, the first of the communication satellites is ejected

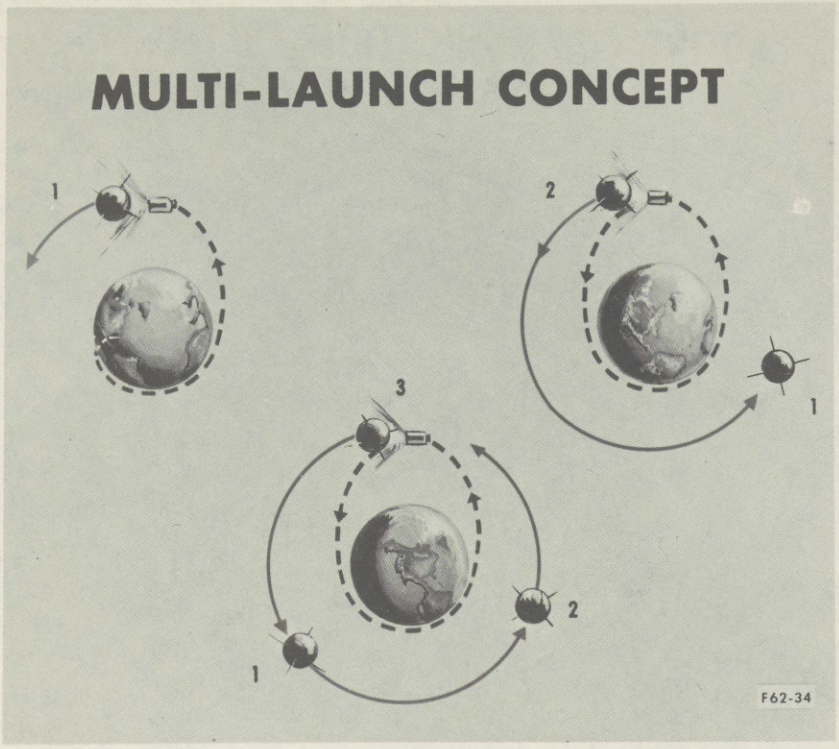

FIGURE 525

and an additional rocket propulsion unit attached to the satellite is fired. This satellite is therefore put into a circular orbit about the Earth because of the additional velocity that has been given to it.

At the same time, the spacecraft, now carrying two communications satellites, continues in its elliptical path as shown in the second part of the chart. It takes longer for the communications satellite to get around than it takes the spacecraft carrier and the next time the spacecraft reaches its apogee it is in the position shown in the chart relative to the first ejected satellite.

At this point the spacecraft unit again ejects a communications satellite which is also given sufficient additional velocity by an appropriate rocket for it to maintain a circular orbit. Once again the spacecraft goes around in its elliptical orbit. The third time around it again ejects a satellite and so it has, in the course of three of its elliptical orbits, put three communications satellites into circular orbit.

Obviously, this carrier is a fairly complex spacecraft, since it must maintain its attitude throughout the time of each injection, so that the injection of the individual communication satellites will take place into the preselected orbit. Also, it must either contain within itself sufficient sensory mechanisms to determine when apogee is reached, or it must carry a command unit to respond to signals from an appropriate ground control system.

This is needed to insure that the injection of the individual satellites will take place at the proper times. A procedure for multiple satellite injection seems to be a necessity, if we are to proceed with operational low-altitude communication satellite systems. While I have discussed the multilaunch concept in a general way and have indicated that it can be used with either active or passive low-altitude satellites, it is probable that its first test will be with passive satellites in the carrier.

NASA now has a contractor working on the initial design study for such a spacecraft. This study will define the controlling factors in the design of such a system. At the completion of the study, we intend to let a development contract for the construction of the first of these multilaunch spacecraft, most probably for the launching of three Echo II spheres. This activity has been designated Project Rebound.

Having discussed some of the reasons for the different orbital configurations proposed for communications satellites, let me now review the satellites themselves. Basically, the simplest of all the communication satellite techniques is the passive reflector—the radio mirror in the sky.

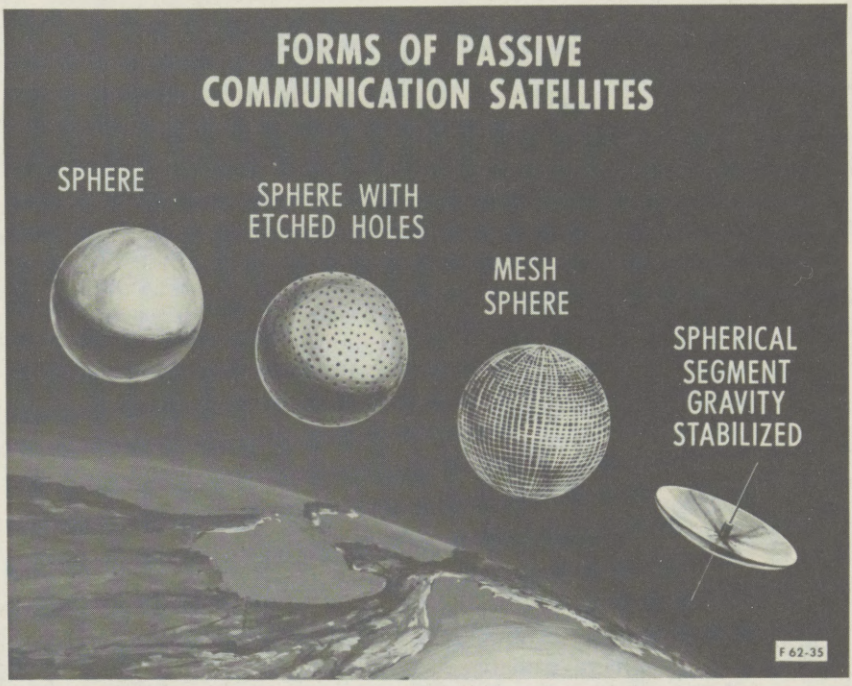

FIGURE 526

The passive reflector can take many forms and over the years a number of specific configurations have been suggested. At the present time NASA is investigating four of these configurations, as they appear to have the most promise for immediate application. These

four are shown on this chart (fig. 526). The first is the simple reflecting sphere. This, of course, has been tried already, in Project Echo, of which I will say more in a few moments.

As a followon to the simple sphere with a continuous surface, there are two varieties of surface structure which promise better overall performance so far as the passive reflector communications system is concerned. One of these is a sphere which has been lightened by etching holes in the metallic foil which constitutes the reflecting surface. A booklet of samples of the passive communications satellites material has been distributed to you.

Mrs. WEIS. They were given to us yesterday.

Mr. STOLLER. You gentlemen have them already?

Mr. DAVIS. Yes.

Mr. STOLLER. This reduces the weight and makes it possible to orbit a larger satellite, which will have correspondingly improved performance, with the same launch vehicle. An alternative method of reducing the weight of the sphere is to make the sphere of an appropriately sized wire mesh. We are not sure at this time which of the two techniques for lightening the sphere will actually prove to be the most effective.

As we wish to make the sphere very much larger insofar as its reflection characteristics are concerned, we are also looking into the possibilities of effectively accomplishing this without actually orbiting the whole sphere. In normal circumstances only the bottom face of the sphere, the portion facing the Earth, is actually used in reflecting the signal from one station to another. For this reason it seems rather unnecessary to orbit the upper portion, which serves no purpose in the communication satellite system.

The problem then becomes one of erecting, and then stabilizing, the spherical segment that is placed in orbit. With a complete sphere, regardless of stabilization there is always a lower surface available to act as a reflector. The spherical segment on the other hand, shown over on the right of the chart, if not provided with stabilization very often would not face in the proper direction.

As a result, the reflecting area that the antenna on the ground would see would often be very small, just as if you were looking at a shallow bowl, edge on, and it would not be possible to establish an effective transmission path. Therefore, to use the spherical segment, it is necessary that we add a stabilization device, which will hold the reflecting face toward the Earth. Studies of the spherical segment reflector and of the stabilizer will therefore be carried on together, because without the second, the first is of little use.

NASA's passive satellite program includes several flight tests. The properties of the sphere as a communications reflector are being evaluated in these flight tests. The first of these tests was the Echo I project. Most of you have probably seen Echo moving across the sky and may be interested to learn that we are continuing to measure its reflection characteristics to see if any more significant changes in its shape or surface conditions occur.

To refresh your memory, the left side of the next chart (fig. 527) shows that Echo was 100 feet in diameter, weighed 135 pounds and was constructed of Mylar plastic film five ten-thousandths of an inch in thickness.

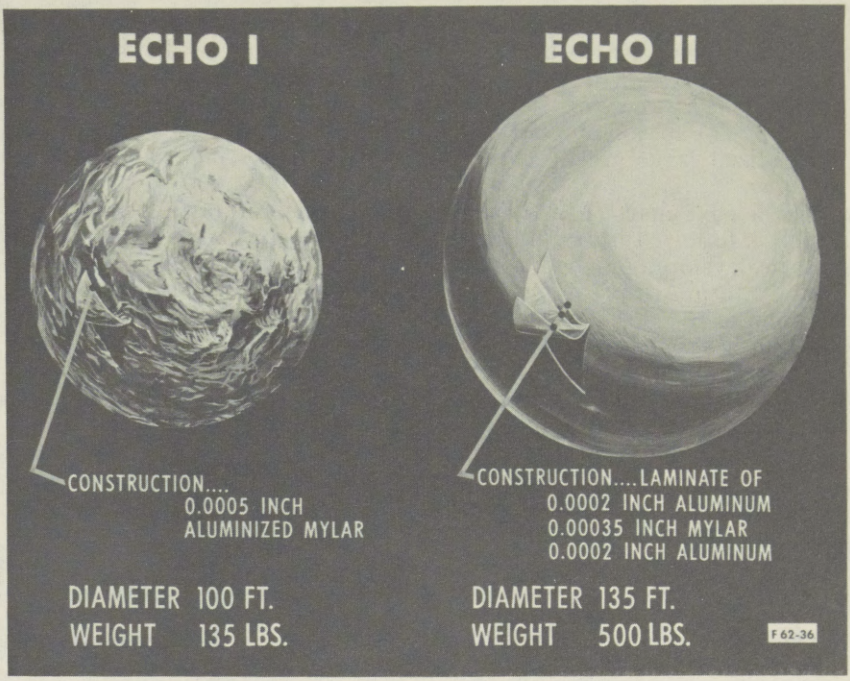

FIGURE 527

This is approximately five hundred millionths of an inch in thickness, about one quarter of the thickness of a human hair. The Mylar film was made reflective to radio waves by evaporating an aluminum film on to the plastic in a vacuum chamber. The aluminum was therefore extremely thin and contributed no structural strength to the sphere. After the Echo sphere had been in orbit for some time it exhibited a certain amount of wrinkling and there were small changes in its shape which are associated with the loss of the original volume of inflation gas. As the sphere wrinkled, it became less acceptable as a communications reflector, as a smooth surface is the best reflector.

Accordingly, we now have a new version, Echo II, which is shown on the right, a sphere which will maintain a fairly smooth surface characteristic. In designing this reflector, we took advantage of the availability of a large booster vehicle to make the sphere larger. It will now be 135 feet in diameter, and will weigh about 500 pounds.

In this case the sphere is made of a laminate, a combination of two layers of aluminum foil, and of Mylar, as is indicated on the chart. The total thickness will be seven hundred and fifty millionths of an inch. This is 50 percent thicker than Echo I, but it is appreciably stiffer because of the presence of the two layers of aluminum foil.

When this sphere is inflated and somewhat overpressured, it takes on a permanent set, and does not tend to resume its earlier wrinkled condition when the gas pressure drops. Consequently, it is our hope, that even though the inflation gas will not remain within the sphere

for any appreciable time, as a result of the punctures which will occur from micrometeorites, that the fairly smooth surface that is shown on the next chart (fig. 528) will be maintained for quite some time, and the effectiveness of the reflector will be demonstrable over a long period. The major objective of the Echo II project is to show that a rigidized structure of this type is a practical one as a passive reflector.

In the next chart (fig. 529) we show the very interesting procedure which is followed in testing the Echo II sphere. You may remember that in developing Echo I a number of tests were run at the Wallops Island Station to prove out the packing and inflation techniques for the sphere.

In the course of these tests we learned a great deal about the details of the techniques required to build the canister containing the sphere, how to inflate it, and how to make sure that it was not damaged in the inflation process. Our experience with Echo I convinced us that similar procedures must be followed with Echo II.

The first of the Echo II tests was conducted on January 15 of this year. The sphere ruptured during the test. After I describe the test sequence outlined on the chart I will show some of the films obtained in the first test.

In the case of Echo II, because the sphere alone without its container weighs about 500 pounds, a large rocket vehicle is needed to get the sphere to the proper altitude for inflation. A Thor rocket is used

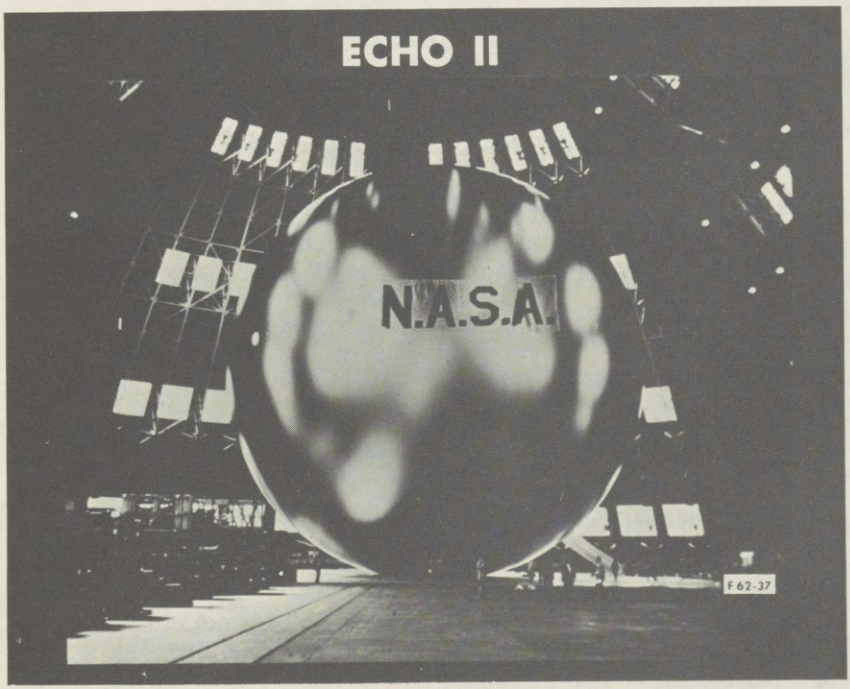

FIGURE 528

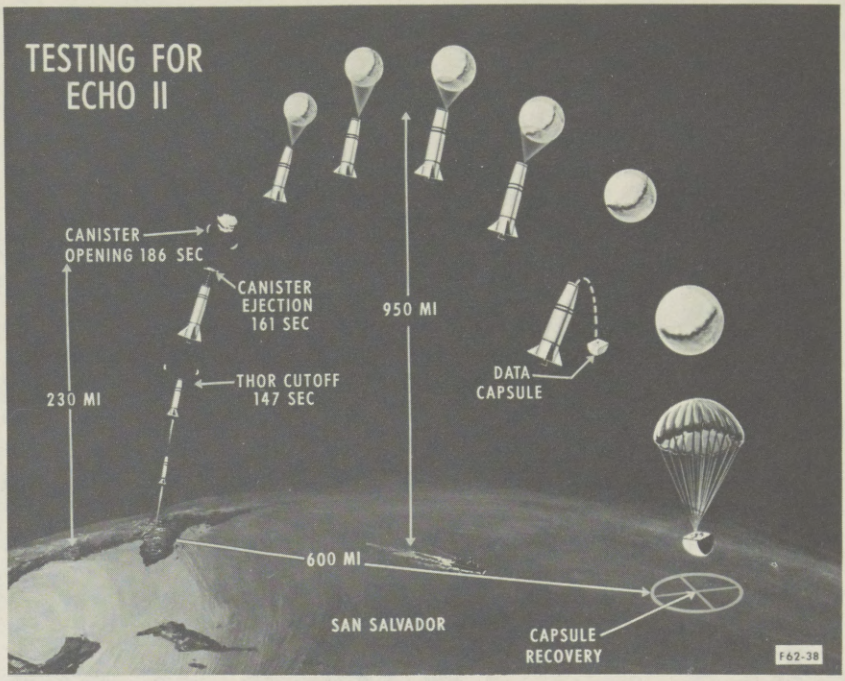

FIGURE 529

and launched at the Cape Canaveral range. At 147 seconds after lift-off, as shown on the chart, the shroud at the nose end of the vehicle is ejected, and at 161 seconds the canister containing the sphere is freed from the booster. At 186 seconds, the canister is opened by an explosive device, and the sphere, which has been folded within the container, starts to inflate as the solid, gas-generating material within it begins to evaporate.

As it inflates, we observe in detail how the process proceeds. For example, we want to know whether or not the loose metallic parts, which are in the vicinity after the separation of the canister halves, interfere with the unfolding of the sphere or perhaps even puncture it. The unfolding and inflation takes place at an altitude of over 200 miles.

It is obvious that it is not going to be possible to make the detailed observations with optical instruments back at the cape. Accordingly, we made provisions for the installation in the Thor vehicle of a television observation system and a camera observation system.

Both of these devices record continuously as the canister is ejected and opened and as the sphere inflates. The chart indicates that observations from the Thor vehicle continue as the sphere rapidly reaches its full inflation and then follows a ballistic trajectory to a peak altitude of 950 miles and then drops back to the terminal atmospheric reentry.

Both the Thor and the sphere are outside the atmosphere in this phase and they will maintain their relative positions as they move

along the trajectory. Before the vehicle gets too far back into the atmosphere on reentry a data capsule is ejected. This capsule contains the data recording camera and recovery aids and is lowered by parachute to the predicted impact area where a recovery team is waiting. At the same time the TV camera mounted in the Thor has been transmitting data to the cape, so that if by any chance we lose the data capsule, we will not lose all the information from the test flight.

Now, if I may have the film, please. The film which follows shows first the record of the television transmission from the Thor vehicle to the cape receiving station. You may have seen this at home TV. Then we show the run of film made by the camera within the data capsule. We show this twice so you will have a good chance to see the events as the capsule leaves the Thor vehicle and is opened, and the sphere starts to inflate and is ruptured on opening (fig. 530).

FIGURE 530

We also show the same piece of film from the camera run backwards. This happens to be a technique which over the period of years has been shown to be very profitable for showing motion picture films of mechanical events, because you can follow back to the origin better when you watch it in reverse. We have made this particular film in four different segments, accordingly. Now if we are ready for the film, please.

(At this point a film was shown to the subcommittee.)

The actual field of view of the two cameras is somewhat different. The lenses used on the television camera and the film camera were somewhat different. This is the canister leaving the Thor. I should point out that in the early Echo I tests we had to do all our observation from the beach, in effect. Echo I was tested at Wallops Island and at lower altitudes and it was easier to obtain observations but we certainly had no such detail as you see here.

You can see the difference in resolution and quality of the camera on board and the television.

The Thor vehicle itself is pushed back from the canister with some small rockets at the time of separation. There is the big rip.

Mrs. WEIS. It did rupture, really, didn't it?

Mr. STOLLER. Yes.

Now the fact that it ruptured almost immediately on the canister opening is an indication there is probably an excess pressure within the canister. This tends to shock the sphere out into the open state and rips it. So one of the major changes in the next test will be to reduce the internal canister pressure.

You see there is a piece of loose material that went across there. I wonder if you noticed it. This is thought to be one of the instrument compartment covers from the rocket itself. Our analysis indicated it would not have flown into the sphere to puncture it as such. It was not on such a trajectory.

When we first saw the films, this was quite a worry as to whether this was the trouble.

Mrs. WEIS. Did it come as a surprise to you?

Mr. STOLLER. I think it came as a disappointment, a surprise and a disappointment. We instrument to make sure that we can get the most information back in case we have this kind of trouble, because if we just depended on successes to prove that everything was all right, when we would have such a failure we would have no way to move in correcting it on a logical basis.

Mr. ROUSH. Why does the camera remain so well oriented? It is very stable.

Mr. STOLLER. The canister itself is separated from the Thor vehicle by a device which makes it possible to move forward quite slowly, from the spring force, and doesn't tend to give it any tip or tilt. Then the rocket itself is pushed backward by some retrorockets—out of the way to get it far enough away. It was easier to push the rocket back than to try to impart the major velocity to the canister itself.

Mr. ROUSH. The rocket in the camera was moving away.

Mr. STOLLER. That is right. Now at the same time the rocket system was modified to provide stabilization during this portion of its life. Ordinarily the Thor rocket would not have a stabilizer in it to maintain it on the same attitude, to insure that the camera would always be pointing at the sphere in front of it. But this particular Thor was modified with an extra element of control systems so that after ejection of the sphere it maintained its attitude with respect to the Earth so it would in effect continuously be pointing the camera at the sphere in front of it.

Mr. HECHLER. What makes you so sure in your analysis that this thing that came across didn't cause the rip?

Mr. STOLLER. Well, they can't tell the size from the analysis, because you can't find range in such a picture, only angular motions. But if you take the timing and the angular motions and the change in size, that gives you a rate of change of range, not absolute range, you can compute trajectory with respect to the canister and say this would not have gone through the place where the sphere was. That is about the only way we can tell.

I would like to turn to the active repeater program. The general configuration of an active repeater is shown on this chart (fig. 531).

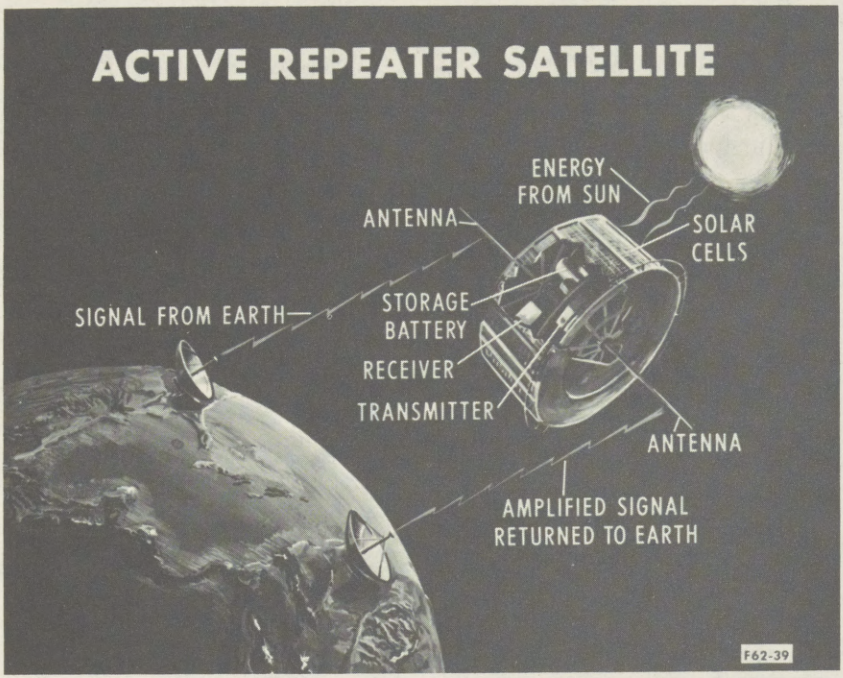

FIGURE 531

The satellite contains storage batteries which are kept charged by the external solar cells. These are used to power the receiver and the transmitter. An antenna system consisting of two units, one for the earth-to-satellite link and a second for the return link, is also necessary.

Ground terminals with steerable, high gain antennas and associated transmitters and receivers are needed to complete a point-to-point channel. With this statement of the general concept of the active repeater, let us look at the specific versions in NASA communications systems program.

The Relay developmental spacecraft is shown in this chart (fig. 532). This is the test model which was built by the Radio Corp. of America, the prime contractor for Relay. An artists conception of the Relay satellite in orbit is shown on this chart (fig. 533). The

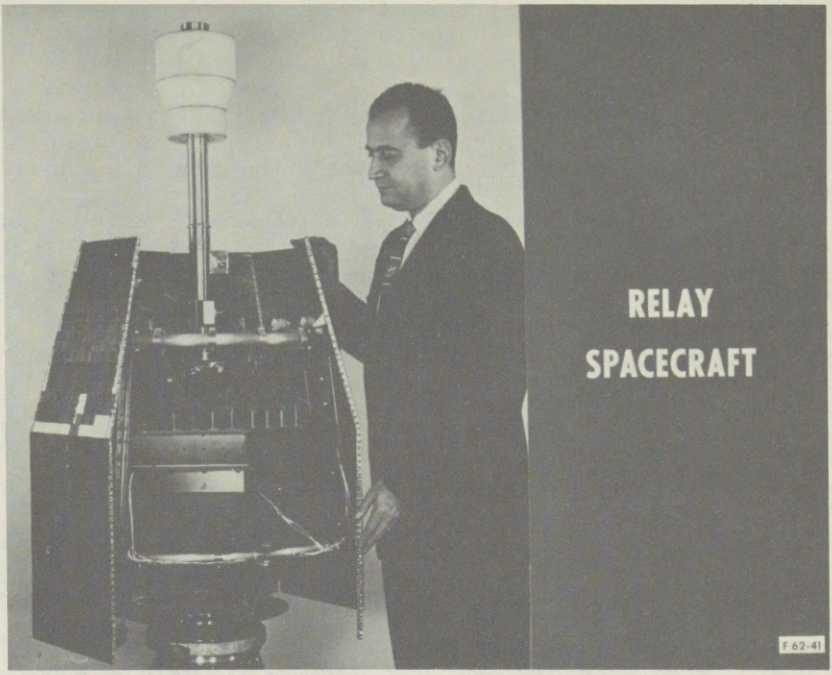

FIGURE 532

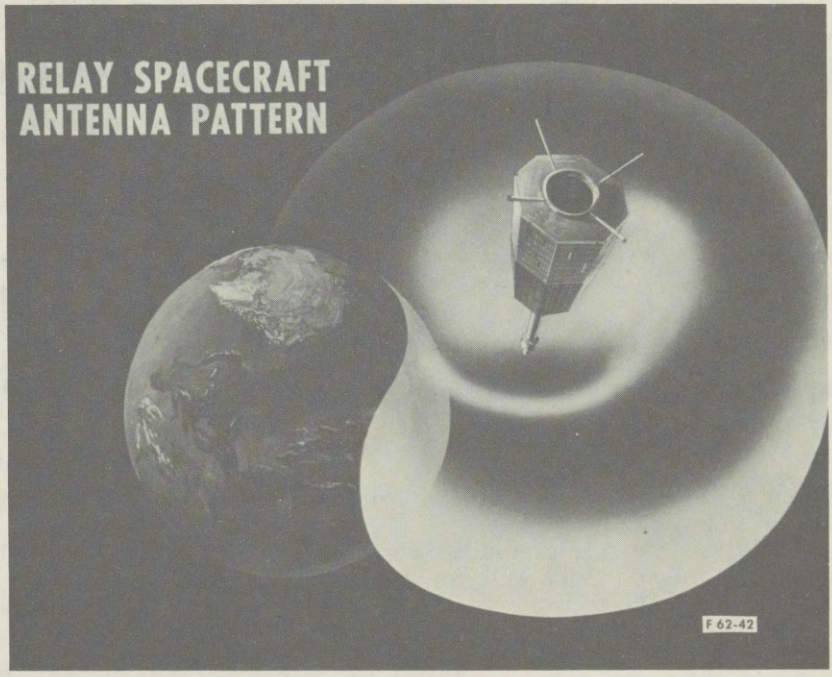

FIGURE 533

shaded area which you see here indicates the antenna pattern of the Relay satellite. Notice that it is doughnutlike in form so that even though Relay spins on its long axis, some of its energy will be radiated toward the earth.

A magnetic attitude coil similar to that used in TIROS will be used periodically to adjust the orientation of this axis to a favorable position with respect to the ground stations cooperating in the Relay experiment.

NASA is cooperating with the American Telephone & Telegraph Co. on the Telstar project. This project was initiated by A.T. & T. and also has as its objective the investigation, in orbital flight, of the technical and operational problems of transmission of wide-band communications by an active communications satellite.

The Telstar satellite which is being built by the Bell Telephone Laboratories is of a different configuration, and has a number of technical details which differ from those of the Relay satellite. In the chart (fig. 534) we have a photograph showing the configuration of

FIGURE 534

Telstar. You notice it is quite a bit different in basic structure than that of Relay.

The division of responsibilities for the work that is being carried on by NASA and A.T. & T. for Telstar is indicated on this chart (fig. 535). NASA is responsible for the establishment of the environmental test specifications which the spacecraft will have to meet be-

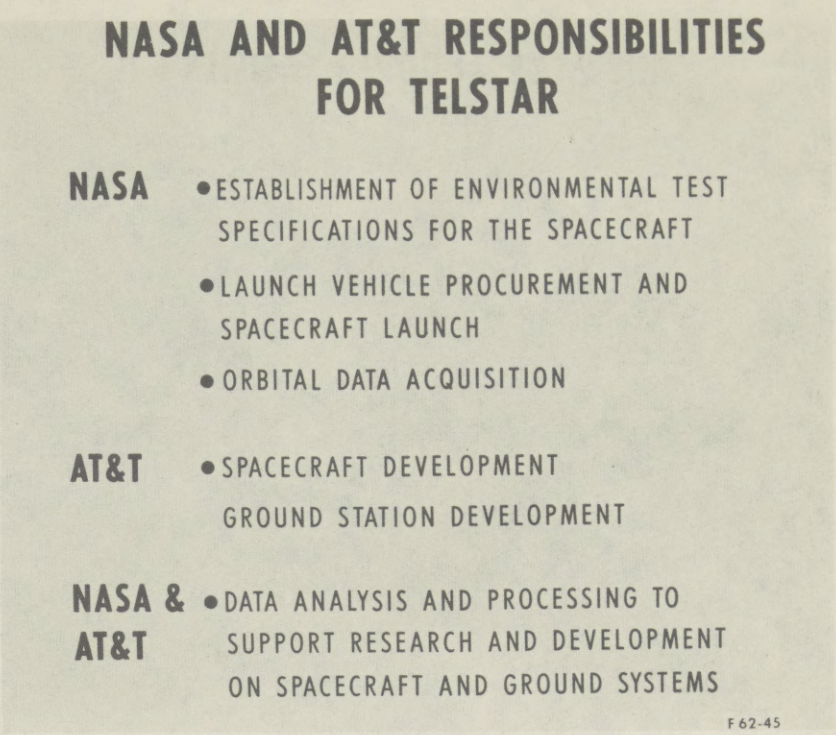

FIGURE 535

fore it is launched. NASA will procure the launch vehicle and launch the spacecraft, and will undertake the orbital data acquisition necessary for the operation of the ground tracking stations.

A.T. & T. is responsible for both spacecraft development and ground station development. Both NASA and A.T. & T. will undertake data analysis and processing so as to support the development of future spacecraft and ground systems. The data resulting from this project will be exchanged without any constraints between the two organizations and will also be available to others in this country and in the international community.

The telephone company is building at Andover, Maine a very interesting facility for its ground systems support of the communications satellite. This chart (fig. 536) gives an artist's view of the facility which is now under construction at that location. You will note that a large horn-type antenna is contained within a flexible radome.

The radome is to be 210 feet in diameter and is maintained in shape by air pressure from a set of blowers located in the service building, which is down at the bottom of the chart. The small pressure difference that the blowers maintain is sufficient to keep the radome up.

Should there be a heavy wind, or a dangerous storm, it is intended to increase the internal pressure on the radome somewhat, to make it more rigid and so resist the deforming forces of the winds. The radome should be installed in the near future. At the present time,

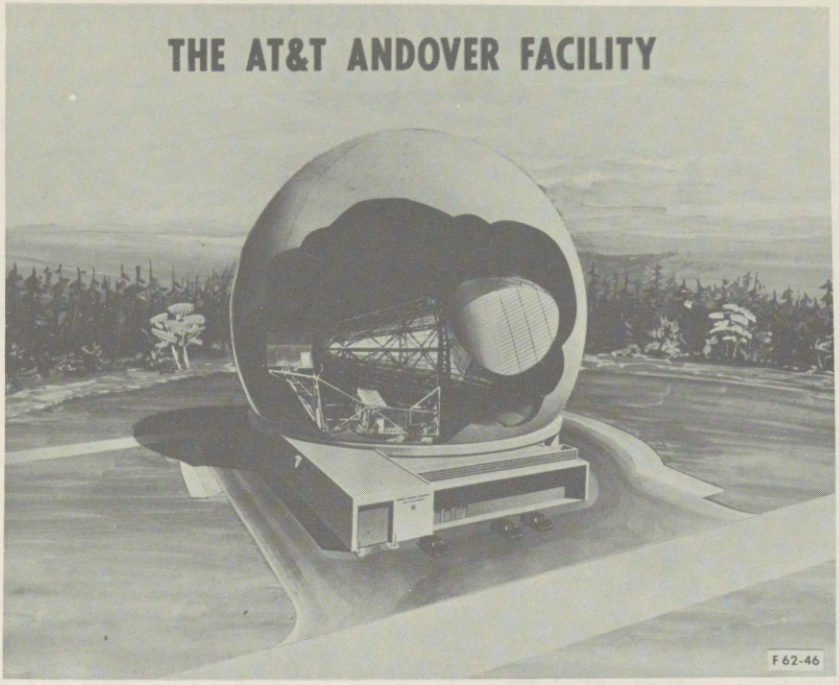

FIGURE 536

the station is being built under a temporary inflated construction shelter. A photograph of the site in its present stage is shown here on the chart (fig. 537). I could modify this. This was taken before the winter storms, so it is at least a few months old. You can see the large inflated shelter down at the end and the control system for the building is down at the bottom. The site is admirably located for communication work as it is surrounded by a ring of mountains which shield it from external manmade disturbances to a great extent and yet are not high enough to prevent the central antenna from seeing satellites close to the horizon.

NASA will use this facility on a contract basis for its Relay program. NASA will also provide for its own purposes, two smaller antennas and ground communication stations which will be used in checking out the Relay system performance. These will probably be located at the Goldstone facility in the Mohave Desert of California and at the Wallops Station on the Eastern Shore of Virginia.

Both Relay and Telstar have already given rise to a great deal of international interest and NASA has entered into agreements for experimental work with the Relay satellite with Great Britain, France, Germany, and Brazil. Negotiations are near completion with Italy. Discussions with other countries have taken place, and it is expected that additional agreements will eventually result.

A joint planning committee for the ground station activities related to Relay, and to Telstar as well, has been established and has had a

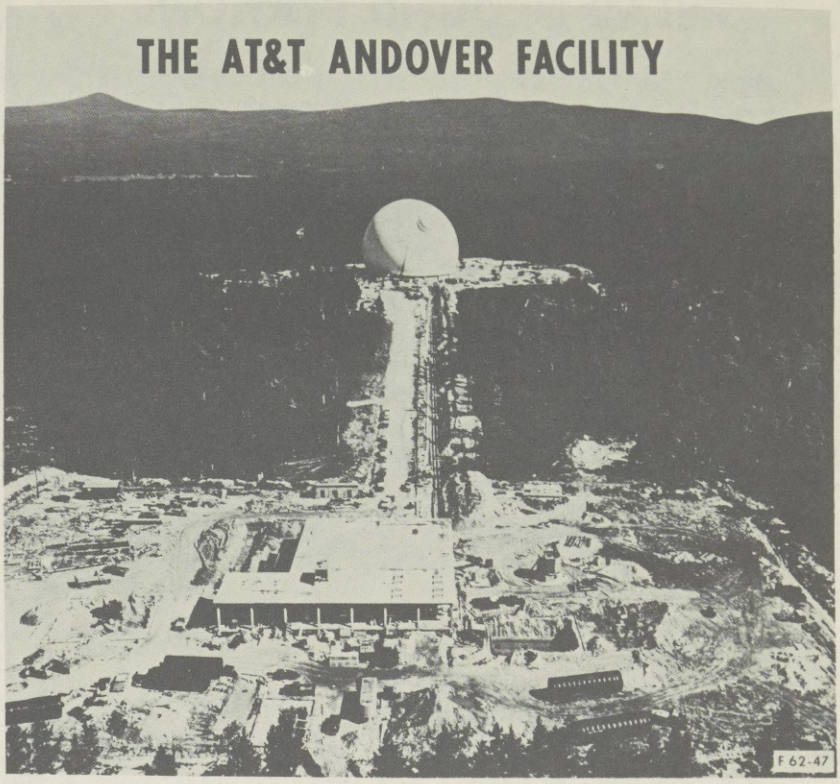

FIGURE 537

most successful meeting here in Washington early in December. Last week this committee was holding its second meeting in England. I haven't heard the reports but I presume they made out fairly well, too. At present, the stations which are preparing for the Relay operations are shown on the chart (fig. 538). Those in Maine, England, and France will also take part in Telstar tests.

The third active satellite project in our present program is Syncom, which is being built by the Hughes Aircraft Co. (fig. 539)—this is NASA's initial effort directed to the development of the synchronous satellite. Its objectives are to provide experience in using communications satellites in a 24-hour orbit at the earliest possible time; to develop the capability of launching satellites into the 24-hour orbit using existing launch vehicles plus additional "apogee kick" rockets and to test the life of communications satellites components at the 24-hour orbit altitude. The spacecraft itself is shown in this artist's conception chart (fig. 540).

You can see the conventional components, that is the solar cells for power supply, the antennas, and the drumlike structure. The interesting part here is the addition to the spacecraft of the apogee rocket motor which is inside the spacecraft and the nozzle down at the bottom, the control jets for orientation and positioning, and solar sensors.

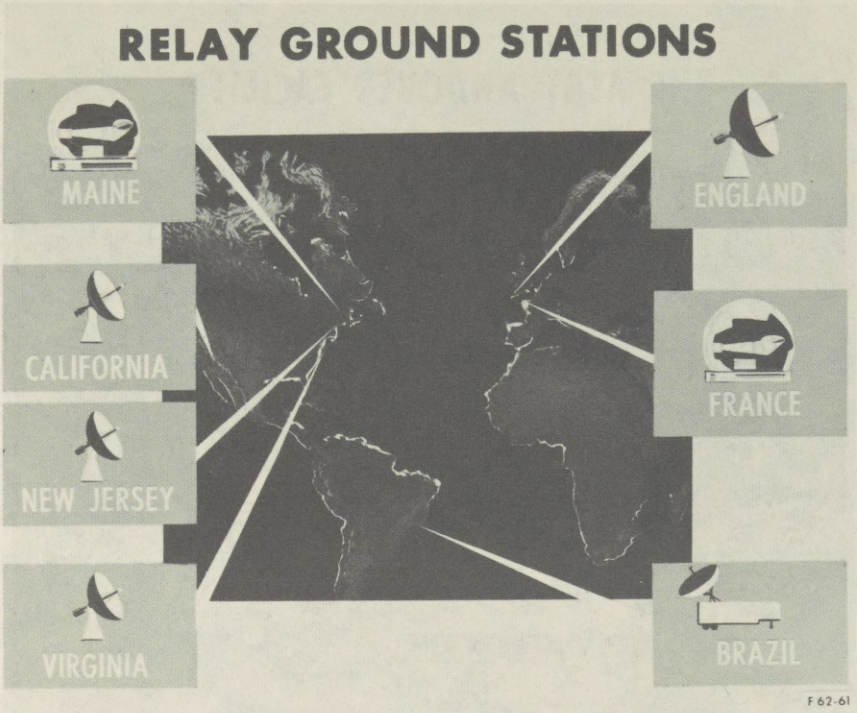

FIGURE 538

SYNCOM OBJECTIVES

- PROVIDE EXPERIENCE IN SYNCHRONOUS ORBIT AT EARLIEST TIME
- DEVELOP CAPABILITY FOR LAUNCHING INTO 24-HOUR ORBIT WITH "APOGEE KICK" TECHNIQUE
- TEST COMPONENTS LIFE AT 24-HOUR ORBIT ALTITUDE

FIGURE 539

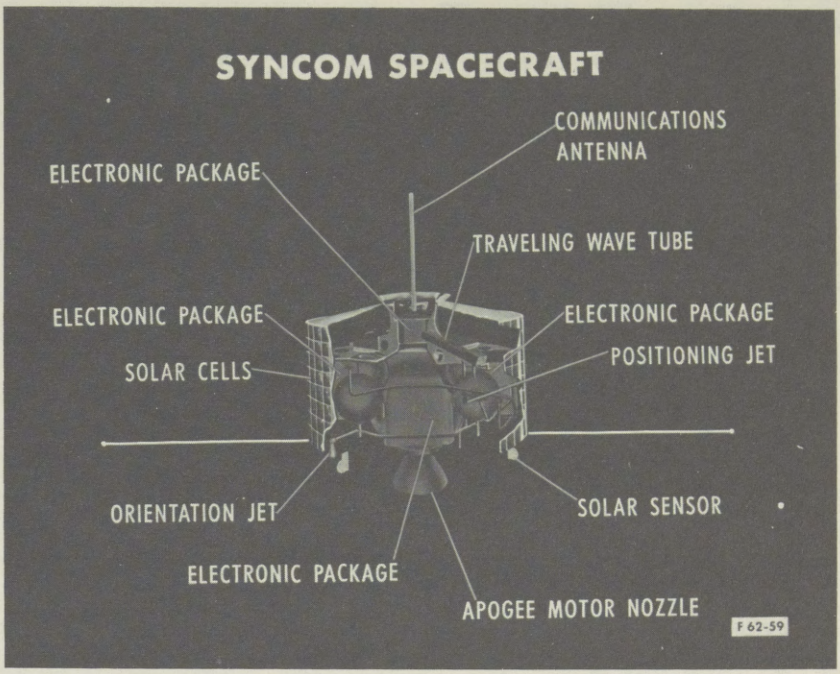

FIGURE 540

The traveling wave tube is a particular type of electronic tube used in the transmitter of the three active satellites because of its excellent performance characteristics. It is particularly useful when a wide range of frequencies is to be amplified as is the case here.

Now, with the help of the charts which follow I will try to outline for you the way in which it is intended to get the Syncom satellite into a satisfactory synchronous stationary orbit at an altitude of 22,300 miles (fig. 541). The initial projection of the satellite will be from the cape into a very highly elliptic orbit. The planned apogee of this elliptic orbit will be at 22,300 miles. As a result when the satellite reaches the apogee altitude, it will be at the desired altitude for synchronous rotation with the Earth. However, it will not have had enough energy imparted to it to stay at that altitude and the internal apogee rocket must be fired to add the energy required. The small smoke trail you see in the upper part of the diagram represents the apogee rocket.

Since the launching will take place from the cape, we can launch directly only into an inclined orbit, as a launch into an equatorial orbit would require an extra velocity impulse at an angle to the original direction of motion. This is one of the constraints resulting from limited vehicle performance which we must accept at this time.

When the satellite is separated from the lower stages of the Delta vehicle, it is spun about its axis and so it is rotating much as a gyroscope would rotate, as it comes up in altitude. The gyroscopic effect

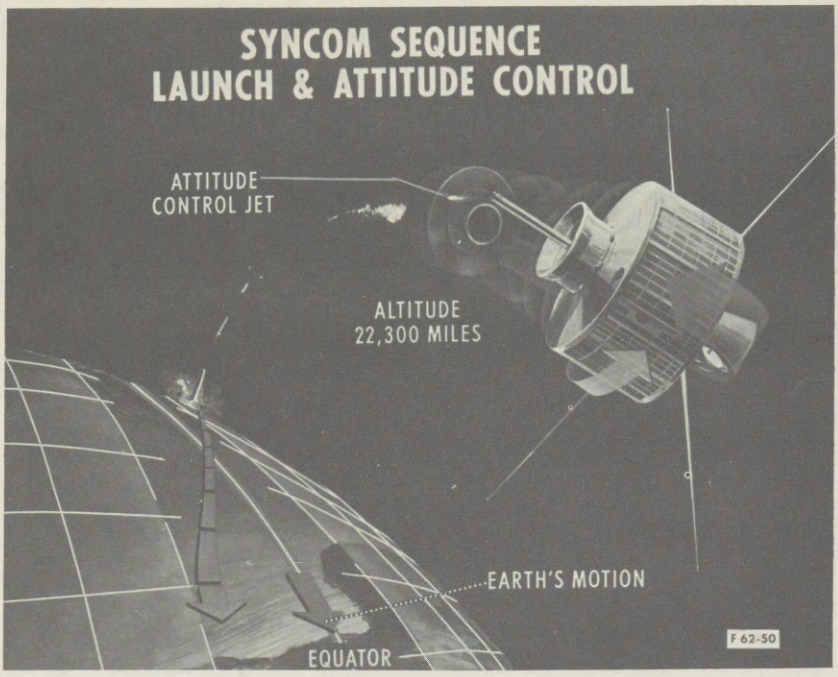

FIGURE 541

holds the axis of the satellite in the attitude with which it was separated from the Delta booster, so that when through either ground control or by proper timing, the apogee rocket is fired, the satellite will be injected into a circular orbit. At this time the attitude control jet in the end of the satellite can be actuated by ground control to provide a force to turn the satellite. The result of this operation is indicated at the end of the chart. The satellite then appears to be rotating on its axis like a wheel as it moves in its orbit.

On the next chart (fig. 542) we see the satellite in its orbit above the Earth. I have already remarked that the orbit is inclined. It is more than likely that the satellite's speed in orbit will be somewhat too fast or too slow for an exact match with the Earth's rotation and it will tend to progress or retrogress around the Earth.

A result of the inclination of the orbit is then to make the point below the satellite trace a path resembling a series of connected figure 8's as shown here in the chart. An additional element of ground control is then available.

Data from the solar sensor is transmitted to the ground and there a control signal is computed which will activate the positioning gas jet in the side of the satellite. This force will slow the satellite down or speed it up in its orbit depending on the direction in which the jet is pointed when it is operated. This controllable jet can be used to reposition the satellite from its original injection point close to the African coast, to the location somewhere over the Atlantic Ocean, where we would like to have it for communications experiments.

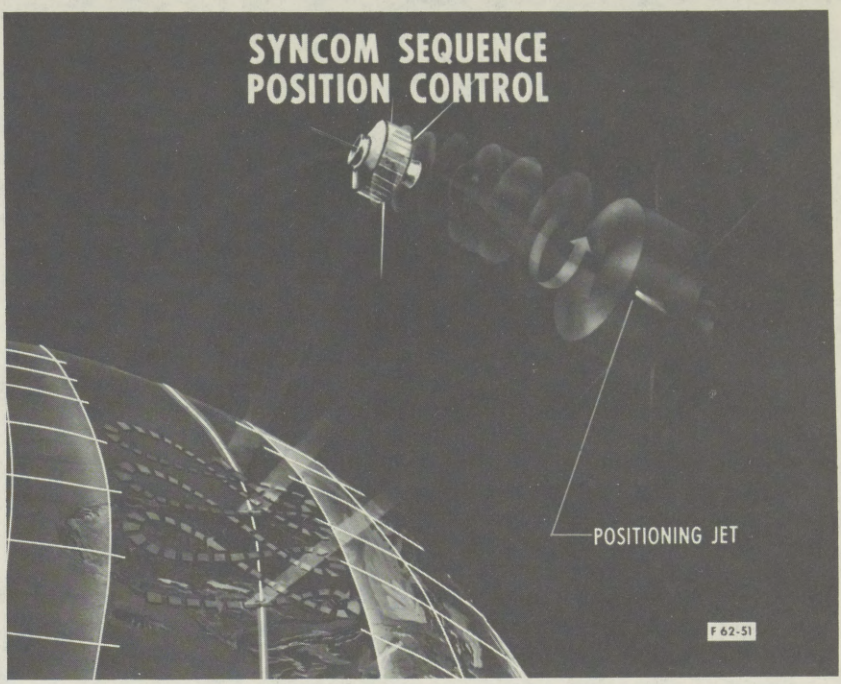

FIGURE 542

The next chart illustrates the final position of the Syncom satellite (fig. 543). It will still be rotating about its axis and will be moving back and forth in a figure 8 pattern about 30° above and below the Equator.

The antenna pattern of Syncom is indicated on the right-hand portion of the chart. It resembles that of Relay in that it is uniform around the satellite axis and so the rotation of the satellite will not affect its performance. With this antenna pattern we should achieve effective coverage of almost all that portion of the hemisphere which can be seen from the satellite.

NASA and the Department of Defense both have responsibilities in the Syncom project. These are shown on the next chart (fig. 544). NASA is responsible for the spacecraft development and launching, and for the orbital data acquisition and processing. The Department of Defense is responsible for the development of transportable ground stations for use with Syncom.

As you know, the DOD has had underway for some time the development program for the Advent communication satellite. This too is a communications satellite intended for operation in synchronous orbit, but one which is to meet the specific requirements of the military communications services.

Much experience has already been accumulated within the Department of Defense on ground station design for this type of service. It was possible to take advantage of this experience by arranging with

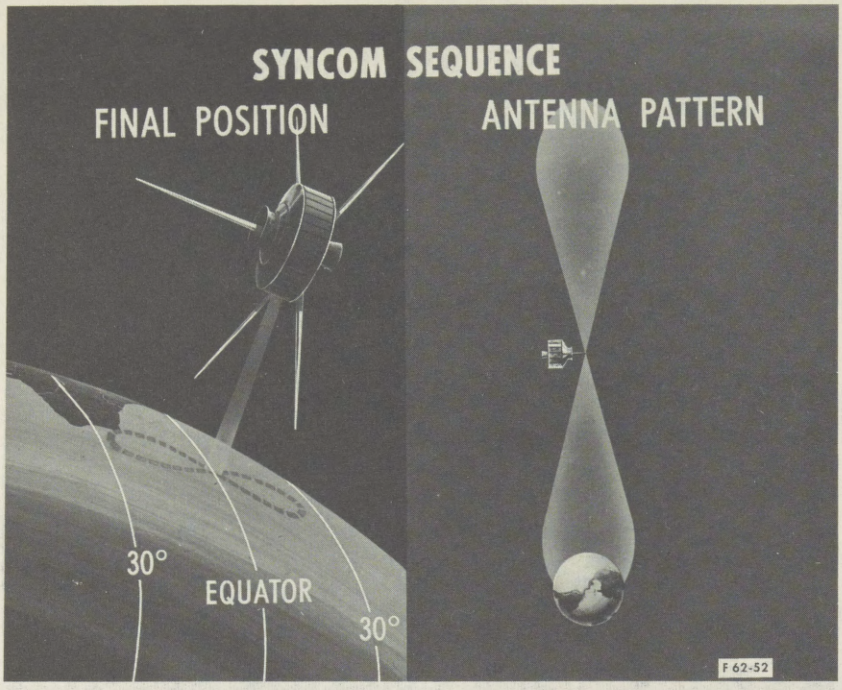

FIGURE 543

NASA AND DOD RESPONSIBILITIES FOR SYNCOM

NASA	• SPACECRAFT DEVELOPMENT AND LAUNCH
	• ORBITAL DATA ACQUISITION AND PROCESSING
DOD	• GROUND STATION DEVELOPMENT
NASA & DOD	• DATA ANALYSIS AND PROCESSING TO SUPPORT RESEARCH AND DEVELOPMENT ON SPACECRAFT AND GROUND SYSTEMS

FIGURE 544

the Department of Defense for a supporting effort for the Syncon project.

Both NASA and the DOD will undertake data analysis and processing to support further research and development on both the spacecraft and the ground systems for synchronous satellites.

We are now formulating and firming up the advanced research and development for the communication systems which will follow the first phase of the passive and active satellite project developments I have just discussed.

The chart (fig. 545) lists several major areas in the general category of advanced research and development.

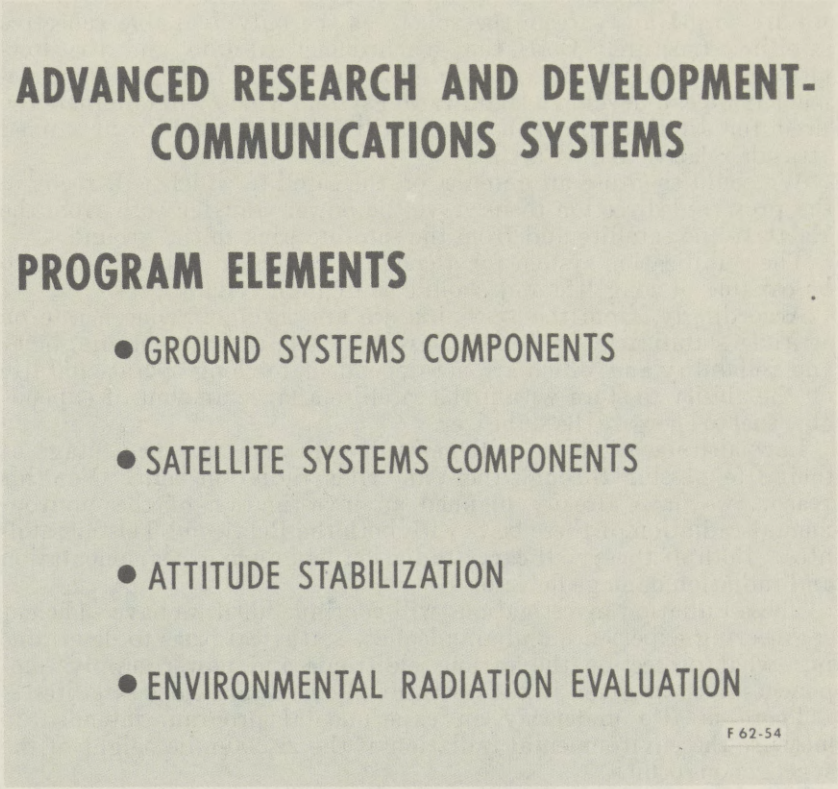

FIGURE 545

Studies of ground systems components, satellite systems components, attitude stabilization, and an evaluation of the effects of the orbital environmental radiation are underway.

There are several distinct satellite systems techniques which may be of eventual use which will require evaluation in arriving at an operational communication's satellite system.

To realize any one of these major systems configurations, a number of specific technological investigations will be required. In considering

ground systems components, detector units, receiver circuits, transmitters, modulators, and antennas are of primary concern.

Antenna tracking and pointing techniques and decisions as to whether horns or parabolas are the best type of antenna to use for a specific test will depend on the results of detailed research investigations.

Insofar as the satellite systems are concerned, it is obvious that the testing of particular receiving and transmitting systems, and power supply arrangements will be required.

Studies of the configurations needed for redundancies in spaceborne systems in order to develop the reliability required for long operational life will have to be continued.

Attitude stabilization for passive satellites is vitally important if we are to get away from the sphere as the only available reflective satellite structure. Both the synchronous satellite and the low-altitude satellite will also show a great deal of performance improvement if we can develop a stabilization system which will eliminate the need for satellite spin and which will hold the satellite in a fixed attitude relative to the Earth.

We could then use an antenna on the satellite which will focus in the preferred direction to improve the power transfer both from the Earth to the satellite and from the satellite back to the ground.

The stabilization system for a communication satellite will have to be capable of long life and should be of high reliability.

Accordingly, from the very first we are trying to concentrate on attitude stabilization system designs which have inherent simplicity and reliability and which are not dependent for long operational life on the ability to store within the satellite a large amount of expendable fuel to energize the stabilizer.

Low altitude satellites will generally spend a fair percentage of their life passing through the Van Allen radiation belts. For this reason, we have already planned an investigation of the environmental radiation of these belts with both the Relay and Telstar satellites. Both of these will carry radiation monitoring instrumentation and radiation damage detectors.

These radiation investigations will continue until we have sufficient engineering experience and an adequate statistical basis to determine just what protection the various electronic and power supply components must be given in the operational communications satellites.

There is also underway an experimental program intended to measure the environmental radiation at the 22,300-mile height of the synchronous orbit.

This investigation will make use of a satellite very similar to that which was flown in the space sciences program as Explorer XII, but with the specific instruments and their ranges adjusted for the constant altitude orbit.

This satellite is to be orbited on a developmental Centaur vehicle in the course of that vehicle's test sequence. In this connection, NASA also will have the benefit of another set of data which should be relevant to our problem from the Arents satellite of the Department of Defense.

This satellite is also to be flown on a development Centaur, in this case in support of the DOD Advent Project. An exchange of what-

ever radiation data may be collected is of course a part of both plans.

The steps proposed for the advanced satellite flight program which will follow on beyond Relay and Syncom are shown on the next two charts. Performance improvement of the active satellite systems is the primary objective (fig. 546).

ACTIVE COMMUNICATIONS SATELLITES SYSTEMS IMPROVEMENT

LOW ALTITUDE SYSTEMS		SYNCHRONOUS SYSTEMS	
RELAY	ADVANCED	SYNCOM	ADVANCED
DELTA VEHICLE	ATLAS-AGENA B VEHICLE	DELTA VEHICLE	ATLAS-AGENA B VEHICLE
150 LBS.	600 LBS.	55 LBS.	500 LBS.
700 TO 3,000 MI. ELLIPTICAL ORBIT	UP TO 12,000 MI. CIRCULAR ORBIT	22,300 MI. INCLINED ORBIT	22,300 MI. EQUATORIAL ORBIT

FIGURE 546

The first step in this direction is to take advantage of the growth that can come about as we move to larger launch vehicles. This is illustrated on this chart—Relay uses the Delta vehicle.

Delta will put a Relay satellite weighing 150 pounds into a elliptical orbit with 700-mile perigee and 3,000-mile apogee. With this type of orbit most of the data transmission can take place only when the 3,000-mile apogee is in the proper position with respect to the two terminal ground stations.

The advanced low altitude satellite we are proposing will use a larger vehicle, the Atlas-Agena B. Here we can expect to put a 600-pound spacecraft into a circular orbit with an altitude of over 6,000 miles and perhaps as high as 12,000 miles. The advantages to be gained from these weight and orbit changes will be shown on the next chart.

Insofar as the synchronous systems are concerned, Syncom also uses a Delta as a launch vehicle. Here the satellite weight including the apogee rocket is 125 pounds, of which the communications package itself is 55 pounds.

The Delta plus apogee rocket combination can be used to get the 55 pounds into a 22,300-mile altitude inclined orbit. By changing to

the Atlas-Agena B we expect to bring the weight of the communications package for the advanced system up to about 500 pounds and at the same time should have enough booster performance to get truly equatorial orbit at 22,300 miles altitude.

If we now look at the second chart (fig. 547) we find that the Relay satellite is designed to handle a single TV channel Relay is spin stabilized and with the presently planned orbital altitude, only about 10 percent of the time in orbit is usable for communications between the two major terminal points.

Also, Relay is essentially a two-station system. By two station, I mean that the system capacity is limited because communications can be passed back and forth only between a single pair of stations.

Actually, a number of telephone conversations could take place at the same time but they all would have to be routed between the two terminals that were selected for the given operating period.

As we develop more advanced techniques for application to the low altitude system, and change to the larger launch vehicle, it is our objective to bring the capability of the system to what is shown in the right-hand column. That is, we hope to increase the capacity to four TV channels or its equivalent in telephone channels.

We would like to have the satellite Earth oriented so as to take advantage of the improved performance of directed antennas.

By increasing the altitude in orbit by several thousands of miles the time available for transmission between a pair of typical stations should increase to 25 percent, and we would like to rework the elec-

ACTIVE COMMUNICATIONS SATELLITES
SYSTEMS IMPROVEMENT

LOW ALTITUDE SYSTEMS		SYNCHRONOUS SYSTEMS	
RELAY	ADVANCED	SYNCOM	ADVANCED
1 TV CHANNEL	4 TV CHANNELS	1 TELEPHONE CHANNEL	4 TV CHANNELS
SPIN STABILIZED	EARTH ORIENTED	INCLINED ORBIT	EQUATORIAL ORBIT
AVAILABLE 10% OF THE TIME	AVAILABLE 25% OF THE TIME	AVAILABLE 75% OF THE TIME	AVAILABLE 100% OF THE TIME
2-STATION SYSTEM	MANY-STATION SYSTEM	2-STATION SYSTEM	MANY-STATION SYSTEM

F62-56

FIGURE 547

tronic design of the satellite and the ground stations so that many stations can simultaneously have access to the satellite and so can then transmit to any of the other stations with a minimum of constraints.

The Syncom plans now call for a capability of transmitting at least one telephone channel. This restriction on message-handling capacity is a result of having to work with a very lightweight satellite.

We therefore are concentrating our experimental effort on getting the satellite into the synchronous orbit and on testing out orientation and position control techniques.

Syncom will be launched into an inclined orbit, as I have noted before, and will be available for transmission between stations only about 75 percent of the time, chiefly because of its motion to either side of the Equator. It, too, is a two-station system.

An advanced synchronous system should increase the message-handling capacity to four TV channels. With increased vehicle performance, we should obtain the true equatorial orbit, and the satellite should be available for 100 percent of the time.

As in the low altitude system, the system design will be modified to provide for multiple-station access to the satellite.

The schedule for communications satellite flights is shown on this chart (fig. 548). The second test for the Echo II sphere will take place in a few months. If this operation is successful, the orbital Echo flight will follow.

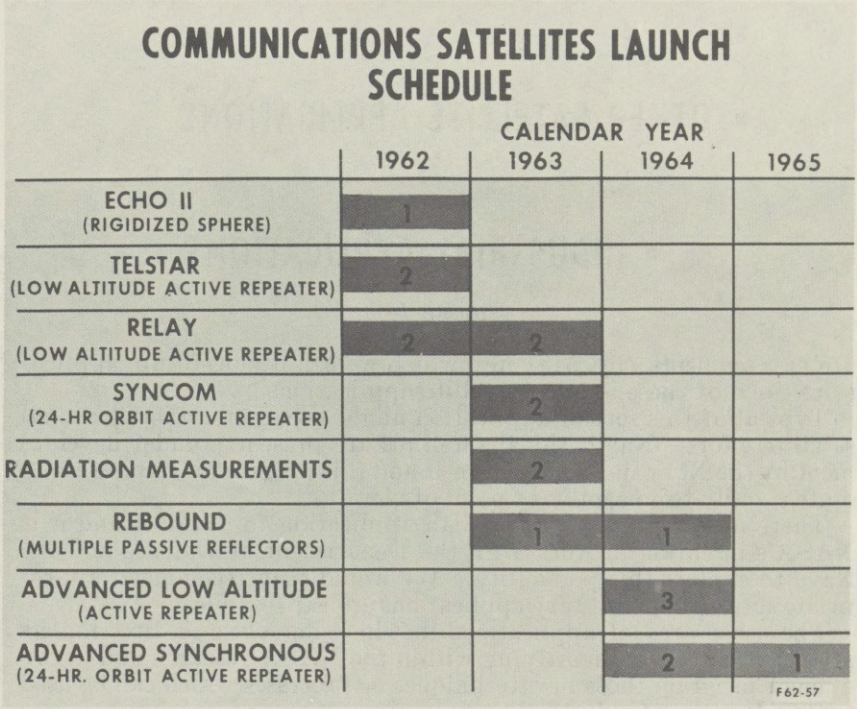

FIGURE 548

The Telstar flight program for the American Telephone & Telegraph Co. is to be initiated later this spring with a followon flight scheduled for later in the year.

The Relay program should find its first flight taking place this fall and it, too, has followons, which in this case run on into next year.

The first launching of the Syncom program should take place at the beginning of next year. The second Syncom test is also planned for 1963.

The radiation measurements satellites to be flown on the Centaur development vehicles are scheduled for 1963.

The tests of the multilaunch concept, using passive reflectors of the Echo II design, known as Project Rebound, are for 1963 and 1964.

The advanced research and development flights of which I have spoken are to test the intermediate altitude and the synchronous satellite component and system developments. These should make their first flights late in 1964 and will continue into 1965.

Before concluding, I would like to say a few words about the area of future applications that was indicated on my first chart. There

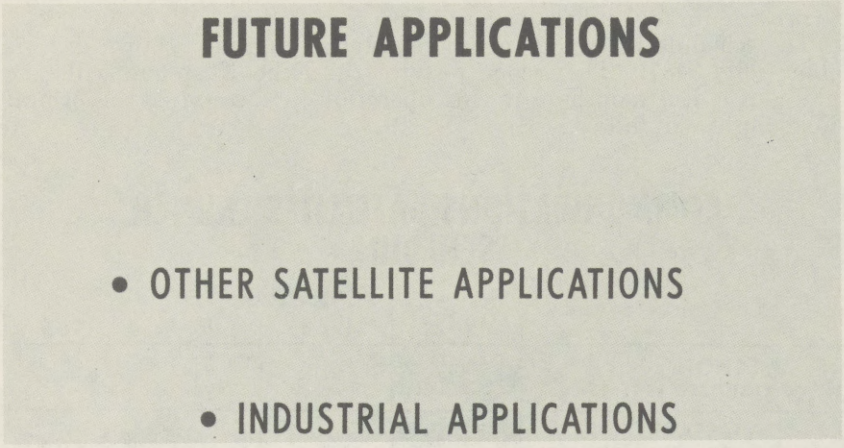

FIGURE 549

are two segments (fig. 549) into which we can divide future applications—one of these is other satellite applications.

Typical of this sort of application might be a civilian navigational satellite effort. Navigational satellites are presently under development by the Navy in Project Transit and this program is coming along quite rapidly from a military point of view.

There may be an area of civilian application for Transit and it is NASA's intention to work with the Department of Defense and the Navy to explore this possibility. We would then recommend appropriate action if nonmilitary applications appear feasible.

The other area of applications to which our office is directing its attention is that of identifying within the NASA research and development program those new techniques or processes which can be used by a wide range of industrial organizations.

Many industrial firms normally will not be exposed to the new developments in space technology in the course of their routine operations. However, NASA's program will be generating much in the way of new technical capability which all commercial organizations should have an opportunity to evaluate and use.

This chart (fig. 550) has been prepared to indicate what we think we must do to accelerate the process of getting this new data to potential users.

First, we must recognize a process, material, or a device as having potential industrial value.

Then we must catalog the useful properties and values so that we can refer the new development to anyone who has an interest in a specified area.

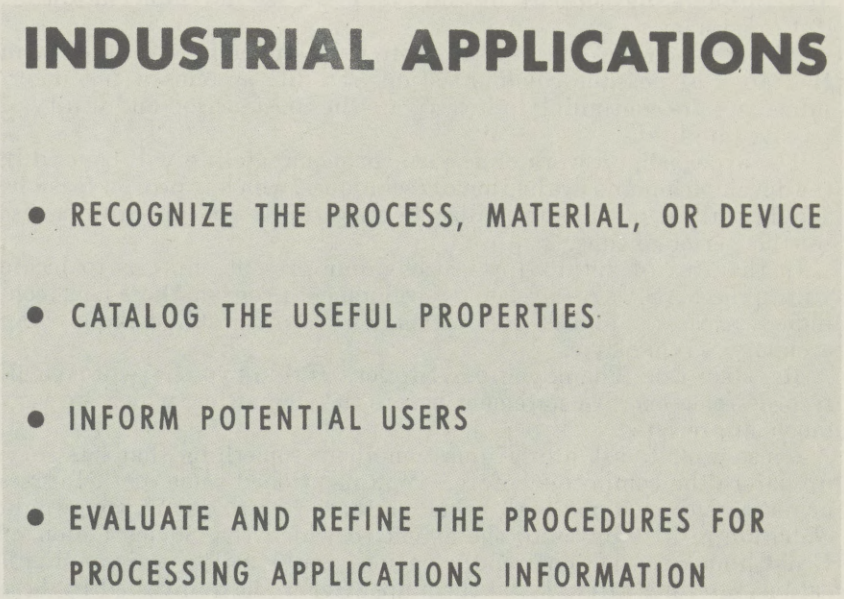

FIGURE 550

Third, we must take action to inform those whom we think have potential use for the new idea, so that as rapidly as possible, the benefits of new developments are fed out to the various segments of industry which can make use of it.

Finally, we will have to continuously evaluate and refine our procedures for processing applications information, so that we arrive at the most effective way of accomplishing the three activities just discussed.

These two elements, the review of the total range of space flight program proposals for satellite applications which can effectively serve the public and the search for devices and techniques of broad applicability arising in the space program's daily operations, constitute the elements of NASA future applications program.

In summary, the Office of Applications has three major areas of activity in its program; these are meteorological systems, communications systems, and future applications.

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The first two of these are programs for satellite systems development. A specific line of satellite development is already underway in meteorological systems. This line carries from TIROS through Nimbus to Aeros.

The final system for operational meteorology will probably use a combination of the Nimbus and Aeros satellites.

In communications we feel that quite probably the ultimate system may use the synchronous orbit satellite. As this is a difficult technical development, in the interim, efforts leading to the establishment of a communications satellite system using low or intermediate altitude active repeaters have been initiated.

We are pursuing the work necessary to define the characteristics of the low altitude system through the development of the Relay system and through the support of A.T. & T. in its development of the Telstar system.

At the same time, since the ultimate value of the passive satellite in the range of possible communications satellite systems is not determined, we are continuing to investigate the construction and utility of passive satellites.

The experimental work on the synchronous satellite will be used in the development and evaluation of techniques, which if proven feasible, should make it possible to realize an operational system within a reasonable period of time.

In the area of future applications, our present effort is to locate within the NASA's research and development program those new techniques, processes, and devices which can be of benefit to the civilian economy. I thank you.

Mr. HECHLER. Thank you, Mr. Stoller. I think you have broken all records for a massive statement before the committee, which we very much appreciate.

I just want to ask a brief question about something that has come up before the committee before. You mentioned some of the agreements and discussions with other nations. I wonder if you would elaborate a little bit as to the extent to which the Soviet Union or Red China or other unfriendly nations could utilize the communications satellites after we put them up, after we have invested in these systems?

Mr. STOLLER. I think there are two phases to this. One phase is associated with the actual locations of ground stations that they would find desirable to establish for their own use without participating in an international communications satellite system.

In this area of the problem, it would depend on whether they thought it were worth while, for instance, to install stations to carry messages from Russia to China or to other areas.

This I can't say very much about, not knowing much of their concepts of where they would use communications satellite systems.

The other aspect of the problem is whether or not they could use the satellite as put into orbit by a satellite communications system operation.

Access to the satellite, as we see it now, would require cooperation with a ground control station. In other words, the satellites must be turned on and off at the present time by a ground control station.

And the frequencies and codes involved in this are obviously not broadcast to everyone, but they are also obviously subject to an intelligence type of operation and the system could be interfered with if someone were sufficiently interested to do so.

To this extent, if someone were willing to mount an intelligence operation and interfere with the system and try to take control of it, I presume it could be done. I don't know whether this really answers your question.

Mr. HECHLER. Well, this is more serious so far as communications satellites than it was for our discussion of meteorological satellites. Isn't it easier for an unfriendly nation to utilize data from communications satellites than from meteorological satellites?

Mr. STOLLER. I think they could, under this interference type of operation basis, if it were purely over their own territory. That is, they could capture the satellite for a short period of time, once they had gone through the intelligence operation of determining exactly what control mechanisms were involved.

Under the circumstances where the satellite is normally in position for the ground stations that had been initially established for its use, it would constitute essentially a jamming operation. They could not make, I don't think, effective use of it while we were trying to use it.

Mr. HECHLER. Has NASA been approached in a friendly way by nations other than the ones that you mentioned to enter into agreements for the sharing of these communications satellites?

Mr. STOLLER. Yes; we have had inquiries from other countries as to how they could participate in the communications satellite program.

Mr. HECHLER. Specifically, have you had any inquiries from the Soviet Union?

Mr. STOLLER. We have had no direct indication of interest from any of the Iron Curtain countries that I know of.

Mr. HECHLER. Have you offered any?

Mr. STOLLER. The offers for this kind of cooperation have generally been made in the public statements that have been made about cooperation and through the Cospar mechanism at the Cospar meetings, indicating that we are always willing to sit down and discuss a cooperative program in any area of space technology.

We have also had at Cospar meetings individual discussions with Soviet scientists in this area, but in the area of communications have never had any indication of a response.

Mrs. WEIS. May I just ask one that is relevant to this?

Mr. HECHLER. Yes.

Mrs. WEIS. Have you any indication that the Russians are working on a similar scheme, or similar communications satellites?

Mr. STOLLER. All we have are publications of a routine nature, you might say, in the press or periodcials over there made by professors or people associated with various institutes saying that there is a great future for communications satellite systems. But we have no positive indication, that I am familiar with, that they are actually working on such a system.

Mrs. WEIS. You have scientific meetings with these international groups. I gather the Russian scientists are very careful in what they say.

Mr. STOLLER. They generally are. In most cases their statements at the scientific meetings are restricted to what might be called pure science, and as as soon as questioning or discussion leans toward what we would call technology, there is very little said.

Mrs. WEIS. About future plans?

Mr. STOLLER. Yes. Those matters are not discussed in open meetings.

Mrs. WEIS. Thank you.

Mr. HECHLER. To preserve continuity, do any members of the committee have any questions on the international aspects of communications satellites?

Mr. WILCOVE. Mr. Stoller, you pointed out in your statement that on the Relay program you have international agreements with Great Britain and various other countries.

Mr. STOLLER. Yes, sir.

Mr. WILCOVE. Will you please place in the record one of them?

Mr. STOLLER. Pardon me?

Mr. WILCOVE. Could you place in the record one of the agreements?

Mr. STOLLER. Certainly.

(The document referred to follows:)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA HEADQUARTERS

Washington 25, D.C.

MEMORANDUM OF UNDERSTANDING

The Deutsche Bundespost of the Federal Republic of Germany and the U.S. National Aeronautics and Space Administration intend to participate jointly in intercontinental testing in connection with experimental satellites launched by NASA for communications purposes.

Specifically in connection with the NASA Projects Relay and Rebound, as appropriate, each cooperating agency agrees to provide a ground station to receive and/or transmit television and multichannel voice signals between the two stations in the course of these projects. No exchange of funds between the two agencies is contemplated.

Each cooperating agency agrees—

(i) To obtain the necessary radio frequencies which shall not be selected by NASA until after consultation between the cooperating agencies;

(ii) To make available to the other such operating schedules as are necessary for the communications tests;

(iii) To facilitate demonstration tests involving, as necessary, temporary connections to its telecommunciations networks.

In the event that there are additional experimenters participating in the testing, NASA will undertake to determine suitable schedules in the interests of all experimenters.

NASA agrees to provide satellite radiation characteristics and orbital parameters as required for the design, construction, and operation of the Bundespost ground station. In this connection, the exchange of such information as is covered by proprietary rights shall be arranged in such a manner as fully to respect those rights.

Data, including information relating to the space environment, obtained in the intercontinental communications tests shall be exchanged and made freely available to the scientific community. Signals transmitted over the satellite links in this cooperative program are to be used for test purposes only and are not for commercial exploitation.

Each cooperating agency shall designate a point of contact for technical liaison purposes in the conduct of this program and shall provide suitable and periodic progress reports to the other.

This understanding between the cooperating agencies shall not preclude the use of the ground stations for tests outside the cooperative projects covered by this understanding.

This memorandum is conditional upon the concurrence of the respective governments.

ARNOLD W. FRUTKIN.
ROBERT E. WARREN.
(For the National Aeronautics and Space Administration).
E. O. DIETRICH,
(For the Deutsche Bundespost).

WASHINGTON, D.C., *June 22, 1961.*

Mr. HECHLER. Mr. Hines?

Mr. HINES. Mr. Stoller, it has been stated that the present ground-based international communications system cannot meet the current requirements and demands placed upon them at the moment.

Can you give us some idea of what will be the comparative capacities of both the passive and active satellite systems? What will be the improvement in communications over the present ground-based system?

Mr. STOLLER. I don't think I can do that very easily in comparing the passive and active in this sense, because so many numbers depend on the specific parameters of the operation you presuppose as being an operational communications satellite system.

I could point out the type of increased capacity that we are concerned with. We seek the capability to multiply by several times the number of telephone channels that are now available, in the transatlantic cables with, say, a single active satellite. At the same time we desire to make it reasonably possible to transmit a wide band of information, such as television is characterized by, with a satellite, for if the number of telephone channels tied into the cable are all put side by side, they still will not carry a television channel.

Mr. HINES. Do you envision with the advancement of the laser or maser technology the possibility of using that device in a communication satellite system?

It has been said that the laser can offer one pencil-thin beam of energy and perhaps hundreds of thousands of available channels. Do you envision this as a future possibility?

Mr. STOLLER. I would say this is a possibility. But I would also say there are many years of what we normally call research and development to take place before we know to what extent we will actually be able to use it in the satellite.

Mr. HINES. When do you expect the Rebound or Relay, Syncom, and Telstar satellite systems will become operational? Can you give us dates at this time?

Mr. STOLLER. I would like to point out that no one of these systems is intended to be operational.

Mr. HINES. Not even Telstar?

Mr. STOLLER. Not even Telstar.

All of these satellite systems at this time are considered by their sponsors to be experimental projects.

On these experimental projects will be built the next step, which may again be an experiment or may well be the first of the operational satellites. But certainly each one of these is presently considered to be an initial experiment, phase 1.

And the number of intervening experiments before the operational system comes into existence is quite difficult to predict. It may be that with Relay's experience and Telstar's experience those people

interested in establishing the operational satellite and having the ultimate authority to do so may move on the basis of those two experiments to put an interim operational system into existence. I can't anticipate that at this time.

Mr. HINES. But you do envision a standardized operation that will perform primarily as a communications system and will have only a very small R. & D. program associated with it for the sake of improvement? You do envision this eventually, do you not?

Mr. STOLLER. Oh, I think the operational system will use essentially standardized hardware so far as, let's call it, the terminal connections are concerned although over a period of time there may be more than one shape satellite or detailed satellite incorporated in the system.

But all of these will be able to cooperate with the ground terminals and so forth and so on.

Mr. HINES. Can we look forward to increased finding or continuous funding by NASA for replacement of satellites in the interim and the standardized systems?

Mr. STOLLER. As we see it, NASA's job will be to carry out a continuing research and development operation in support of the operational communications satellite system, and in coordination with it.

As the operational people get underway, they will certainly, if our experience in all other fields of technology are any example, come up with questions that they do not have the engineering answers to, and they will require that certain R. & D. be done.

Some of that will turn out to be best suited to NASA investigation and support, some will be the communications satellite system itself. We will undertake this supporting R. & D.

Fundamentally, I would expect that the operational system will, of course, fund for its operational satellites and it will pay for the launch vehicles and everything. We will fund only R. & D. activity in much the sense that we discussed yesterday for putting R. & D. meteorological satellites into sort of a continuous supporting program while the Weather Bureau continues to handle the operational meteorological system.

Mr. HECHLER. Mr. Waggonner?

Mr. WAGGONNER. Could you estimate the total cost of the launching vehicle for experimentation, combined with the cost of the Echo I, Echo II, Relay, Telstar, and Syncom, through the research and development period?

Is there an overall figure of the cost of this program, including launch vehicles?

Mr. STOLLER. I think we can get a number for the record for you.

Mr. WAGGONNER. I think that is going to be rather important, Mr. Chairman. If you have no objection, I would like to have that information in the record, because we are already hearing that Government money will be needed to finance the communication satellite program. I request it be included.

Mr. HECHLER. You might make certain assumptions as you are presenting these figures.

Mr. STOLLER. We will have to, to give you a number that has any meaning.

Mr. HECHLER. I mean you might have to go between a range and make certain assumptions.

Mr. STOLLER. For instance, we will have to probably exclude Telstar, because in a sense much of the expenditure on Telstar has already taken place within the telephone company, and we do not have the detailed internal bookkeeping of the phone company's expenses in preparing the developmental satellite, the R. & D. that went before it.

Mr. WAGGONNER. In the figures you provide, you can specify whether you leave out that item or estimate it.

Mr. STOLLER. Yes.

Mr. HECHLER. I think that would be very helpful.

(The table referred to follows:)

Estimated flight program costs for approved communications satellites (includes Echo I, Echo II, Relay, Syncom, and Rebound)

[Costs in thousands of dollars]

Fiscal year	Total	Cumulative
1959	1,000	
1960	1,500	2,500
1961	29,903	32,403
1962	43,727	76,130
1963	40,110	116,240
1964	[1] 5,000	[1] 121,740
1965	[1] 1,000	[1] 122,740

[1] Fiscal year 1964 and 1965 costs projected.

Mr. HECHLER. Mr. Davis.

Mr. DAVIS. I would like to ask Mr. Stoller this: Inasmuch as the military will develop its own communications system, the Advent program, and there will be also one more or less a civilian system, of course it would be natural to expect that there could be a great danger of duplication of effort.

I was wondering what safeguards have been set up to see that tax money isn't wasted in that way.

Mr. STOLLER. Well, there are various procedures involved. There is a committee known as the Technical Committee on Communications Satellites, which has been set up between DOD and NASA. Now the A.T. & T. people are in it, too, because they are in the communications satellite business.

This committee meets regularly and the project people responsible for carrying out the projects report to each other what they are doing technically. Each man has a pretty good idea of what the technical program is doing, so he doesn't go off on test sequences which have already been conducted or items of that sort.

Mr. DAVIS. You said they meet regularly. Does that mean once a month?

Mr. STOLLER. It is of the order of about every 6 weeks—less than 2 months apart generally. This is considered to be adequate for this kind of coordination at the rate at which these projects move.

Mr. DAVIS. Has thought been given to the establishment of an office like that of Mr. Finger, who coordinates NASA with AEC and seeks to eliminate needless duplication?

Mr. STOLLER. I don't have any memory, that I can bring forth, of such a suggestion. You recognize that the DOD's Advent program is intended to provide a communications satellite adapted to the military needs. That is, it has the jam-resistant and security measure

type of electronics built in, so as to maintain security on their communications and to prevent interference in terms of military terms.

Their satellite system, then, requires special characteristics that you would not expect to build into a civilian communications system. It is also adapted for the military's use under field conditions where they may wish to put a station in the field at a specific location for control purposes.

It is generally conceded that the military will continue to use the commercial system much as they use the telephone system now for its routine communications traffic. It will use the commercial communications satellite system as a link in its day-to-day traffic, just the way it always uses the undersea cables now, and so forth.

Mr. DAVIS. Does the Advent program include a lot of work on the techniques of putting a 24-hour satellite in orbit, or projects of that kind, which might be duplicated by NASA?

Mr. STOLLER. Well, its effort to put a satellite into 24-hour orbit is based on using a large launch vehicle, and in effect a direct injection.

This is why in our Syncom project we have concentrated chiefly on this apogee-kick technique which I described, with the extra rocket aboard the satellite itself, and the correcting jets. We are concentrating on that in an effort to see whether there is an alternate way of injecting satellites into 24-hour orbit that would be more economical of launch vehicle capacity.

So, it is a complementary in that sense in the launch vehicle area.

Now, the General Electric Co. is doing much of the control system work for our Nimbus satellite, as I mentioned yesterday. They are also doing work on control systems for Advent. So we get the benefits of the Advent control system development, they get the benefits of Nimbus control system development because the same engineering sctaff coordinates the work on the two projects.

In this way we save going through a complete development for either one of the two projects. It is this kind of cooperation that is taking place.

Mr. DAVIS. Based on what you know now, then, do you feel any apprehension that there is needless duplication; do you feel it is an efficient operation?

Mr. STOLLER. I think it is working out pretty well. We are also taking advantage of the ground stations in Advent for the work on the ground stations for our Syncom operation, so that we don't have to break in a whole new group of engineering people into the business.

Mr. DAVIS. That is all.

Mr. HECHLER. Mr. Roush?

Mr. ROUSH. Mr. Chairman.

Mr. Stoller, I am interested in the practical applications of all of this. I think I have enough imagination to know that we can't even begin to anticipate all that might come in the future, but I believe that there have been certain things which have come out of the research and development program to date which right now are receiving practical application in industry and in our ordinary life.

Could you list a few of them for us?

Mr. STOLLER. Some of these we found, when we tried to dig back into the detail, are pretty hard to identify. The connections are sometimes tenuous. However, some things that I know of are the fact that

in the development of testing facilities, for instance for reentry bodies, a great deal of work was done on what are known as plasma jets. It is now possible to buy in the commercial market a hand-held plasma torch based on the design and development effort that went into these large jets. This torch is used for heating bodies, and welding all kinds of high temperature work.

This is a specific small element which has turned into a commerical product as a result of R. & D. sponsored for space and missiles research.

You find that the large amount of effort that has gone into aeromedical work is generally credited with having led the hospitals to accelerate their use of remote devices to monitor cardiac cases.

Now, this one is one of the more difficult ones to pin down as to whether the medical profession was already on its way in this area. Whether the aeromedical work accelerated it or not is something we are trying to actually define. But we do know now that in general techniques very similar to that used in aeromedical studies for the piloted aircraft and astronaut-type of work in monitoring physiological reactions at a distance are now being incorporated in hospitals so that a single nurse can monitor a number of cardiac cases and keep right up as to whether there is a relapse and so forth.

Mr. ROUSH. How about the remote control of television sets? Is that an outgrowth of this program?

Mr. STOLLER. I know what you are talking about. I don't think you could tie it to our space program as such.

Mr. ROUSH. I am going to have to change my speeches.

Mrs. WEIS. Isn't the whole field of miniaturization——

Mr. STOLLER. Yes, the whole field of miniaturization as such.

Mrs. WEIS. I think you can claim that. Did miniaturization come first?

Mr. STOLLER. The desire to reduce the weight and size of components for the aircraft missiles started the development of miniaturization. The missiles and space systems are now starting to adopt them. For instance one of the companies, I think it is Hoffman, makes a solar cell-powered transistor radio that you can carry around. It is their feeling that this would not be a commercial product if it had not been for the fact that the needs for the production of solar cells for space projects had established, in effect, their production line for cells at such a level that they can afford to use cells in selling a civilian product of this sort.

They would not have had as economical a solar cell available and there wouldn't have been such a product.

Mr. HECHLER. Mr. Waggoner.

Mr. WAGGONER. Did I understand you, Mr. Stoller, to say that the telephone people have not paid the cost of research on anything except Telstar?

Mr. STOLLER. No, I don't think I quite said that.

Mr. DAVIS. As I understand the answer, he simply said that he couldn't give the cost of Telstar because so much of it had been paid by the telephone company.

Mr. WAGGONER. In other words, that is a joint venture.

Mr. STOLLER. Well, the arrangement with the telephone company is simply that they will pay the cost of all the Telstar activity. In

other words, they are doing all the R. & D. at home; they are building prototypes, and so forth and so on.

We have a project man who is intimately connected with the project and the information that is developed in the course of the work is made available to him, reports are written and turned over to NASA as project activities are completed.

There will be joint release of data at various phases, and so forth. In general, all the work carried on in-house in the telephone company is funded by them. We don't fund them for any of the work they are doing.

Mr. WAGGONNER. It would be more nearly correct to say then that the only money the private telephone companies are spending is on the Telstar project—to your knowledge.

Mr. STOLLER. No; I wouldn't say that, either.

There has been a lot of money spent by other companies on studies and prototyping of various sorts of communication satellites systems. I am sure that RCA has spent money, for example, GE, Sylvania, Hughes Aircraft, and so forth, but these have not resulted in specific satellite projects in the sense of flight projects. They have been in-house efforts at one or another level of investment.

Mr. WAGGONNER. It appears the meteorological satellite Aeros and the Syncom communications satellite are going to be stationary satellites at about the same altitude. Is there any intention to use one to transmit for the other?

Mr. STOLLER. At the present time we have this as a possibility, I think it was mentioned yesterday. I think there is a possibility that we could use a single 24-hour stationary satellite for both communications and meteorology. This will actually depend on our working out the numbers, the weight of the combined satellite and the available vehicle, and the launch technique.

At the moment, it appears from the vehicles that we have in the stable, that for the early phases of the R. & D. we would be best guided to carry out the R. & D. in the first phase with individual projects and then when the vehicle performance is well known for the larger vehicles to decide on a combination.

Mr. HECHLER. Mr. Stoller, would it be possible to put into the record the text of the working agreement that you have with A.T. & T. on communications satellites?

Mr. STOLLER. I think so. I don't know whether there are any restrictions on its publication.

(The agreement referred to follows:)

COOPERATIVE AGREEMENT BETWEEN THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AND THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY FOR THE DEVELOPMENT AND EXPERIMENTAL TESTING OF ACTIVE COMMUNICATIONS SATELLITES

Whereas the achievement of an operational communications satellite system will be materially accelerated through cooperation between the United States Government and American private industry in the development and testing of experimental communications satellites; and

Whereas the American Telephone and Telegraph Company (hereinafter referred to as AT&T) has proposed, and the National Aeronautics and Space Administration (hereinafter referred to as NASA) has agreed, that they should join together in a cooperative agreement (hereinafter referred to as Agreement) for the development and testing of experimental active communications satellites; and

Whereas the Federal Communications Commission has granted to AT&T an experimental license and assigned the necessary frequencies for conducting experimental tests of active communications satellites;

Now, therefore, the parties to this Agreement agree that a cooperative project shall be carried out between them in accordance with the following terms and conditions:

ARTICLE I—DEFINITIONS

(a) The term "NASA" means the National Aeronautics and Space Administration.

(b) The terms "AT&T" and "BTL" shall refer to the American Telephone and Telegraph Company and to the Bell Telephone Laboratories, respectively, it being understood that the terms are used interchangeably throughout this Agreement and Annex A hereto.

ARTICLE II—DESCRIPTION OF PROJECT

(a) The cooperative project which has been agreed upon between NASA and AT&T and which is the subject of this Agreement is set forth in detail in Annex A hereto, entitled "Project Development Plan." Annex A is hereby incorporated as part of this Agreement, and the obligations imposed therein upon NASA and AT&T represent the statement of work to be performed under this Agreement.

(b) Since the Project Development Plan (Annex A) was drafted primarily to provide technical and managerial guidance rather than to serve as a contractual document, it contains material that is duplicated to some extent in the Articles of this Agreement. In the event of any inconsistency between provisions of the Project Development Plan (Annex A) and provisions of the articles of this Agreement, the provisions of the Articles shall govern.

(c) In the event it becomes necessary to make changes in the Articles of this Agreement or in the Project Development Plan (Annex A), such changes shall be incorporated as supplements to this Agreement to be signed by both parties hereto.

ARTICLE III—AVAILABILITY SCHEDULE FOR SPACECRAFT

(a) AT&T will make two spacecraft available at the Atlantic Missile Range (AMR) not less than thirty days prior to the first scheduled launching date of April 17, 1962, and not less than thirty days prior to the second scheduled launching date of October 15, 1962. AT&T will have the option of calling for the back-up launching of an additional spacecraft on June 15, 1962, and/or December 15, 1962, and in the event AT&T exercises either or both of these options, it will make two spacecraft available at AMR not less than thirty days prior to the scheduled date of each such optional launch.

(b) In the event that any spacecraft is damaged or destroyed prior to launching, at AMR or in transit thereto, AT&T shall have the option of promptly repairing or replacing such spacecraft, and the dates set forth in (a) above shall be adjusted by mutual agreement.

ARTICLE IV—REPORTS AND TECHNICAL INFORMATION

(a) NASA, through the Goddard Space Flight Center, will provide AT&T with —

(1) telemetry information in the form of magnetic tapes as recorded by Minitrack stations, and

(2) spacecraft acquisition information as outlined in Part IV of the Project Development Plan (Annex A).

(b) AT&T will provide NASA with—

(1) the immediate results of communications experiments by furnishing copies of memoranda of the BTL project manager setting forth such results;

(2) significant information developed during evaluation of an experiment which may directly bear on concurrently developing communications satellite programs;

(3) advance copies of technical papers, for NASA information, which BTL may publish in its own journal or in other professional and scientific journals; and

(4) a final report, six to nine months after each successful attainment of orbit, for distribution as a NASA publication, with due credit being given in such publication to BTL.

ARTICLE V—FINANCIAL ARRANGEMENTS

(a) AT&T will bear all costs of discharging its obligations under the cooperative project, and will reimburse NASA for all identifiable additional costs incurred by the Government in carrying out its obligations hereunder which are allocable to the cooperative project, except such additional costs as may be incurred because of the payment of claims of third parties resulting from bodily injury, death, or damage to or loss of real or personal property, including claims of contractors or subcontractors of the Government under agreements to indemnify them against the consequences of unusually hazardous risks. Subject to the foregoing limitations, the costs reimbursable by AT&T to NASA (hereinafter referred to as "governmental costs") shall include but not be limited to—

(1) Costs of the Delta vehicle or vehicles used, including all stages and engines therefor, and the cost of any modifications necessary to make the vehicles suitable for use with the spacecraft. If a vehicle which is made available for the project is not used, AT&T will not be obligated to pay the full cost of the vehicle, but will pay the cost of modification, and the costs, if any, including costs of transporation, necessary to restore it to production status.

(2) Costs of transportation of the vehicles from the West Coast to AMR.

(3) Costs of range and associated services, including costs of base operations at AMR, range instrumentation, data acquisition, range overtime, specific range work orders, and propellants.

(4) Costs of launch crew services for the launching of Delta vehicles in connection with this project.

(5) Costs incurred in providing such services as tracking and associated communications services, telemetry recording, and other orbital computations.

(b) NASA will bill AT&T 120 days in advance of the April 17th and October 17th scheduled launch dates for the total of the estimated governmental costs of each such launching, including post launch and other associated operations, together with a supplemental bill covering the estimated governmental costs of the optional back-up launches scheduled for June 15th and December 15th. AT&T will pay NASA the full amount of the estimated bills for the April 17th and October 15th scheduled launches at least sixty days prior to each such launch. If AT&T exercises its option to supply spacecraft for the June 15th and/or December 15th back-up launches, it will pay NASA the full amount of the estimated bill for each such launch at the time it notifies NASA of the exercise of the option, which shall not be later than forty-five days prior to each such launch.

(c) If actual governmental costs exceed the previously billed estimate for any launching, NASA will bill AT&T for the amount of such excess, and any such bill shall be paid by AT&T within thirty days of its receipt, or of a final determination of actual governmental costs by the Associate Administrator, NASA, under (e) below.

(d) If actual governmental costs are less than the amount of the estimated billing, the amount overpaid will be credited by NASA toward the cost of the next vehicle to be launched under the program. If there is a net overpayment after the completion of the last scheduled launching, NASA will refund such overpayment to AT&T.

(e) At or before the time NASA takes action under (c) or (d) above with respect to the actual governmental costs of any launching, it will furnish AT&T with a statement, itemized in reasonable detail, of the actual governmental costs of that launching. Within thirty days after the receipt of such a statement, AT&T shall have the right to request a review of its correctness by the Associate Administrator, NASA, who will make a final determination, which shall be binding on AT&T, of the actual governmental costs which are reimbursable by AT&T for that launching.

ARTICLE VI—TERMINATION

(a) The cooperative project under this Agreement may be terminated by NASA under the following circumstances:

(1) Upon a declaration of war, or of a national emergency by the Congress of the United States.

(2) Upon a determination by the Administrator, NASA, that termination is necessary in the best interests of the Government: *Provided*, That no such termination shall take effect during any period beginning ninety days prior

to a scheduled launching date and ending with the day upon which NASA fulfills its tracking responsibilities.

(3) Upon failure of AT&T to furnish a spacecraft within thirty days after it is scheduled to do so under Article III of this Agreement.

(b) The cooperative project under this Agreement may be terminated by AT&T at any time, subject to the proviso contained in (a) (2) above.

(c) In the event NASA terminates the project under (a) (1) or (a) (2) above, AT&T will not be required to reimburse NASA for any governmental costs of the project, as defined in Article V, except such costs as are attributable to an actual launching occurring prior to the effective date of such termination by NASA and any post-launching and other associated activities.

(d) In the event NASA terminates the project under (a) (3) above, AT&T will reimburse NASA for all governmental costs, as defined in Article V, that have been incurred up to the date of notice of termination, exclusive of the cost of the Delta vehicles not used but including the cost of any modification of the vehicles from production status, and the costs, if any, including costs of transportation, necessary to restore such vehicles to production status.

(e) In the event AT&T terminates the project under (b) above, AT&T shall reimburse NASA for all governmental costs, as defined in Article V, that have been incurred up to the effective date of the termination, subject to the same exclusions and inclusions set forth in (d) above.

ARTICLE VII—PROPERTY RIGHTS IN INVENTIONS

(a) As used in this clause:

(1) "Invention" includes any invention, discovery, improvement, or innovation;

(2) "Made" when used in relation to any invention means the conception or first actual reduction to practice of such invention; and

(3) "To practice" an invention means to manufacture, use, and sell and dispose of according to law any article or material; or to use any method.

(b) AT&T will furnish promptly to NASA a written report containing full and complete technical information concerning any invention made in the performance of any work performed under or in anticipation of this Agreement or under any other AT&T-sponsored research and development project which has as one of its purposes advancement of the state of the art in communications satellite systems, equipment, components, or ground tracking, transmitting, or receiving facilities therefor; *Provided*, that this reporting requirement shall apply only to inventions made during the period from May 18, 1961, to the expiration of one year after the last launching under this Agreement, or to the effective date of termination of this Agreement under Article VI.

(c) At the time of furnishing the written report required by (b) above, AT&T will designate in writing those of the inventions reported which resulted from any work performed under or in anticipation of this Agreement. The rights and obligations of the parties hereto respecting the inventions so designated shall be governed by the provisions of an Instrument of Waiver executed by NASA and AT&T contemporaneously with the execution of this Agreement.

(d) As to any invention required to be reported under (b) above, but not designated in accordance with (c) above, AT&T agrees, upon request of NASA, to furnish a statement executed under oath setting forth the full facts concerning the circumstances under which such invention was made and stating the relationship (if any) of such invention to the performance of any work under or in anticipation of this Agreement. If the Administrator of NASA determines that any such invention was made in the performance of any work under or in anticipation of this Agreement, such invention shall become subject to the provisions of the Instrument of Waiver identified in (c) above.

(e) With respect to all other inventions required to be reported under (b) above, but which do not become subject to the provisions of the Instrument of Waiver under (c) or (d) above, AT&T agrees to and does hereby grant to the Government an irrevocable, nonexclusive, nontransferable, and royalty-free license to practice such inventions throughout the world, by or on behalf of the United States; together with the right in the Administrator to grant licenses to business entities domiciled in the United States, under such terms and conditions as the Administrator may prescribe, for the practice of such inventions throughout the world in the design, development, manufacture, operation, maintenance, and testing of communications satellite systems, equipment, components, and ground tracking, transmitting, and receiving facilities therefor.

(f) Within eighteen months after the last launching under this Agreement, or six months after any termination of this Agreement under Article VI, AT&T shall furnish to NASA a final report listing all inventions required to be reported under (b) above.

ARTICLE VIII—DATA

(a) As used in this Article, the following terms shall have the meaning set forth below:

(1) The term "communications satellite data" means all technical information, however recorded and whether or not copyrighted, which is reasonably necessary to the design, development, manufacture, operation, maintenance, or testing of communications satellite systems, equipment, or components, or ground tracking, transmitting, or receiving facilities therefor, and which results from or is accumulated in the performance of this Agreement, and which is retained by AT&T in the ordinary course of business.

(2) The term "proprietary data" means data providing information concerning the details of a company's secrets of manufacture, such as may be contained in but not limited to his manufacturing methods or processes, treatment and chemical composition of materials, plant layout and tooling, to the extent that such information is not disclosed by inspection or analysis of the product itself and to the extent that the company has protected such information from unrestricted use by others.

(b) Except as otherwise provided in Article IV with respect to reports and technical information required to be furnished to NASA, AT&T shall furnish to NASA, upon request, at any time prior to the expiration of one year after the last launching under this Agreement or after the termination of this Agreement under Article VI, any and all communications satellite data as specifically identified in such request.

(c) The furnishing of communications satellite data shall be at the expense of the Government. Such cost shall be limited to the material, direct labor, and reasonable incidental expenses involved in the reproduction or preparation of the data and shall not include any amount representing the value of the data.

(d) Any portion of communications satellite data delivered under this Agreement which is proprietary data may be marked with the following legend:

"Furnished pursuant to a Cooperative Agreement with the National Aeronautics and Space Administration and shall not be disclosed, used, or duplicated for any purpose other than for design, development, manufacture, operation, maintenance, or testing of communications satellite systems, equipment, or components, or ground tracking, transmitting, or receiving facilities therefor, without the permission of AT&T."

The Government assumes no obligation to enforce the above restrictions but does agree to mark this legend on any reproduction of such marked data, in whole or in part, and to neither remove, obliterate, nor modify the same.

ARTICLE IX—RESPONSIBILITY FOR AT&T PROPERTY

The Government will not be responsible for any damage to, or destruction of, a spacecraft or other property which has been delivered by AT&T to NASA pursuant to this Agreement, regardless of whether such damage or destruction is the result of acts or omissions of civilian or military employees of the Government or employees of Government contractors.

ARTICLE X—SECURITY REQUIREMENTS

(a) The provisions of this Article shall apply to the extent that access to information classified "Confidential" or higher is required.

(b) NASA shall notify AT&T of the security classification of this Agreement and the elements thereof, and of any subsequent revisions in such security classification, by the use of a Security Requirements Check List (DD Form 254), or other written notification.

(c) AT&T agrees to execute, if it has not already done so, a Security Agreement (DD Form 441) with the Government, represented by the Military Department assigned security cognizance over its facilities. To the extent the Government has indicated, as of the date of this Agreement, or thereafter indicates a security classification under this Agreement as provided in paragraph (b) above, AT&T shall safeguard all classified elements of this Agreement and

shall provide and maintain a system of security controls within its own organization in accordance with the requirements of—

(1) the Security Agreement (DD Form 441), including the Department of Defense Industrial Security Manual for Safeguarding Classified Information in effect on the date of this Agreement, and any modification to the Security Agreement for the purpose of adapting the Manual to AT&T's business; and

(2) any amendments to said Manual made after the date of this Agreement, notice of which has been furnished to AT&T by the Security Office of the military department assigned security cognizance over the facility.

(d) Representatives of the military department having security cognizance over the facility, and representatives of NASA, shall have the right to inspect at reasonable intervals the procedures, methods, and facilities utilized by AT&T in complying with the security requirements under this Agreement. Should the Government, through these representatives, determine that AT&T is not complying with the security requirements of this Agreement, AT&T shall be informed in writing by the Security Office of the cognizant military department of the proper action to be taken in order to effect compliance with such requirements.

(e) AT&T agrees to insert in all subcontracts hereunder which involve access to classified information, provisions which shall conform substantially to the language of this article, including this paragraph (e).

(f) AT&T also agrees that it shall determine that any subcontractor proposed by it for the furnishing of supplies and services which will involve access to classified information in AT&T's custody has been granted an appropriate facility security clearance, which is still in effect, prior to being accorded access to such classified information.

ARTICLE XI—NONDISCRIMINATION IN EMPLOYMENT

In connection with the performance of work under this Agreement, AT&T agrees as follows:

(1) AT&T will not discriminate against any employee or applicant for employment because of race, creed, color, or national origin. AT&T will take affirmative action to ensure that applicants are employed, and that employees are treated during employment, without regard to their race, creed, color, or national origin. Such action shall include, but not be limited to, the following: employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; lay-off or termination; rates of pay or other forms of compensation; and selection for training, including apprenticeship. AT&T agrees to post in conspicuous places, available to employees and applicants for employment, notices to be provided by NASA setting forth the provisions of this nondiscrimination clause.

(2) AT&T will, in all solicitations or advertisements for employees placed by or on behalf of AT&T, state that all qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

(3) AT&T will send to each labor union or representative of workers with which it has a collective bargaining agreement or other contract or understanding, a notice, to be provided by NASA, advising the said labor union or workers' representative of AT&T's commitments under this section, and shall post copies of the notice in conspicuous places available to employees and applicants for employment.

(4) AT&T will comply with all the provisions of Executive Order No. 10925 of March 6, 1961, and of the rules, regulations, and relevant orders of the President's Committee on Equal Employment Opportunity created thereby.

(5) AT&T will furnish all information and reports required by Executive Order No. 10925 of March 6, 1961, and by the rules, regulations, and orders of the said Committee, or pursuant thereto, and will permit access to its books, records, and accounts by NASA and the Committee for purposes of investigation to ascertain compliance with such rules, regulations, and orders.

(6) In the event of AT&T's noncompliance with the nondiscrimination clauses of this Agreement or with any of the said rules, regulations, or orders, this Agreement may be cancelled in whole or in part and AT&T may be declared ineligible for further Government contracts in accordance with procedures authorized in Executive Order No. 10925 of March 6, 1961, and such other sanctions may be imposed and remedies invoked as provided in the said Executive Order or by rule, regulation, or order of the President's Committee on Equal Employment Opportunity, or as otherwise provided by law.

(7) AT&T will include the provisions of the foregoing paragraphs (1) through (6) in every subcontract or purchase order unless exempted by rules, regulations, or orders of the President's Committee on Equal Employment Opportunity issued pursuant to section 303 of Executive Order No. 10925 of March 6, 1961, so that such provisions will be binding upon each subcontractor or vendor. AT&T will take such action with respect to any subcontract or purchase order as NASA may direct as a means of enforcing such provisions, including sanctions for noncompliance: *Provided, however,* that in the event AT&T becomes involved in, or is threatened with, litigation with a subcontractor or vendor as a result of such direction by NASA, AT&T may request the United States to enter into such litigation to protect the interests of the United States.

ARTICLE XII—CONVICT LABOR

In connection with the performance of any work under this Agreement, AT&T agrees not to employ any person undergoing sentence of imprisonment at hard labor.

ARTICLE XIII—EIGHT-HOUR LAW OF 1912—OVERTIME COMPENSATION

This Agreement, to the extent that it is of a character specified in the Eight-Hour Law of 1912, as amended (40 U.S.C. 324–326) and is not covered by the Walsh-Healey Public Contracts Act (41 U.S.C. 35–45), is subject to the following provisions and exceptions of said Eight-Hour Law of 1912, as amended, and to all other provisions and exceptions of said Law:

No laborer or mechanic doing any part of the work contemplated by this Agreement, in the employ of AT&T or any subcontractor contracting for any part of the said work contemplated, shall be required or permitted to work more than eight hours in any one calendar day upon such work, except upon the condition that compensation is paid to such laborer or mechanic in accordance with the provisions of this Article. The wages of every laborer and mechanic employed by AT&T or any subcontractor engaged in the performance of this Agreement shall be computed on a basic day rate of eight hours per day; and work in excess of eight hours per day is permitted only upon the condition that every such laborer and mechanic shall be compensated for all hours worked in excess of eight hours per day at not less than one and one-half times the basic rate of pay. For each violation of the requirements of this Article, a penalty of five dollars shall be imposed for each laborer or mechanic for every calendar day in which such employee is required or permitted to labor more than eight hours upon said work without receiving compensation computed in accordance with this Article, and all penalties thus imposed shall be withheld for the use and benefit of the Government.

ARTICLE XIV—WALSH-HEALEY PUBLIC CONTRACTS ACT

If this Agreement is for the manufacture or furnishing of materials, supplies, articles or equipment in an amount which exceeds or may exceed $10,000 and is otherwise subject to the Walsh-Healey Public Contracts Act, as amended (41 U.S.C. 35–45), there are hereby incorporated by reference all representations and stipulations required by said Act and regulations issued thereunder by the Secretary of Labor, such representations and stipulations being subject to all applicable rulings and interpretations of the Secretary of Labor which are now or may hereafter be in effect.

ARTICLE XV—OFFICIALS NOT TO BENEFIT

No member of or delegate to the United States Congress, or resident commissioner, shall be admitted to any share or part of this Agreement, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this Agreement if made with a corporation for its general benefit.

ARTICLE XVI—COVENANT AGAINST CONTINGENT FEES

AT&T warrants that no person or selling agency has been employed or retained to solicit or secure this Agreement upon an agreement or understanding for a commission, percentage, brokerage, or contingent fee, excepting bona fide employees or bona fide established commercial or selling agencies maintained by AT&T for the purpose of securing business. For breach or violation of this warranty, NASA shall have the right to annul this Agreement without liability

on its part, and AT&T shall reimburse NASA for governmental costs as provided in paragraph (d) of Article VI.

In witness whereof, the parties hereto have executed this Agreement as of July 27, 1961.

THE UNITED STATES OF AMERICA,
By ROBERT C. SEAMANS, JR.,
Associate Administrator, NASA.
AMERICAN TELEPHONE AND TELEGRAPH COMPANY,
By F. R. KAPPEL, *President.*

195 Broadway, New York, N.Y.

I, A. G. Barry, certify that I am the secretary of the American Telephone and Telegraph Company, a party to the foregoing Cooperative Agreement; that F. R. Kappel who signed said Cooperative Agreement on behalf of A.T. & T. was then president of said corporation; that said Cooperative Agreement was duly signed for and on behalf of said corporation by authority of its governing body and is within the scope of its corporate powers.

[CORPORATE SEAL] A. G. BARRY.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION INSTRUMENT OF WAIVER

Whereas the American Telephone & Telegraph Co. (hereinafter referred to as A.T. & T.) and the National Aeronautics and Space Administration (hereinafter referred to as the Administration or as NASA) have agreed to join together in a program of cooperation for the development and experimental testing of active communications satellites, in accordance with the terms of a cooperative agreement executed contemporaneously herewith (hereinafter referred to as the agreement); and

Whereas inventions may be conceived or first actually reduced to practice in the performance of work under or in anticipation of the agreement on or after May 18, 1961, and such inventions may be regarded as being made in the performance of work under a contract of the Administration within the meaning of section 305 of the National Aeronautics and Space Act of 1958 (hereinafter referred to as the act), thereby entitling the United States to exclusive rights thereto; and

Whereas section 305(f) of the act authorizes the Administrator of NASA (hereinafter referred to as the Administrator) to waive all or any part of the rights of the United States to inventions which may be made in the performance of work under a contract of the Administration if the Administrator determines that the interests of the United States will be served thereby; and

Whereas the Administrator has determined that the interests of the United States will be served if a waiver of the rights of the United States in any inventions which may be made in the performance of work under or in anticipation of the agreement is granted, subject to the terms and conditions hereinafter set forth which the Administrator has determined are required for the protection of the interests of the United States;

Now, therefore, the Administrator hereby waives in favor of A.T. & T. the rights of the United States—

(*a*) to exclusive ownership, and

(*b*) to apply for U.S. and foreign patents and to have the same issued to the Administrator on behalf of the United States—

with respect to any invention or inventions made or which may be made on or after May 18, 1961, by any person or persons in the performance of any work under or in anticipation of the agreement, subject, however, to the reservation by the Administrator of an irrevocable, nonexclusive, nontransferable, royalty-free license for the practice of such invention or inventions throughout the world by or on behalf of the United States or any foreign government pursuant to any treaty or agreement with the United States, and subject further to the reservation by the Administrator of the right to grant licenses to others, under such terms and conditions as the Administrator may prescribe, for the practice of such invention or inventions throughout the world for any purpose whatsoever.

This waiver is conditioned upon A.T. & T.'s doing the following:

(*a*) Taking all customary measures and precautions necessary to protect the patent rights in any invention subject to this waiver, including promptly filing or causing to be filed a U.S. patent application therefor unless an application covering the invention has already been filed; and on request,

furnishing to the Administrator or his representative an irrevocable power to inspect and make copies of each such U.S. patent application.

(*b*) Upon receipt of the serial number and filing date, furnishing same, together with a copy of the application as filed, to the Administrator if not already so furnished.

(*c*) Executing and furnishing to the Administrator instruments fully confirmatory of the rights herein reserved by the Administrator.

(*d*) With respect to any license granted by A.T. & T., and any sublicense granted by any licensee of A.T. & T.—

(1) Requiring that each instrument granting such license or sublicense contain a notation of the rights reserved herein by the Administrator;

(2) Upon request, furnishing information to the Administrator concerning the grant of such licenses and sublicenses, together with the relevant terms and conditions thereof.

(*e*) In the event any U.S. patent application filed on such invention, or any patent issued thereon, becomes involved in interference proceedings, making no concession of priority, abandonment of contest, nor disclaimer, except with the written consent of NASA, without first obtaining an irrevocable, nonexclusive, nontransferable, royalty-free license for the practice of such invention throughout the world by or on behalf of the United States or any foreign government pursuant to any treaty or agreement with the United States; together with the right in the Administrator to grant licenses to others, under such terms and conditions as the Administrator may prescribe, for the practice of such invention throughout the world for any purpose whatsoever.

(*f*) In the event A.T. & T. decides not to file a patent application on such invention, or elects not to continue prosecution of any application already filed—

(1) Conveying to the U.S. Government as represented by the Administrator the entire right, title, and interest in the invention by delivering to the Administrator such duly executed instruments as are necessary to vest in the U.S. Government the right, title, and interest aforesaid, subject to the reservation to A.T. & T. of the rights to the invention in countries other than the United States in which the Administrator does not desire to file an application for patent for the invention, and subject to the reservation to A.T. & T. of an irrevocable, nonexclusive, royalty-free, nontransferable license to practice the invention, including the right to grant sublicenses to its subsidiaries and to operating companies of the Bell System, and subject also to licenses which were granted by A.T. & T. or any of its subsidiaries, or which A.T. & T. or any of its subsidiaries was committed to grant, prior to the date of this instrument of waiver; and

(2) Informing the Administrator in writing of any act known to A.T. & T. which constitutes a potential statutory bar to the filing of a patent application under 35 U.S.C. 102.

(*g*) With respect to any foreign country in which A.T. & T. has not filed an application on such invention within—

(1) Nine months from the date a corresponding U.S. application is filed;

(2) Six months from the date permission is granted to file foreign applications where such filing has been prohibited for security reasons; or;

(3) Such longer periods as may be approved by the Administrator;

conveying to the U.S. Government upon written request A.T. & T.'s entire right, title, and interest in such invention in such foreign country or countries in which an application for patent has not been filed within the times above specified, subject to the reservation to A.T. & T. of an irrevocable, nonexclusive, royalty-free, nontransferable license to practice the invention, including the right to grant sublicenses to its subsidiaries and to operating companies of the Bell System, and subject also to licenses which were granted by A.T. & T. or any of its subsidiaries, or which A.T. & T. or any of its subsidiaries was committed to grant, prior to the date of this instrument of waiver.

Done at Washington, D.C., this 27th day of July 1961.

JAMES E. WEBB, *Administrator.*

Accepted on behalf of the American Telephone & Telegraph Co. by:

F. R. KAPPEL, *President.*

195 Broadway, New York, N.Y.

Attest:

A. G. BARRY.

SUPPLEMENTAL AGREEMENT NO. 1 TO THE COOPERATIVE AGREEMENT BETWEEN THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AND THE AMERICAN TELEPHONE & TELEGRAPH CO. DATED JULY 27, 1961

Pursuant to article II(c) of the cooperative agreement between the National Aeronautics and Space Administration (NASA) and the American Telephone & Telegraph Co. (A.T. & T.) for the development and experimental testing of active communications satellites, the said agreement is hereby amended as follows:

1. Article III(a) is amended to read as follows:

"(a) A.T. & T. will make the first spacecraft available at the Atlantic Missile Range (AMR) by April 21, 1962, and a second spacecraft available at AMR by April 26, 1962, for the purposes of the first scheduled launching date of May 22, 1962. A.T. & T. will have the option of calling for the backup launching of an additional spacecraft on July 17, 1962, and in the event A.T. & T. exercise such option, it will make a third spacecraft available at AMR by June 16, 1962, and a fourth spacecraft available at AMR by June 21, 1962; *Provided*, That for the purposes of making a third and fourth spacecraft available at AMR, A.T. & T. may utilize the first and/or second spacecraft if NASA agrees that such utilization is technically feasible."

2. Article III(b) is renumbered as article III(c) and a new article III(b) is inserted, to read as follows:

"(b) For the purposes of the second scheduled launching, to take place in October 1962, on a date to be mutually agreed upon in writing by the project managers at least 90 days in advance, A.T. & T. will make two spacecraft available at AMR not less than 30 days prior to the agreed date. A.T. & T. will have the option of calling for the backup launching of an additional spacecraft during December 1962, on a date to be established at the same time the date of the second scheduled launching is agreed upon, and in the event A.T. & T. exercises such option, it will make two spacecraft available at AMR not less than 30 days prior to the scheduled date of the backup launching; *Provided*, That for the purposes of making two spacecraft available at AMR for either the second scheduled launching or the backup launching, A.T. & T. may utilize any of the spacecraft previously made available at AMR if NASA agrees that such utilization is technically feasible."

3. Article III(c) (formerly article III(b)) is amended by putting a period after the word "spacecraft" as it appears in the fourth line and deleting the remainder of the sentence.

4. A new article III(d) is added, to read as follows:

"(d) Any of the dates specified in (a) above, or agreed upon under (b) above, and the dates set forth in part V of annex A hereof, may be revised by mutual agreement of the project managers, to be evidenced in writing, without further amendment of this agreement."

5. Article V(b) is amended to read as follows:

"(b) On or before January 23, 1962, NASA will bill A.T. & T. for the total of the estimated governmental costs of the first scheduled launching, including postlaunch and other associated operations, together with a supplemental bill covering the estimated governmental costs of the first optional backup launching. On or before June 18, 1962, NASA will bill A.T. & T. for the total of the estimated governmental costs, as described above, of the second scheduled launching, together with a supplemental bill covering the estimated governmental costs of the second optional backup launching. A.T. & T. will pay NASA the full amount of the estimated bills for the first and second scheduled launchings by March 24, 1962, and August 17, 1962, respectively. If A.T. & T. exercises its options to call for a backup launching after either the first or second scheduled launching, it will pay NASA the estimated bill for each such launch at the time it notifies NASA of the exercise of the option, which shall not be later than 45 days prior to either such backup launching. The dates specified in this article V(a) may not be changed except by further amendment to this agreement."

6. Part V of annex A hereof, entitled "Management Plan," is amended by deleting everything on pages V–12 and V–13, and substituting the following:

"SCHEDULES

"Key milestones for the accomplishment of the project are shown in the schedule which follows:

"Proposed project schedule

"Milestone:	*Date*
S/C Design & Dev Start	Aug. 1, 1960
Andover Ant Const Start	May 29, 1961
Andover Cont Bldg Rdy for Occupation	Nov. 1, 1961
Prelim Reqmts for Launch Support	Nov. 9, 1961
AMR Ant Tower Const Compl	Dec. 10, 1961
Orbit Spec & Weight Statement	Dec. 15, 1961
Comd Trk Van at AMR	Jan. 4, 1962
Andover Ant Con & Mech Align Compl	Jan. 7, 1962
Telemetry Van at AMR	Jan. 18, 1962
Proto S/C Assy Compl	Jan. 31, 1962
S/C Van at AMR	Feb. 1, 1962
Proto S/C Elec Tsts Compl	Feb. 7, 1962
Opr Plan Compl	Feb. 15, 1962
Detail Test Object Compl	Feb. 22, 1962
Fl 1 & 2 S/C Assem Compl	Feb. 28, 1962
Proto S/C Quld Tst Compl	Mar. 15, 1962
Andover Ant Elec Cal Compl	Mar. 15, 1962
Fl 1 s/c Elec Tst Compl	Mar. 21, 1962
Range Safety Plan to AMR	Mar. 15, 1962
Fl 2 S/C Elec Tst Compl	Mar. 26, 1962
Andover Station Opr	Apr. 6, 1962
AMR 3 Vans & Tst Equip Fully Opr	Apr. 1, 1962
Fl 1 S/C Accept Tst Compl	Apr. 12, 1962
Fl 2 S/C Accept Tst Compl	Apr. 17, 1962
Fl 1 S/C Available at AMR	Apr. 21, 1962
Fl 3 & 4 Assem Compl (optional)	Apr. 25, 1962
Fl 2 S/C Available at AMR	Apr. 26, 1962
Fl 1 S/C to DAC/Mate/Bal	May 3, 1962
Fl 2 S/C to DAC/Mate/Bal	May 9, 1962
Fl 3 Elec Tst Compl (optional)	May 16, 1962
Fl 4 Elec Tst Compl (optional)	May 21, 1962
Launch Telstar 1 on Delta 12	May 22, 1962
Fl 3 Accept Tst Compl (optional)	June 7, 1962
Fl 4 Accept Tst Compl (optional)	June 12, 1962
Fl 3 S/C Available at AMR (optional)	June 16, 1962
Fl 4 S/C Available at AMR (optional)	June 21, 1962
Fl 3 S/C to DAC/Mate/Bal (optional)	June 28, 1962
Fl 4 S/C to DAC/Mate/Bal (optional)	July 4, 1962
Backup Telstar 1 with Delta 15 (optional)	July 17, 1962
Launch Telstar 2 on Delta 20	Oct. —, 1962
Backup Telstar 2 with Delta 23 (optional)	Dec. —, 1962"

In witness whereof, the parties hereto have executed this supplement agreement No. 1 to the said agreement as of March 2, 1962.

THE UNITED STATES OF AMERICA,
By ROBERT C. SEAMANS, Jr.,
Associate Administrator, NASA.

AMERICAN TELEPHONE & TELEGRAPH CO.,
By JAMES E. DINGMAN,
Executive Vice President.

Mr. HECHLER. You might look into it.

Mrs. WEIS. The company is also paying for the cost of the booster.

Mr. STOLLER. That is right. Their agreement calls for them to pay for the cost of the launch vehicle, launching services, and any costs

that are identifiable as chargeable to that project that NASA can identify.

Mrs. WEIS. What will be the lifespan of these satellites?

Mr. STOLLER. Well, we are always trying for numbers of the order of 3 to 6 months on the initial phase. The objective of life in a communications satellite system for some economic studies have indicated that the satellite should live 3 to 5 years before the system's economics will start to balance out.

Mrs. WEIS. It would almost seem essential.

Mr. STOLLER. That is right, because of replacement costs that is right. And for that reason a great deal of effort has been going into internal redundancies and efforts to make very severe environmental tests on the ground to get rid of components that might fail and the like.

Mrs. WEIS. Does NASA have anything to do with the discussion now going on about the ultimate control of the communications system, whether it be by private enterprise or some other method? Do you enter into these discussions at all?

Mr. STOLLER. Well, NASA, as an executive agency, participated in the discussions leading to the preparation of the bill.

The bill was, of course, presented by the Executive. We have testified to the Senate committee in a technical sense with essentially the same material, and if there is any position of NASA, I presume Mr. Webb will be called on to testify in that matter.

Mr. HECHLER. Mr. Stoller, I wouldn't want my earlier remarks about the relations with other nations to be misinterpreted, because I happen to feel the extent to which we can open up peaceful communications with the people behind the Iron Curtain, we have a great deal more to gain than to lose.

I suppose maybe there may be some television programs that might have some adverse effect on our cold-war standing if they were sent out. But I think in general that it certainly would be helpful in terms of building better international relationships.

I wondered if you had any philosophy on this or whether you had any discussions on this so far as the rather delicate question of our relations with the Iron Curtain countries are concerned in communications satellites?

That is a rather broad question, but I was interested in the extent to which you had discussed it within your office or within NASA.

Mr. STOLLER. I think we would feel generally that a cooperative effort would be a good sign; that is, it would show, if carried out in good faith and if it actually became a productive cooperative effort, that there would be some chance for such cooperation in other areas and could be expanded. That is about all I could say at the moment.

Mr. HECHLER. Mr. Hines.

Mr. HINES. I recognize, too, that the communications satellite program and the meteorological satellite programs await upon technical developments in NASA.

For instance a rendezvous capability could be very important, along with techniques which would involve precise tracking and precise positioning. With regard to the synchronous orbiting satellite at the present time it is expected that it will be launched from the cape.

You will therefore have to accept the limitations of inclination. I

assume eventually you do envision switching orbits, in order to put the satellite at a certain altitude and then kick it into a different orbital plane, is that not true?

Mr. STOLLER. This was the indication on the last of the charts in the communications satellites where we indicated we would hope to get into what we call a truly equatorial orbit with the larger vehicles, actually changing the orbital plane after launch.

Mr. HINES. This will require extraordinarily large amounts of energy, extraordinary from our point of view at the moment?

Mr. STOLLER. Well, it requires a sufficient additional amount so that we would not undertake it with the present small Delta system. But with the Atlas-Agena system which was used as the estimating base, we feel that we would have sufficient energy to put the several hundred pound satellite indicated into the true equatorial orbit.

Mr. HINES. In other words, we wouldn't have to look forward to a very large booster to lift a large amount of energy to do this?

Mr. STOLLER. The weight and the Atlas-Agena that I mentioned are compatible at this point.

Mr. HINES. Thank you.

Mr. HECHLER. Any further questions?

Mr. WILCOVE. Yes.

Mr. HECHLER. Mr. Wilcove.

Mr. WILCOVE. With regard to the ground stations that are used in these various systems, such as Relay and Syncom, do you use the same ones or do you have to use separate stations for each system?

Mr. STOLLER. You will find there is a lot of common use at the present phase in the system.

In the chart which showed the various stations, I remarked that the Maine station, the British station and the French station would be used both for Relay and for Telstar. NASA uses some of these stations on a contract basis.

In other words, the stations are built by private enterprise and we rent their use in the course of the Relay operation as required.

Telstar, being a telephone company project, the Maine station is a telephone company-owned station and we are renting services from that station for Relay.

The British station is being built by the British Post Office and will cooperate on both projects.

The French station is being built by the French Post Office and CNET, which works with the Post Office and will cooperate on both projects.

At the present time the station in Brazil and at Nutley, N.J., which were indicated on the chart, are being used chiefly in the Relay project and not in the Telstar project.

Mr. WILCOVE. What about Syncom, when that is set up?

Mr. STOLLER. The communications activity in Syncom is, as we have noted on the chart, just a one-telephone channel-type of operation and it is a limited experiment. Most of the experimental effort is going into getting it into orbit, verifying our ability to position and control it in orbit, and then to pass communications over that simple link.

We will get, with the aid of DOD, some transportable stations and we will be able to cooperate under limited conditions with the Advent

stations that are being built or established for the DOD. These stations, which have somewhat special characteristics in that they are on different radio frequencies than are the ones for Relay and Telstar, will be used for Syncom.

Mr. WILCOVE. Once you have an operational Syncom system, do you anticipate that you will require more permanent stations?

Mr. STOLLER. Oh, yes. The stations we are involved with now are strictly of an experimental nature and a field transportable construction which you would not consider for a permanent operational communications system.

Mr. WILCOVE. Does NASA have any of its own stations now?

Mr. STOLLER. We have some test stations going in for Relay. These are limited capacity stations in the sense that they are not quite as limited in band width to one telephone channel as are the Syncom stations, but are smaller size, and the antennas are of the order of 40 foot, not the very large 85-foot antennas like the British are putting in or the tremendous horn that the telephone company is putting in.

Mrs. WEIS. Are they expensive installations relatively?

Mr. STOLLER. They are of the order of less than a million dollars.

One of their major functions is to provide NASA with the capability for receiving the telemetry data on the state of the satellite and also to carry limited communications experiments from say the west coast and the east coast.

We anticipate that this type of operation is something that, as the R. & D. activity grows, we will have to expand into because we have a feeling that the telephone company station and the other stations will be carrying on a heavy program of their own. And an ability to interleaf our activity with theirs on a contract basis may become difficult.

So we will have to look into this in the next fiscal year as our experience accumulates to see what this amounts to from a planning point of view.

Mr. WILCOVE. In other words, in the future you will probably require additional funding for stations?

Mr. STOLLER. I would say in the future it is likely NASA will require more direct funding to support ground station activity of its own.

Up to now, except for this telemetry-type of support and limited communications capability, we have not gone deeply into the ground station area.

Mr. WILCOVE. Do you anticipate you will be able to use these stations interchangeably for the weather satellite systems?

Mr. STOLLER. No, I doubt it very much.

Mr. WILCOVE. You will require an entire——

Mr. STOLLER. I think the operational weather system for Nimbus will have a sufficient workload that the two stations we talked about yesterday, Alaska and the east coast, will effectively find themselves full up just coping with the Nimbus project.

In fact, there will come a point, I suspect, that, depending upon the experience in the field with these stations that the Weather Bureau people may say that we need a backup station to maintain continuity of service. This will again depend upon experience in the field.

Mr. WILCOVE. Mr. Stoller, let's see if we can't pin down somewhat the period of time when an operational system might come into

being. I notice various private concerns interested in this have come up with their own predictions, usually 1965.

What is the thinking in NASA as to when we can have an operational communications satellite system?

Mr. STOLLER. We would tend, I think, to put it beyond 1965, mostly because, if you remember our schedule, we think we will still be doing—and I think the others will also be doing—R. & D. on these more advanced satellites up to that period.

It may be, as I said before, that based on the experts with Telstar this year and Relay this year, that people like the phone company and others may say, "I am ready to move ahead with an operational system design."

To carry out such a system I should point out will require a great number of satellites if you are going to work at low altitude; they have to be available and kept in orbit and you will also have to supplement the ground stations. You could not run an operational system with only one antenna at each point. You will have to construct several antennas because you will have to hand over the message from one antenna to another.

As one antenna tracks the satellite going by, another antenna has to pick up the next satellite in the chain, be on it, verify everything is working well so that as one fades over the horizon, the next one picks up, then you take up antenna No. 1 and go back and pick up satellite No. 3.

You will have to continue this pass-the-message in the sense of a relay race if you are working at low altitudes. You also then have to provide, depending on the quality of service you are trying to maintain, perhaps a third antenna just for maintenance purposes, so there are always guaranteed to be two on hand for operation.

This kind of thing takes some time and the decision to make whether you are——

Mrs. WEIS. And a great deal of money.

Mr. STOLLER. That is right.

Mr. WILCOVE. Can you give us, and the public, some idea as to what time after 1965 we might anticipate an operational system?

Mr. STOLLER. I would think within 2 or 3 years of that time. I would think it is much more likely 1967 or 1968 that there will be enough hardware and experience that you might say there was an operational system. There may be a limited operational type of thing going on a little earlier. You might be able to pass messages for an hour a day and they may route some messages that way, but in the sense that I said Nimbus is an operational system, it would have essentially 100 percent continuous coverage and so forth, I would think that would be the same definition for a telephone operation.

Mrs. WEIS. That means when I can pick up my telephone, call England and get my party there via a satellite any hour of the day or night?

Mr. STOLLER. That is right. As far as the phone company is concerned they will not give you the privilege of specifying the link you will use. They will furnish the service. You may still go by cable even though satellites are in operation.

But when they can rely on the satellites to pass messages in a routine manner then we will have an operational system.

Mr. WILCOVE. Isn't it true that in all likelihood we will have an operational system between the United States and Europe first before we have one linking the entire globe?

Mr. STOLLER. I would certainly think so, because these are in a sense the centers of traffic origin. This is where the most traffic takes place and you would put in your systems where there is the greatest flow.

Mr. WILCOVE. Of course, if you use the Syncom system, all you would require would be one satellite over the Atlantic Ocean.

Mr. STOLLER. Yes, one or perhaps a second to have a redundant capability so you wouldn't go through a complete down time in case you had a failure.

Mr. WILCOVE. Do you think that could take place before 1967 or 1968?

Mr. STOLLER. I don't think it would come any faster. It would be about the same time period. The 24-hour satellite is a complex device.

Mr. HECHLER. If the Telstar satellite proves to be quite successful, what would the next step be after that?

Mr. STOLLER. You really should ask the telephone company.

Mr. HECHLER. Have they discussed it with you? I presume they have.

Mr. STOLLER. I would think that the next step for the telephone company would be to decide whether they would want redundant systems in the satellite and by that I am indicating the present satellite has only one transponder within it, one receiver-transmitter system. Should any major element in the transmitter or the receiver fail, then the whole satellite is dead.

Mr. WAGGONNER. There isn't any recovery or replacement to it; it is just a matter of putting another there.

Mr. STOLLER. You would have to put another satellite up in case it failed. It may be they will decide that they would undertake to design a satellite the next time through the design cycle with two transponders aboard, so in case one failed the other would still be there to operate and you would continue to get service from a given satellite.

We have tried to go this way in Relay, not from the point of view of an operational system, but to try and get as much experimental time with a single satellite as we can. We have two transponders in Relay at this moment in its design, and they have a control command receiver and the man on the ground can decide whether he wants to receive one or receive two receiver and transmitter systems and use either one.

Mr. WAGGONNER. Is there any speculation or plan on the part of NASA to use one of these experimental communication satellites in conjunction with the lunar landing?

Mr. STOLLER. Not that I am aware of.

Mr. WILCOVE. If the Telstar proves successful, is there anything to stop A.T. & T. from attempting to put an operational system into effect and, if so, could they do that before the time period you mentioned—1967, 1968?

Mr. STOLLER. The only thing I know that will stop them is that they have to have some kind of an operating entity authorized, I suspect, by the FCC, or as a result of hearings on the bills that are now being studied.

Mr. WILCOVE. But from a technical standpoint, if Telstar proves successful, couldn't an operational system be set up before 1967 or 1968?

Mr. STOLLER. I don't see any reason why if they chose to invest their funds that way, they couldn't go ahead and build 20, 30 Telstar satellites, have them all launched, supply the antennas and go into an operational system, if their evaluation tests showed to be practical.

Mr. WILCOVE. Possibly that could be done by 1965 as some of these companies are predicting.

Mr. STOLLER. Yes; I would think you would have to make an estimate of how many low-altitude satellites they really wanted. We would have to then be concerned with the rate at which we would try to get them into orbit. They would have to be interleafed in the NASA and DOD launching sequence down at the cape.

So just how long it would take to get 30 satellites up would be a planning problem for the people involved in the launch sequence. We don't fire 30 satellites out of the cape of one style at the present time. And getting that many launch vehicles ordered—perhaps I should point out that the leadtime on launch vehicles for the larger vehicles is 21 months.

If someone comes in and says: "I want to order a vehicle today," it takes them 21 months to get delivery. It takes 18 months on the Delta which the Telstar is now tied into. So if they came in by the middle of this year they would not expect to actually get delivery on an ordered vehicle until the end of 1963.

Then you have to launch the vehicles in some sequence, each one of them at the moment putting up one satellite. It takes 3 to 4 weeks on a pad down there for a Delta launch, with some reasonable time to do the job thoroughly and not extreme overtime, weekend work, and so forth.

Mr. WAGGONNER. What you are saying is that before you get all 30 of them up, 15 of them may be down.

Mr. STOLLER. I am not saying that. They will stay up for a long while, once launched, but that may be some——

Mr. WAGGONNER. They might be inoperative even though they were up.

Mr. STOLLER. Some might be. It is quite an operational problem to get everything going.

Mr. WAGGONNER. I don't think the telephone people are going to push it beyond the point where they feel they have a satisfactory operation.

Mr. STOLLER. I think this is the case. They are very competent engineers and they will put very careful evaluation on every step of the way.

Mr. WILCOVE. I notice that the funding of the communications satellite system in 1961 was $33.8 million. In 1962 it rose to $48.4 million, and for 1963 you are requesting $85.3 million.

Mr. STOLLER. Yes.

Mr. WILCOVE. Do you anticipate the funding will continue to rise? If so, for how many years? When do you think you will be able to level out? In other words, have you reached a peak on the funding program? The figures I referred to are on page RDO7–1 of the NASA budget book.

Mr. STOLLER. I know where you are at. I am trying to take a look at the funding here. We are now moving from funding in the Delta vehicle type of satellite into funding in the Atlas-Agena vehicle type satellite. The actual rate of launches may decrease somewhat because the R. & D. support may be interleafed with R. & D. that may come from additional commercial work such as the A.T. & T. work.

The actual cost per vehicle and the cost per satellite will continue to rise somewhat, I would think for a while, because we use larger vehicles and somewhat more complex satellites beyond Syncom and existing Relay, when we go to the greater weights and look for stabilization devices. I would anticipate that if you added the additional activity in ground systems support that the funding would go up somewhat for another year or so and then tend to level off. I would think for at least another year or two it would go up. I am not in a good position right now since we haven't taken our detailed look for 1964 at this moment to say whether the rate will be maintained or not.

Mr. WILCOVE. Between 1962 and 1963 the funding almost doubled.

Mr. STOLLER. That is right.

Mr. WILCOVE. You anticipate that for the next few years the funding requirements will continue to rise?

Mr. STOLLER. I think they will go up, but I am not sure that the rate will be maintained at all. This is a question I would have to take another look at our detailed breakdowns.

Mr. WILCOVE. I have just one more question. You mentioned, Mr. Stoller, the Arents satellite of DOD. Could you explain what that is?

Mr. STOLLER. This is a project that is associated with Advent in the sense that I mentioned we had some radiation satellites on developmental Centaurs to measure radiation at high altitudes. This is a project DOD is sponsoring to measure environmental effects on components and systems at high altitudes and they are funding the satellite system and it will also tentatively be flown on a development Centaur vehicle. It will have radiation detectors and a certain number of mechanical types of devices on it which all will be tested in orbit to see how they perform over the period of time which they survive.

Mr. WILCOVE. Thank you, Mr. Stoller. That is all, Mr. Chairman.

Mr. HECHLER. Any further questions?

We certainly want to thank you, Mr. Stoller, for your very instructive testimony both yesterday and today. The subcommittee will not meet tomorrow, but will meet again on Thursday at 10 at which time we will receive testimony from Edmund C. Buckley, Director of Tracking and Data Acquisitions, National Aeronautics and Space Administration. Mr. Buckley has a comparatively modest statement, a quarter of an inch in thickness, that will be available to the members of the subcommittee. The subcommittee will not meet on Friday on account of the projected trip to the Marshall Space Flight Center at Huntsville.

We will resume hearings every day next week.

If there are no further questions or observations, the subcommittee stands adjourned until 10 a.m. on Thursday.

(Whereupon, at 11:50 a.m. the subcommittee adjourned, to reconvene at 10 a.m., Thursday, March 8, 1962.)

1963 NASA AUTHORIZATION

THURSDAY, MARCH 8, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON APPLICATIONS AND
TRACKING AND DATA ACQUISITION,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10 a.m., in room 214–B, New House Office Building, Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. The subcommittee will come to order.

This morning we are continuing our hearings by receiving testimony on tracking and data acquisition activities funded by the National Aeronautics and Space Administration.

We have with us this morning Mr. Edmond C. Buckley, Director, Tracking and Data Acquisition, who will be assisted by Mr. Ralph Ulmer, Director of Facilities Coordination and Mr. David Williamson, Jr., Chief, Program Coordination of Office of Tracking and Data Acquisition.

At this point in the record I would like to insert a staff memorandum outlining the subcommittee's jurisdiction in this area.

I believe the members of the subcommittee have copies of this memorandum. It indicates the general nature of the subcommittee's jurisdiction.

(The memorandum referred to is as follows:)

Memorandum to: Mr. Hechler, chairman, Subcommittee on Applications and Tracking and Data Acquisition.
From: Richard P. Hines and Raymond Wilcove, staff consultants.
Subject: NASA tracking and data acquisition program for fiscal year 1963.

The public hearing Thursday, March 8, will concern itself with NASA's 1963 budget requests for the space tracking networks and the acquisition and reduction of data obtained from spacecraft.

A total of $224,015,000 is being requested by NASA for these categories for the fiscal year 1963.

Of this, $158,410,000 is being sought for research, development, and operations in connection with its three space networks. At total of $65,605,000 is being requested for construction work on the networks.

The $158,410,000 in R.D. & O. funds would be used for the following purposes: Systems development, $15,950,000; network operations, $67,815,000; equipment and components. $74,645,000.

The $65,605,000 being sought for construction would be expanded at 12 sites in the United States and abroad where tracking and data acquisition are handled. These funds would be spent for various operations facilities, laboratories, computation buildings, antenna and instrumentation systems, and range control, safety and support systems and equipment.

NASA's 44-station space networks are composed of three stations in the deep space network, used for lunar and interplanetary flights; 16 stations in the manned space flight network, commonly referred to as the Mercury network;

and 25 stations (12 optical and 13 electronic) in the satellite network. Two additional stations for the satellite network are now under construction and a third is being requested in the 1963 fiscal year budget.

Mr. HECHLER. Mr. Buckley, we are pleased to have you with us this morning and you may proceed in your own way.

STATEMENT OF EDMOND C. BUCKLEY, DIRECTOR, TRACKING AND DATA ACQUISITION; ACCOMPANIED BY RALPH ULMER, DIRECTOR OF FACILITIES COORDINATION; AND DAVID WILLIAMSON, JR., CHIEF, PROGRAM COORDINATION, OFFICE OF TRACKING AND DATA ACQUISITION

Mr. BUCKLEY. Thank you, Mr. Chairman and members of the subcommittee.

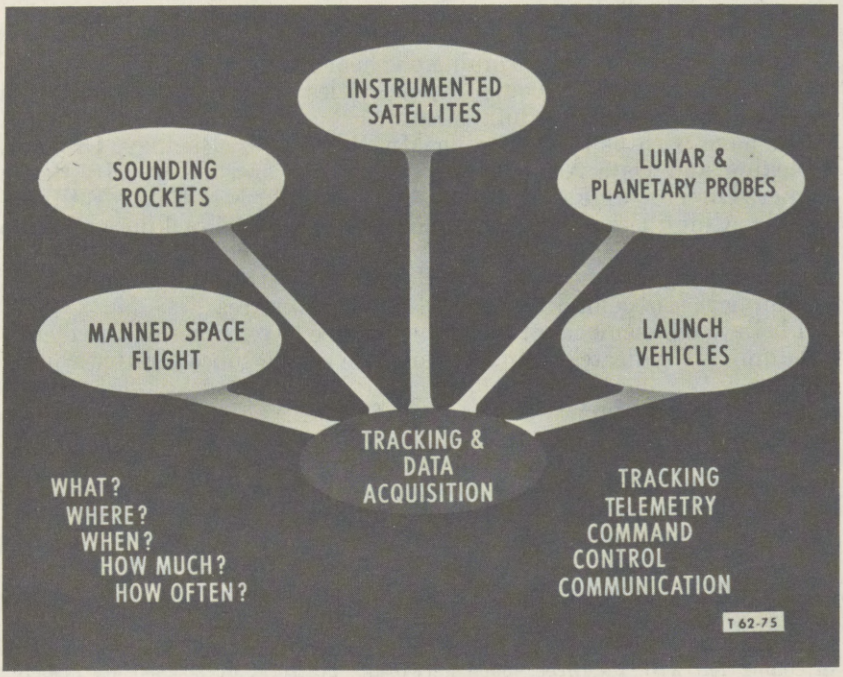

FIGURE 551

With the aid of the first chart (fig. 551), I would like to explain the nature of the services that the Office of Tracking and Data Acquisition provides to the flight programs and projects. It is, of course, absolutely vital in all of the programs that answers to various questions about the spacecraft and its environment be available to the experimenters on the ground for study and analysis. The questions are those in the lower left corner of the chart.

What in that we need to know what is being measured or what functions have been performed operationally by the propulsion system, the control system, etc.

Where is the vehicle? For instance, is it over the North Pole; is it a certain distance from the Earth; or perhaps a certain distance from the Moon?

When in that all events and all measurements have to be tied together to a common time base and all records from the various stations, all computations, had to be referred to that base.

How much refers to the reading of the various instruments in the spacecraft, whether they be measuring some sort of radiation or measuring the magnetic field of the Earth, etc.

How often refers to the fact that through the study and assessment of the received telemetering data, some needed information is provided as to the frequency that certain measurements have to be made. For instance, certain measurements would have to be made oftener, perhaps to the exclusion of other less needed measurements. Another illustration would be the indicated need to make more weather photographs of a particularly severe hurricane.

In order to get these answers, we provide the functions shown on the right side of the chart: tracking, telemetry, command, control, and communication.

By tracking we mean the determination of the position in space of an Earth satellite, of a probe to one of the planets, or a capsule carrying one of our astronauts. Telemetry refers to the remote metering of various measurements, such as the temperature or blood pressure of an astronaut or the condition of his capsule, and the transmitting of this information back to Earth. Command refers, as the name implies, to the function of issuing instructions, for example, telling equipment within the spacecraft to turn on or off, telling the spacecraft to take weather pictures at some chosen time, or ordering it to change orbit or to return to Earth as desired. Control, on the other hand, is the ability to direct the functioning and operation of the entire network of stations that accomplish the tracking, telemetry, and command. Communication is the function of transmitting information, instructions, or decisions between various points in the network, the control center, the launch area, and the various remote stations.

This tracking and data acquisition support must be provided to the manned space flight program, also to the sounding rocket program, for which the majority of launchings take place at the Wallops Island Station off the coast of Virginia. We must support the various Earth satellites, scientific satellites investigating the parameters and phenomena of space, and the meteorological and communications satellites which are assuming greater and greater importance in our program. We support the lunar and planetary exploration missions; and finally, for the NASA development flights of launch vehicles such as the Saturn, the Scout, and the coming liquid Novas, we must see to the provision of the instrumentation that will again give the answers of "what," "when," "where," "how much," and "how often." Taking an actual mission, let me demonstrate how these functions were carried out to give us important answers to some of these questions. Knowing that you followed the recent Mercury flight of Colonel Glenn so closely, I have deliberately used the previous successful Mercury flight as my illustration. I can, however, discuss later on, if you desire, details of the Glenn flight from the point of view of tracking and ground support areas.

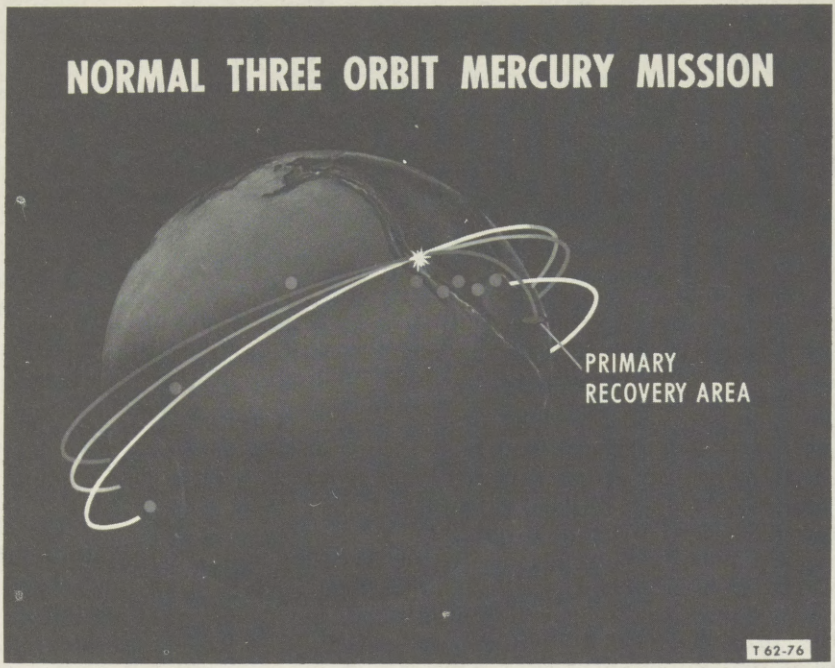

FIGURE 552

This next chart (fig. 552) shows a normal three-orbit Mercury mission. The capsule is launched from Cape Canaveral into a 32½ degree inclined orbit and proceeds around the Earth three times. It then lands and is recovered in the red area labeled "primary recovery." The dots represent some of the stations on the ground that support the mission. All of the stations have two-way communication with the capsule, some have both tracking and telemetering receiving capability, some have only one or the other. Some of the stations also have the ability to send commands to the spacecraft.

The dot at the far left represents a station at Woomera, Australia, which can track the vehicle, obtain telemetered information, and communicate with the capsule. The next station, Canton Island, provides telemetering and communication only. Then Hawaii, Point Arguello, which is at the Navy range in California, and Guaymas, Mexico. We also use a station at the Army range at White Sands, N. Mex., another at Corpus Christi, Tex., one at Eglin Air Force Base in Florida, and one at Cape Canaveral. The control point for these stations, and those on the other side of the globe, is at Cape Canaveral.

Now remember, this is for the normal three-orbit mission. However, the mission known as MA–5, which carried the chimpanzee Enos, was terminated after two orbits. Using the next chart (fig. 553), let me describe what happened on that mission from the point of view of the network, and describe the part that the network played in the decision to end the flight after two trips around the world.

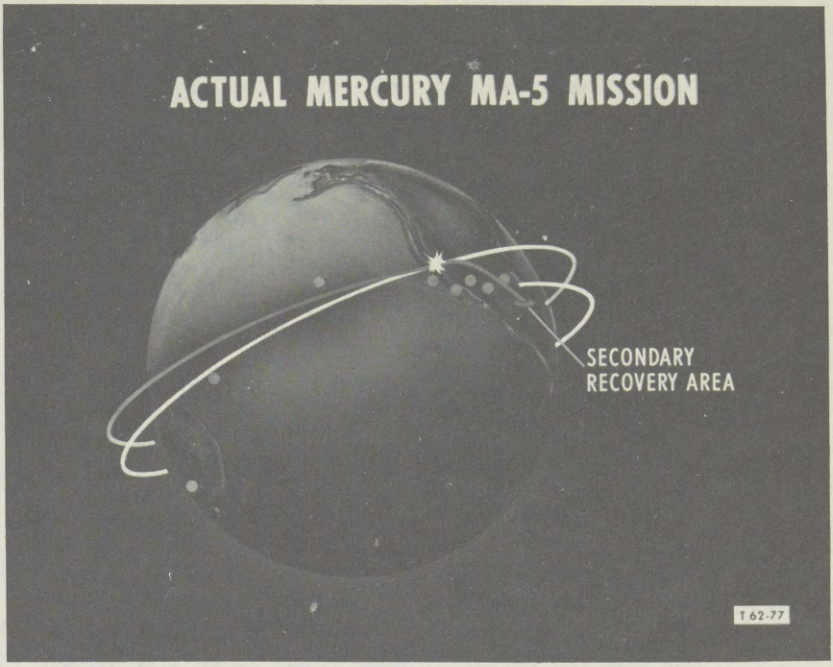

FIGURE 553

The capsule was launched, successfully completed one orbit, and proceeded into the second orbit. Note where the second orbit begins to be shaded in red. It was in this area that telemetered signals seen by the ground-monitoring stations began to indicate that the spacecraft was not operating exactly as desired. This trouble manifested itself as an unusually and abnormally high use rate of the hydrogen peroxide, or H_2O_2, fuel that controls the capsule's attitude in space. The attitude of the capsule must be carefully controlled so that the retrorockets are pointed in the right direction when they are fired to slow down the capsule, thereby causing it to reenter the Earth's atmosphere, and return to Earth as planned.

The station that first noted the high rate of fuel usage was Muchea in Australia, just off the map to the left. This information was obtained through the telemetering equipment. As the capsule passed over the Woomera station, 4 minutes later, the telemetering records were again observed and indicated a continued high rate of H_2O_2 usage. The trend of this high rate was immediately appreciated at the Mercury Control Center in Florida, since all information and data are transmitted and displayed there, virtually instantaneously. As the capsule passed Canton Island, 12 minutes later, the telemetering signals confirmed that the unusual oscillations of the capsule, which caused the high rate of fuel consumption, was still continuing.

The capsule reached Hawaii 5 minutes later on. New readings on the capsule conditions were taken, and the Mercury Control Center

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decided from its accurate and up-to-date information that it would be wise to terminate the mission at the end of the second orbit. The Point Arguello Station on the Pacific coast, therefore, was instructed by the Mission Control Center to command the retrorockets to fire at just the right time so the capsule would land in its secondary recovery area. The decision was made at the Mission Control Center in Florida and could be made there because the information from all these stations is available almost instantly to those directing the mission. The control center knew the exact time to fire the retrorockets, even though this was an abnormal situation, because of the tracking station by station and the continuous computing of the orbit and the continuous display at this control center of the predicted impact point which would result if the retrorockets were fired in any given instant.

The next chart (fig. 554) lists the details of this part of the net-

MERCURY MA-5 NETWORK FUNCTIONS

STATION	EQUIPMENT	RESULT
MUCHEA, AUSTRALIA,	TELEMETRY	• FIRST INDICATION OF HIGH RATE OF H_2O_2 USAGE
WOOMERA AUSTRALIA	TELEMETRY	• CONFIRMATION • TREND CONTINUING
CANTON	TELEMETRY	• TREND ESTABLISHED
HAWAII	TELEMETRY RADAR	• TREND CONTINUING • TRACK UP-DATED • DECISION REQUIRED
ARGUELLO CALIFORNIA	TELEMETRY COMMAND TRANSMITTER RADAR	• TREND CONTINUING • RECOVERY INITIATED • RECOVERY TRACK ESTABLISHED

T 62-78

FIGURE 554

work functions: It lists the stations involved, the equipment used, and the information they obtained that showed us the problem and let action be taken to resolve it. [Pointing to chart.] The Muchea station first noted this high rate of hydrogen peroxide use; Woomera confirmed the trend; and Canton confirmed there was no error in the instrumentation. At Hawaii, the high rate of use of hydrogen peroxide was continuing so we updated the track and reviewed the computation to be sure we knew just where the capsule was and where to fire the retrorockets. Then California commanded retrofire and the recovery was initiated. As the capsule came down from orbit the recovery track was established which allowed the capsule containing the monkey to be picked up out near Bermuda.

Let us compare the MA–5 mission with the recent Colonel Glenn mission of which we all have pretty vivid memories. As you know, somewhat similar problems arose during Colonel Glenn's flight. There were difficulties aboard the capsule and it was only through the telemetering and communications by voice directly to Colonel Glenn that the difficulties could be diagnosed and precautions taken. In the experimental flights that we are undertaking it is very important to have the copilot on the ground. As a matter of fact, it is really a team of copilots. And it is important to give these copilots, by telemetering, the data they need if they are to be of help and, of course, it is vital to provide excellent communication to and from the astronaut.

I have described here only one mission and its support. Let me go on to describe the other aspects of the tracking and data acquisition function.

SUMMARY OF DEMANDS ON T&DA SYSTEMS

	CALENDAR YEAR			
	1962	1963	1964	1965
MANNED FLIGHTS				
MERCURY	5	-	-	-
1 DAY FLIGHT	2	2	-	-
GEMINI		4	6	2
APOLLO	-	-	-	-
SATELLITES				
SCIENTIFIC	12	8	16	20
APPLICATIONS	11	9	8	8
DEEP-SPACE MISSIONS				
LUNAR	3	4	4	8
PLANETARY	2	1	6	4

T 62-79

FIGURE 555

The next chart (fig. 555) summarizes the flight schedules of the individual program offices as presented elsewhere in these hearings. This schedule really only represents a part of the workload—there are launch-vehicle tests, sounding-rocket tests, and spacecraft flown by other agencies that also require support. The spacecraft, shown here, however, are the major customers that must have responsive service. Notice that by 1964 there are some 40 major flights per year. It is unfortunate that each of these types of missions cannot be completely supported with exactly the same tracking stations, the same telemetering stations, the same command stations, or the same control centers. Each type of mission requires some specialized coverage

and support. I will, however, illustrate the integrated and cross use of the various equipments.

I shall now describe the resources we have and the type of support we provide for these various programs, and show you some of the rationale behind the planning that we do in order to insure that adequate coverage is provided for all of the programs.

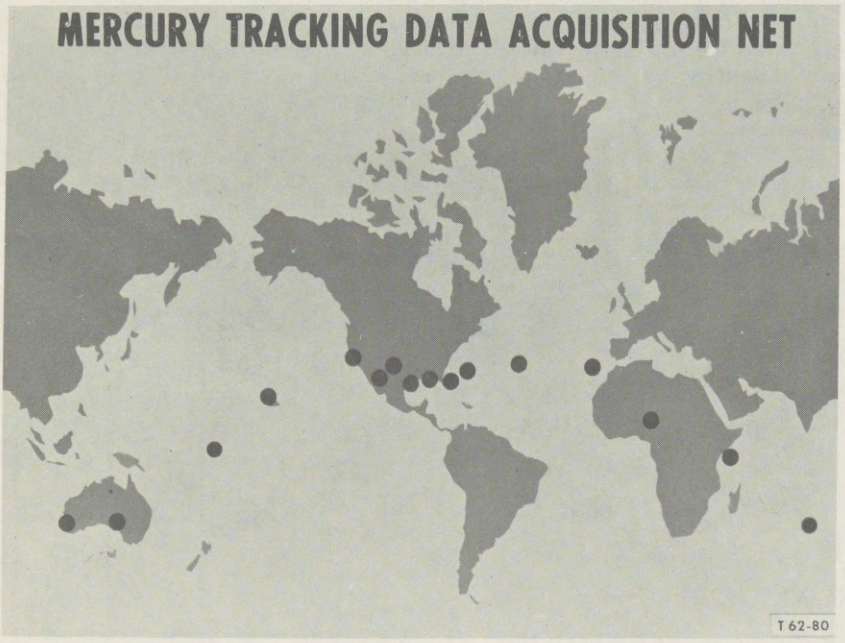

FIGURE 556

The chart (fig. 556) here represents the full Mercury network and includes the stations that were on the back side of the Earth in the sketch used to describe the MA–5 mission. In addition to the stations previously mentioned, there are stations in Bermuda and the Canary Islands, Nigeria, and Zanzibar. In addition, there are two ships: one between Bermuda and the Canaries, which on the Glenn flight was moved down to be in a position nearer Nigeria, and a ship in the Indian Ocean. All of these stations can communicate with the capsule and receive the telemetered data.

The requirements that led to this network included a specification that there be communication with the capsule and reception of the telemetering for 5 minutes out of every 15. Tracking had to provide a very vital "Go-No go" decision as to an acceptable orbit before the capsule reached Bermuda the first time, about 4 minutes after launching. The number of tracking radars and the quality of that tracking that was required stemmed from the specification as to the size of the recovery area into which the capsule must be brought on its return to Earth; that is, we had to know the orbit well enough to predict just where the capsule would land. Most important was the requirement that all data from the tracking and the telemetering stations be

continuously displayed at the Mercury Control Center in Florida. All stations therefore had to be tied together with a real-time communication system. This is the first really truly global network, providing a belt of stations circling the entire world.

The next chart (fig. 557) is a photograph with which I think most of you are familiar by now at the Mercury Control Center at Cape Canaveral. In the foreground are the control consoles where operators

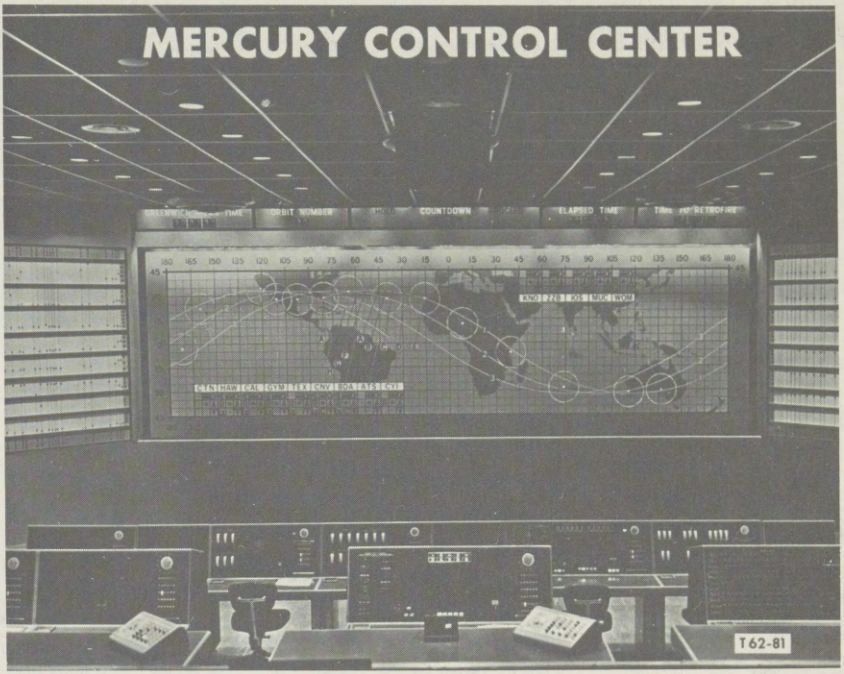

FIGURE 557

sit and evaluate the data that is presented during the course of a mission. The data received at each station is transmitted to this control center as fast as it is received from the capsule.

The large summary plotting board in the center shows the path of the capsule during three orbits and is marked with dots indicating the stations and the surrounding circles showing the actual limit of reception, or the area in which the vehicle is above the horizon, for each station. During a flight, a moving dot shows the actual position of the capsule along with path, and a second moving dot shows where the capsule will land if the retrorockets were fired, as I mentioned a moment ago.

The uniqueness of the Mercury network, the important differences between it and some of the other facilities, comes from the need, wherever a man is involved, to be in closer touch with the vehicle, to have data available very quickly and to hae enough facilities in the right places to cope with any emergencies. Incidentally, the

network worked beautifully for both the MA–5 chimpanzee flight and for Colonel Glenn's flight, as you know. After the capsule passed Bermuda, as it approached each of the tracking stations we compared the predictions as to where the capsule was with the tracking being carried out by that station. We use two criteria in comparing predicted position to actually measured position. One that says it is better than a thousand feet and the other better than a hundred feet. About half of the stations told us that we were predicting position ahead of time to within a thousand feet or better, and the rest was actually better than 100 feet. Of course, this is, if you want to give a little thought as to how well we know the position of a ship crossing the ocean, you will see this is pretty exact information.

Incidentally, this doesn't show the real tracking problem. The real problem is if any of these stations break down in an emergency or a communication to them goes out, for instance, due to propagation, then the quality of this job would not be this 100 feet or 1,000 feet. If everything works you get super results, better results than you need. If it doesn't work quite that well you will be down to something more marginal.

Before leaving the Mercury network, I would like to comment on the dedication, thoroughness, and cooperation of the industrial, Department of Defense groups, and NASA teams which have led to the success of this extremely complex network.

I would now like to cover the networks that provide tracking and data acquisition for the other programs. The next chart (fig. 558)

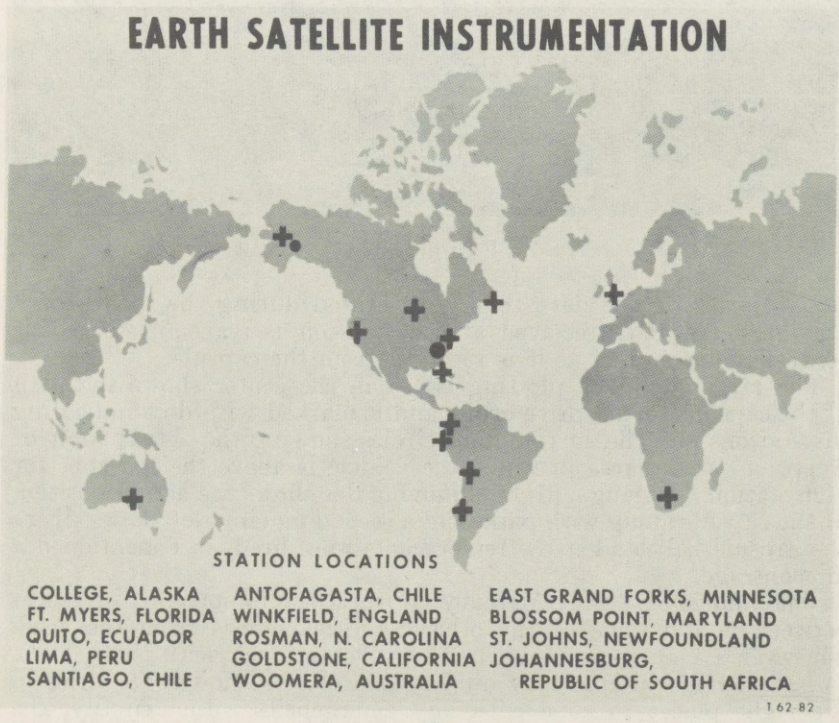

FIGURE 558

shows the locations of the Earth satellite stations. Let me explain the code in the markings. The crosses represent what we call the minitrack stations, which are tracking sites with telemetry reception capability. The dots are two sites having large, 85-foot-diameter antennas to meet requirements for receiving large amounts of telemetry data at these sites.

The minitrack stations are located in Australia, South Africa, England, Newfoundland, Peru, Ecuador, two in Chile, and in the following States: Alaska, Minnesota, Maryland, Florida, and California. The 85-foot-diameter antenna sites are in Alaska and North Carolina.

You will recall that each of the particular spacecraft types has its own tracking and data acquisition requirements. The unmanned Earth satellites are in orbit for days, months, or even years. Because of this, we can afford to use what we call a "sampling" system for keeping track of the satellite while in orbit. In other words, we don't have to keep the minute-by-minute track of it in real time that we do with the Mercury network. We can relax quite a lot and get sample data.

The next chart (fig. 559) discusses the minitrack system which is the particular global network that performs this function of keeping track of the Earth satellite vehicles. I have pictured on the left side of my chart a south polar projection of the Earth, indicating the minitrack stations in Australia, South America, and in the Republic of South Africa. In other words, this is looking at the Earth from the bottom side and picturing three of the minitrack stations only.

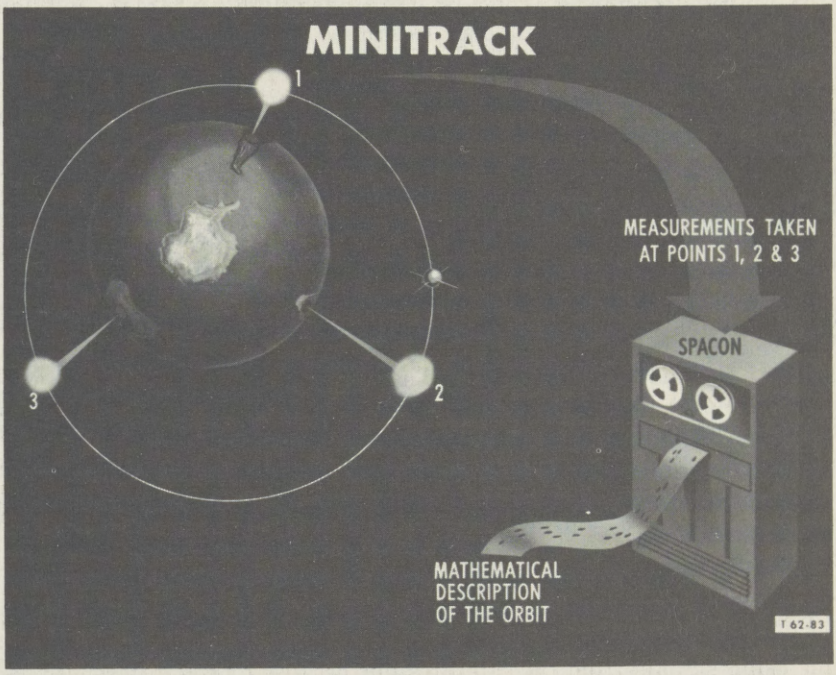

FIGURE 559

I have also pictured the fan-beam type of antenna pattern that is created at these stations. The minitrack radiates no energy as does a radar. It simply has a receiving antenna whose reception pattern is formed in such a way that a very narrow fan results, that is, we know the spacecraft has to be in this very narrow fan if its signal is to be heard. The position of a satellite, carrying a tiny transmitter, is determined with great accuracy therefore as it passes through this narrow fan. These measurements, taken at points 1, 2, and 3, or for that matter, over any of the minitrack stations shown to you on the previous map, are transmitted to the Communications Center (known from its call letters as SPACON) at the Goddard Space Flight Center at Greenbelt, Md. Upon receipt of this information at SPACON, these measurements are fed into the computers located at Goddard and a mathematical description of the orbit is produced.

We need this orbital data for three reasons: We must have a record of just where the satellite was at any time in order to interpret the scientific data recorded by the telemetering system. Secondly, for operational purposes we need to have position data from which we can predict in advance where the spacecraft is going to be in order that we can point antennas in the right direction to pick it up. Finally, the orbital data, if adequately precise, has a scientific value all its own, as from it we can calculate the shape of the Earth more exactly and evaluate the effect on the spacecraft of the unknown forces which are pushing on it out there in space. The minitrack stations provide sampled data that gradually refine the description that can be made of the orbit. Since, however, this minitrack system requires on the order of hours to achieve this refined orbit, you can appreciate why the minitrack system cannot support manned flights where the mission lasts for 4½ hours only and requires immediate position information. That is why we have highly precise radars in the Mercury network that can accumulate such data very quickly.

The chart (fig. 560) is a photograph of the large data receiving antenna which is being installed in Alaska as indicated on the previous map. The antenna is a carefully built parabola, or dish, 85 feet in diameter, covered with a precisely positioned, fine-wire-mesh covering. You will see this type of antenna mentioned repeatedly through the talk, because it is a common tool. I will point out, as I go, the differences of one of these from another even though they look pretty near alike in the photographs. The big dish, as we call it, is a high-quality reflector for the radio signals and focuses them on the very sensitive receiving apparatus mounted above it at the juncture of the quadripod support. The parabola is mounted on an axis that allows it to tip back and forth toward you and away from you in the picture, and all this assembly is mounted on a second axis that allows it to turn in a direction that is right and left in the picture. This mount is designed to let the antenna point from horizon to horizon in any direction without mechanical interferences while following a satellite.

As you can see in the photograph, the antenna is located in a wooded valley, or bowl, in order to minimize any possible interference from radio stations, industrial or mining machinery, or from transmission lines. Now all the minitrack stations have the ability to receive telemetering signals from the satellites but because of the differences be-

tween the various programs which result in different demands from one type of a satellite to another as to how much information is transmitted to the ground, the ground equipment at certain stations is more complex than at others. My next chart (fig. 561) describes why we use these large data acquisition antennas.

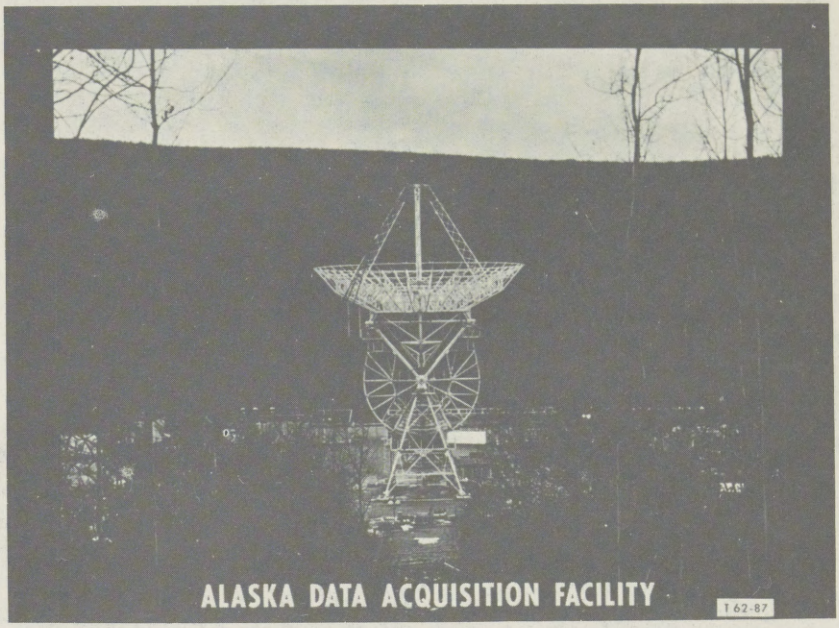

FIGURE 560

Pictured here are three types of antennas. We start with a simple one such as could be used by you or me at home in attempting to listen to a satellite. Then we show the receiving antenna installed at most of the minitrack stations. And finally, the 85-foot-diameter parabolic antenna. We receive a signal from a hypothetical satellite with the smallest antenna of a quality to which we assigned the relative number 1. By using the minitrack receiving antenna system (the one having four helical units), we obtain a signal improvement of 100. However, using the 85-foot-diameter antenna pictured at the right, we improve the quality of this same signal by a factor of 100,000. The antenna achieves this amplification by focusing the minute quantities of radio frequency energy it collects over this large dish to the feed point of the antenna. This advantage can be translated into other terms: The 85-foot antenna can receive a signal from a satellite 300 times farther away than can our simplest system shown on the left. It can also receive a signal having a much wider bandwidth; in other words, a signal containing a greater amount of infor-

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MANHATTAN, KANSAS

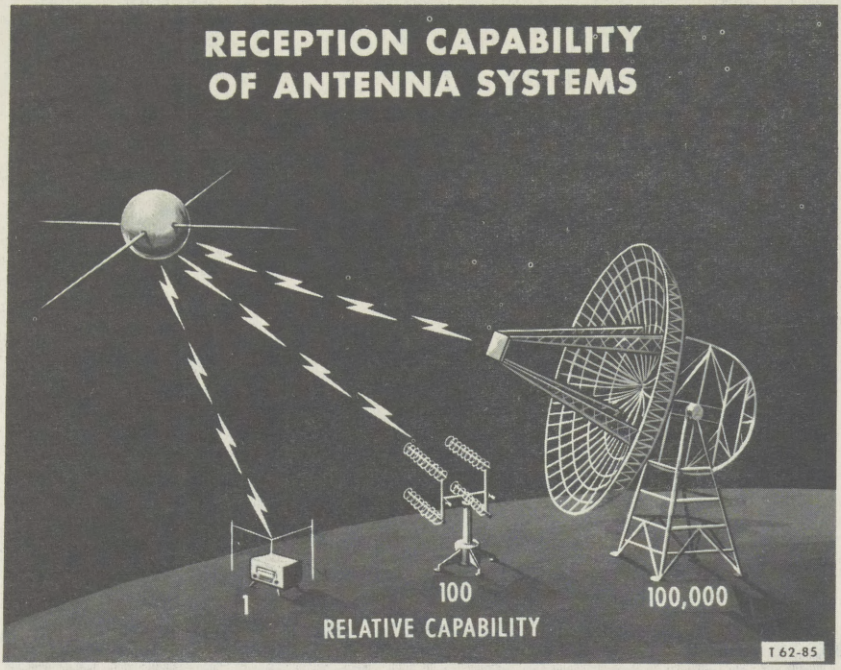

FIGURE 561

mation. A television signal such as is used to bring the weather pictures to the ground is a signal of wide bandwidth. There is a lot of information content to the picture, and hence the need for the dish in Alaska, where the main use of the dish will be for the reception of Nimbus, the meteorological satellite.

My next chart (fig. 562) shows another method by which we obtain tracking information to establish the spatial position of the earth satellites. This is the NASA/Smithsonian Astrophysical Observatory (SAO) optical tracking network. It consists of 12 specially designed satellite-tracking cameras known as Baker-Nunn cameras, named after the two gentlemen who designed this particular instrument. A picture of the Baker-Nunn camera is shown in the upper left-hand corner of the chart. It again has a three-axis mount to permit it to point in any direction and it is actually quite large, standing almost 10 feet high. In the upper right-hand side of the chart is a facsimile of a kind of picture this camera takes. The dots against the dark background represent the light from stars, shown here as the Big Dipper. The traces are made by the satellite moving across the star background. This trace is divided or cut up by the "chopping" action of a timed shutter in the camera. At any point on one of the segments, the angles between the stars and the satellite can be measured to fix the position of the satellite at that particular time, as a comet location would be established by astronomers. The map shows the location of the cameras which are operated by the Smithsonian Institution for

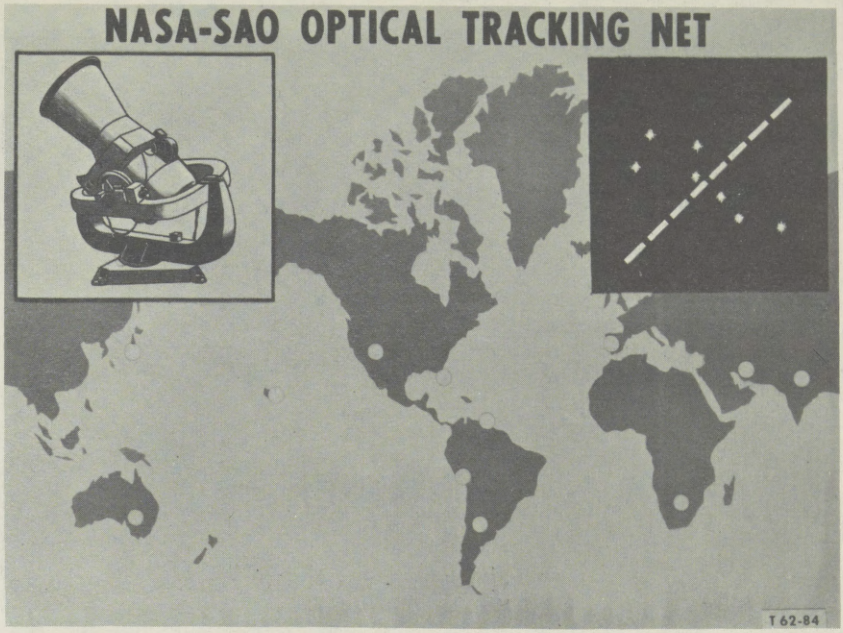

FIGURE 562

NASA. These cameras are currently the most accurate method of fixing the position of a satellite in space. The positional fixes of the orbits derived from these cameras are the standards we use to determine the accuracy of our electronic methods of tracking. These cameras, however, can only be used at dawn and dusk in clear weather, and are limited to close-in satellites.

In summary, therefore, the optical tracking network is a fairly simple and fairly accurate system but major limitations exist as to when it can be used.

Now turning to support of the lunar and planetary missions, the next chart (fig. 563) introduces the Deep Space Network. The three stations listed, Goldstone, Calif.; Woomera, Australia, and the Republic of South Africa, use these specially mounted 85-foot-diameter antennas both to receive data from the spacecraft and to determine its location in space. These dishes look very similar to the one I previously showed you as being under construction in Alaska, but are used in this case because of the need to receive a faint signal from far out in space. Because of the difference in the job they have to do, they also have a quite different mounting and much different electronic equipment.

The Jet Propulsion Laboratory in Pasadena, Calif., operates the Deep Space Net. The computation and communications subcenter for these three stations is located in California. The Jet Propulsion Laboratory has the mission within NASA of the lunar and planetary scientific exploration programs. Remember that this net may support by 1965 over 10 to 12 lunar and planetary shots per year. In addition to the very faint signals from far out in space, these specialized an-

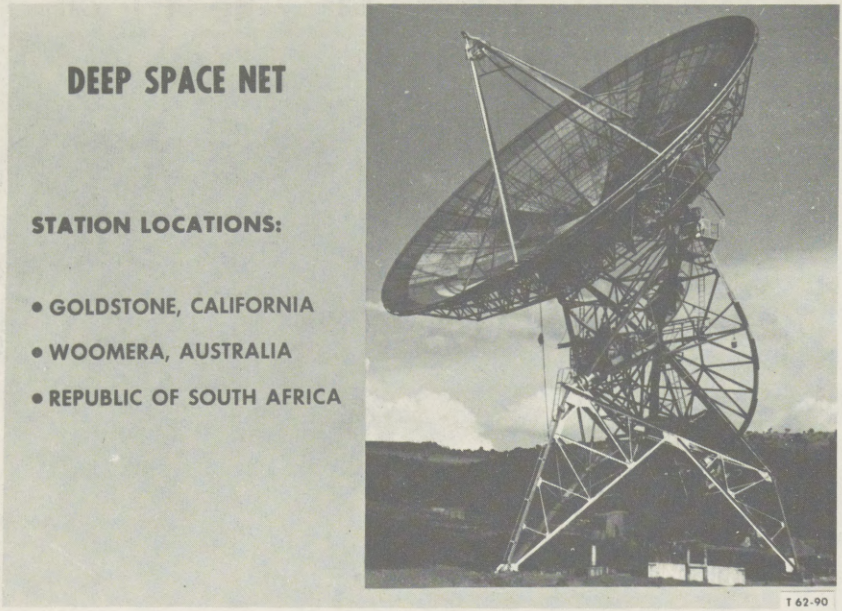

FIGURE 563

tennas allow control to be exercised over the spacecraft during flight, and my next chart (fig. 564) demonstrates one type of control. Incidentally, this also illustrates what happened in our last attempt to shoot to the Moon in our so-called Ranger RA–3 shot. The spacecraft is proceeding as indicated by the dotted arrow. The mission objective is for the spacecraft to land on the moon. However, it is determined from tracking data that if it continues on its present course it will miss the Moon; it will pass ahead of it. Therefore, the course must be changed if we are to reach the point of lunar encounter at the right moment. The magnitude and direction of the required velocity correction is computed. Commands are sent to the spacecraft first to cause it to aline itself in the required direction, and secondly, to fire the auxiliary rocket motor for just the correct time to impart the velocity change required. Its flight path is thus changed and the vehicle progresses along the solid line which should result in a lunar landing. In the case of RA–3, the Atlas had, however, failed to cut off when it was supposed to and the spacecraft was injected into its lunar path at a much higher velocity than planned. So high, in fact, that the maximum correction available was inadequate to put the spacecraft on a collision path with the Moon.

It must be pointed out that the derivation of these measurements requires observation of the spacecraft by these Deep Space Net stations over long periods of time. We do not want to lose sight of the spacecraft because it is on the other side of the Earth. This is why we have three of these stations. They are located about 120° apart around the Earth, in the United States, in Australia, and in South Africa. As a result of the Earth's rotation, one or another of these

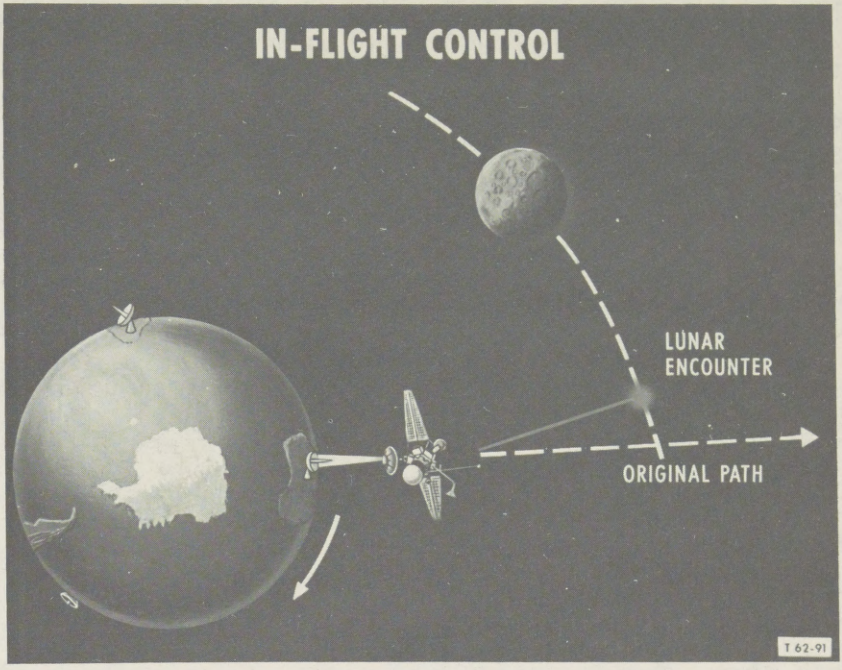

FIGURE 564

stations can observe the spacecraft in flight at all times. As the spacecraft goes below the horizon for one station, it rises above the horizon for the next station. At times such as when a vehicle is close to an encounter with the Moon or a planet, or when the vehicle is transmitting after a landing say on the Moon, we will have to keep a continuous watch on the vehicle. We will want to listen to it continuously. This will, of course, require the full and continuous attention of the station.

Mr. HECHLER. May I interrupt to ask would it have been possible with the recent attempt to land an instrument package on the Moon to change the course sufficiently, through your facilities, to have made sure that that instrument package landed on the Moon?

Mr. BUCKLEY. If the Atlas had not had the unanticipated higher speed, we would have been able, through the use of our equipment, to make the correction we believe that would have allowed it to land on the Moon and the telemetering signals that were going to be transmitted back again to be received by these dishes would certainly have indicated such a landing.

Does that answer your question, sir?

Mr. HECHLER. Do you think the point would be reached where your facilities could have been developed to a degree that would have been able to overcome that problem, the overspeed of the Atlas?

Mr. BUCKLEY. This is a question of the design of the spacecraft, as to how much fuel you can put in the spacecraft to change the velocity

the required amount. There are, I know, two or three precautions being taken to prevent that happening again. There are precautions being taken to insure that the Atlas will more definitely cut off the next time, but there are also changes being made in the spacecraft, I believe, that will probably add more fuel to it, if possible, so that they can obtain a larger velocity change out there.

Our tracking equipment and the command equipment that goes with it allows the people that have this mission to carry out the capabilities they have built in the vehicle to do things, but it can't go beyond what is built in the sphere.

Mr. WAGGONNER. I think that is the question Mr. Hechler was asking. Can you build a greater correction factor into the vehicle which would allow you to correct more than you were allowed to at this time?

Mr. BUCKLEY. This is a question that should be asked Dr. Newell, and that part of the program, but I believe they are attempting to the next time.

Mr. HECHLER. All right.

Mr. BUCKLEY. My next chart (fig. 565) deals very briefly with the launch area instrumentation. We use the Department of Defense launch ranges and their extensive instrumentation whenever possible. However, with the advent of the Saturn and the liquid Nova, and the implementation of the new launch area for the manned lunar landing program at Cape Canaveral, we are increasignly concerned with the requirements for launch area instrumentation resulting from these programs. This involves, as the chart indicates, some of the same

FIGURE 565

types of radar and telemetering receiving equipment that are used in support of the spacecraft missions I have been describing thus far. However, we are now introducing several additional terms such as range safety, some sequential photography so we can tell just what happened, some frequency monitoring interference control, and geodetic control. Range safety covers the devices, electronic or optical, that maintain a very close surveillance of the launch vehicle in the initial phases of its trajectory—those phases during which if there is some failure or incorrect signals in the guidance system could return it dangerously to earth. High-speed photographic monitoring of the various functions and phases of the launch is, of course, a major importance if we are to diagnose the trouble that happens during launchings. Frequency monitoring and interference control equipment maintain surveillance over the immediate launch area to detect troublesome radio signals which could cause interference even to the extent of causing premature destruction of the rocket during its early flight.

Finally, all stations, whether in the launch area or around the world, must be tied together through common timing and geodetic control systems as well as with communications.

It is this communications function that I will cover next (fig. 566). Here is a diagram of our communication linkage that ties together our worldwide networks. These are combinations of telephone, teletype, and microwave installations usually rented from commercial common carriers. We use this communications system to control the

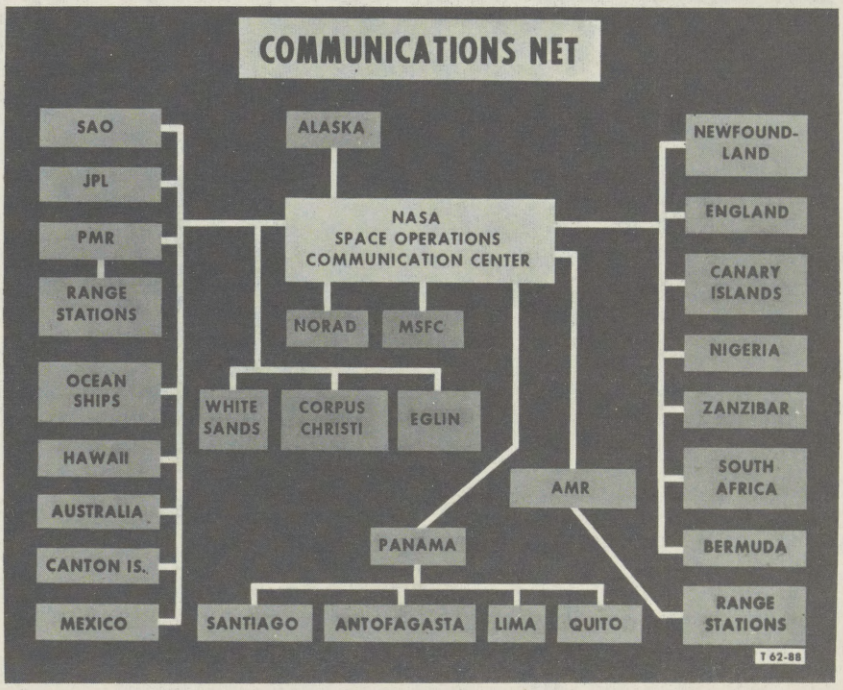

FIGURE 566

networks and for the transmission of data and information. Note that the space communications operations center, or spacon, at Goddard is the focus of the entire system. In the upper left-hand corner we show the link to the Smithsonian Astrophysical Observatory over which information goes out from spacon to SAO to help the cameras locate their satellite targets. Next, the Jet Propulsion Laboratory is listed. This ties in the deep space network that I mentioned earlier. Continuing down, we see various Mercury stations, including the ocean ships. Other Mercury stations are indicated on the right side of the chart as well as circuits to Newfoundland and England. The circuits to Cape Canaveral and its range stations are shown. Toward the bottom of the chart there is a line which fans out to our South American stations via Panama.

Also there you will see a circuit to Norad, the North American Air Defense Command at Colorado Springs. This link between spacon and Norad lets us give the defense people all the information that they need on the satellites we launch and track.

FIGURE 567

My next chart (fig. 567) shows a photograph of a part of the communications center at Goddard Space Flight Center. This is the nerve center where we keep our finger on every station and every vehicle. From here we have direct contact with the stations around the globe and we watch over their functioning and evaluate their well-being with a critical eye.

Now the last resource I would like to mention is an intangible one. It is the cooperation we receive from other agencies and nations. For example (fig. 568), you can see that the Department of Defense either operates or provides many of the stations we use in support of Project Mercury. Similarly, NASA provides tracking or data acquisition support to DOD projects as required.

The next chart (fig. 569) shows some of the statistics of the international participation. Note particularly that one-half of our oversea stations are actually managed by foreign nationals, and that foreign nationals are employed in some capacity at all our foreign sites.

These, then, are the both material and intangible resources we use to support the different types of flight programs. Let me show you (fig. 570) one excellent example of the integrated use of these resources in support of a specific mission. Here is a profile of the Centaur flight. What you are looking at is what we could refer to as a sort of "edge view." You can see the continents of North America, Africa, and Australia, and North America again laid out along the bottom of the chart. The Centaur is launched from Cape Canaveral, at the left-hand side of the chart, and goes into a "parking orbit" 100 miles above the earth. The first station to observe it after that, after Cape Canaveral, is the Mercury station located on the island of Bermuda. It then crosses the Mercury ship in the mid-Atlantic Ocean, the deep space stations in Africa, the Mercury ship in the Indian Ocean, and then it reaches the continent of Australia, where it is again observed by the Mercury and deep space stations. At that point, the Centaur engine burns for the second time, that is, the engine reignites. The guidance system then places the Centaur

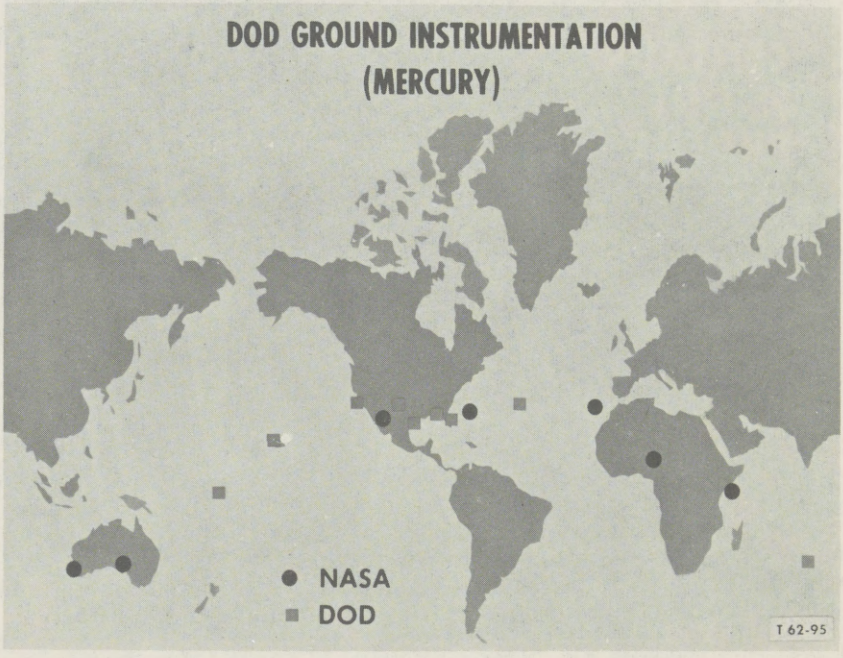

FIGURE 568

FOREIGN GOVERNMENT PARTICIPATION IN DATA ACQUISITION

95% OF FOREIGN STATIONS ARE LOCATED ON CONTRIBUTED LAND

60% OF FOREIGN STATIONS ARE MANAGED BY FOREIGN NATIONALS

100% OF FOREIGN STATIONS HAVE SOME FOREIGN NATIONAL STAFF

45% OF FOREIGN GOVERNMENTS PROVIDE SOME FINANCIAL SUPPORT TO THE STATIONS

T 62-100

FIGURE 569

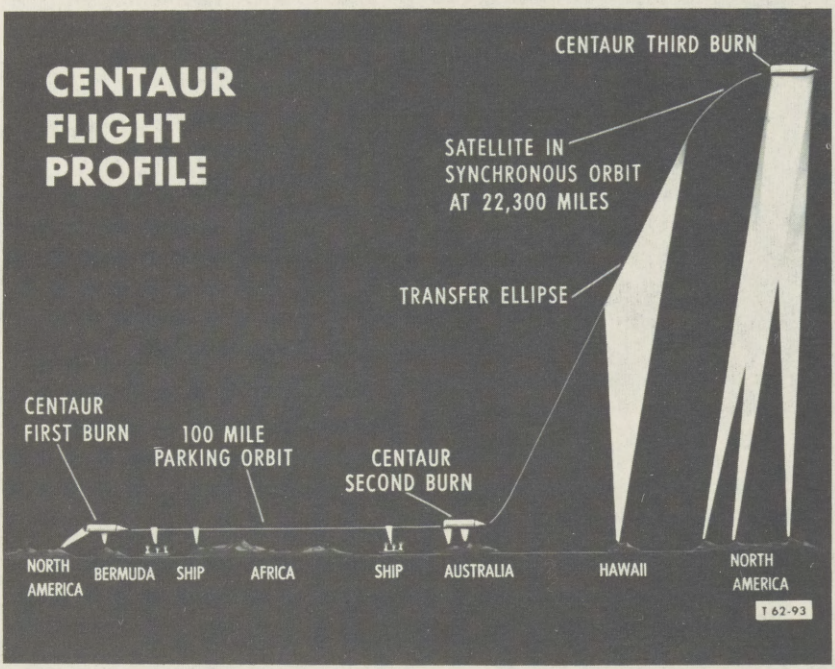

FIGURE 570

into a transfer ellipse. It goes from this "parking orbit" up into a synchronous orbit at roughly 22,000 miles altitude, as is indicated. The Mercury stations at Hawaii and many of the various stations in North and South America receive the signals telling where the satellite is and what it is doing. Before I remove the chart, I would like to point out again that the instrumentation used to support this flight is located on three different continents, on two major islands (Bermuda and Hawaii), and on two ships.

The next chart (fig. 571) names the stations again and shows their affiliations. This is a real example of integrated use of some of the special-purpose instruments that I discussed earlier. During first

CENTAUR GROUND INSTRUMENTATION

EVENT	STATION	AFFILIATION
FIRST BURN	CAPE CANAVERAL	DOD/MERCURY RADAR
	BERMUDA	MERCURY RADAR
SECOND BURN	WOOMERA	WRE/MERCURY RADAR
	WOOMERA	DEEP SPACE NET
THIRD BURN	HAWAII	DOD/MERCURY RADAR
	GOLDSTONE	DEEP SPACE NET
	POINT ARGUELLO	DOD/MERCURY RADAR
	WHITE SANDS	SAO/BAKER-NUNN
		DOD/MERCURY RADAR
	PERU	MINITRACK
	ECUADOR	MINITRACK
	CAPE CANAVERAL	DOD/MERCURY RADAR
		DOD/AZUSA

T 62-94

FIGURE 571

ignition of Centaur near Bermuda, we are able to get the required data by the use of the existing Mercury radars. During second burn near Australia, we use another existing Mercury station as well as a deep space 85-foot-antenna station. During the third burning and in synchronous orbit, we use elements of the deep space net, the Mercury net, the SAO optical net, the minitrack satellite net, and even special-purpose equipment located in the Cape Canaveral launch area. This, we feel, is a judicious and intelligent employment of a variety of specialized equipment to solve a really difficult instrumentation problem.

Not all of our problems, however, can be solved in this way. With my next chart (fig. 572) let me introduce a discussion of several problems and their possible solutions. This chart shows the changes we will make in the manned space flight net to support the 1-day missions.

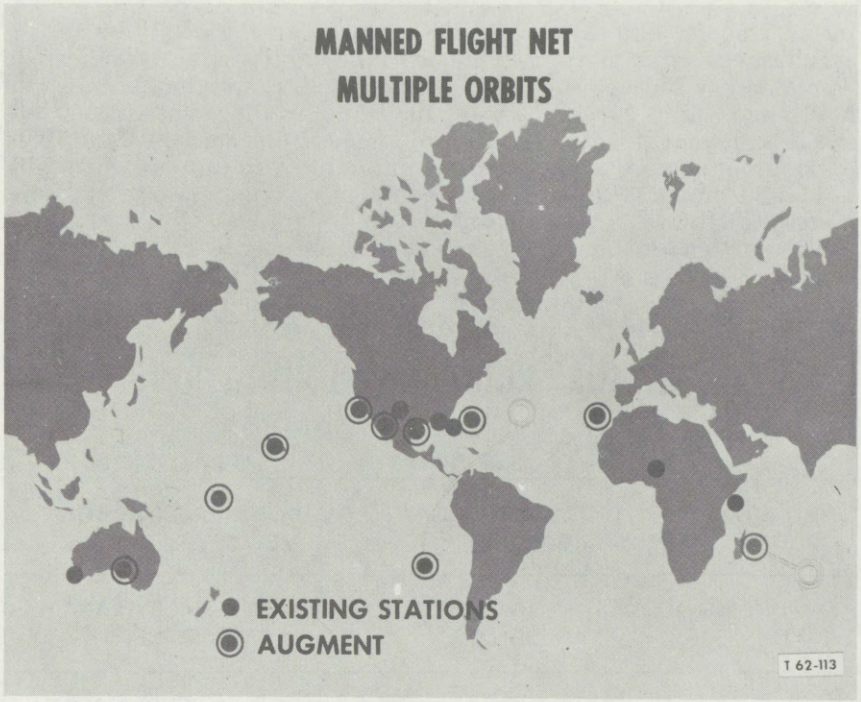

FIGURE 572

First, let us see how the requirements for the 18-orbit, 1-day mission differ from the requirements for the current Mercury flights. For Mercury we had to provide contact and communication for 5 minutes out of every 15, as you remember me mentioning, but only for 4½ hours, the duration of the mission. For the 1-day mission, the current requirements are to provide only 1 contact per orbit, but there are 16 to 18 orbits taking 24 hours, and passing over land and sea areas that are not presently covered by our existing stations. You will notice that this map shows essentially the lineup of stations you have seen before. Some of the orbits of the 1-day Mercury will not pass over a Mercury station in their present position. That is, we could not communicate with the capsule once per orbit. However, the movement of the mid-Atlantic ship to a point in the Pacific west of Chile and the shifting of the Indian Ocean ship to a point near Madagascar would result in the requirement of communicating once each orbit being met.

In other words, taking the original Mercury stations and laying out the full series of 18 orbits over them we found that there was a gap of some 6 or 8 orbits in the middle from about the 5th to the 12th orbit in which there was no contact. However, by moving these two ships each orbit is seen by at least one station.

In addition, the ability to receive more extensive telemetry information will have to be incorporated at many sites as shown by the larger circles. Certain sites not now having the ability to send commands

to the vehicle will have that capability installed. This augmentation is already underway and will continue to fiscal year 1963.

For the Gemini and the Apollo orbital programs we also expect to rely heavily on this existing network of stations, but we do not yet have the final requirements. It is natural that we would lean on a network that works so thoroughly instead of starting off on a brandnew one and going through the troubles of trying to work it out all over again. So we plan to make extensive use of it in the follow-on to the Mercury program. The requirements are being developed right now as a result of the heavy study effort in both programs. We foresee, however, that the rendezvous requirement and the landing maneuver regime will both require very specialized instrumentation mating with the system in the capsule.

The next problem area I would like to discuss is shown on this chart (fig. 573). You will recall that the satellite known as the Eccentric Geophysical Observatory, discussed by Dr. Newell in other meetings before other subcommittees, will have a highly eccentric orbit with an apogee of 50,000 miles; that is, at its farthest distance from the earth it will be 50,000 miles away. This means that the period of revolution is long (in the order of 40 hours); consequently, it takes a long time to go from point 1 to point 2. This means that the number of observations per hour, or per day, is far less than for a more normal, low-altitude satellite with a period of, say, 90 minutes. Because of the far fewer number of observations around the earth,

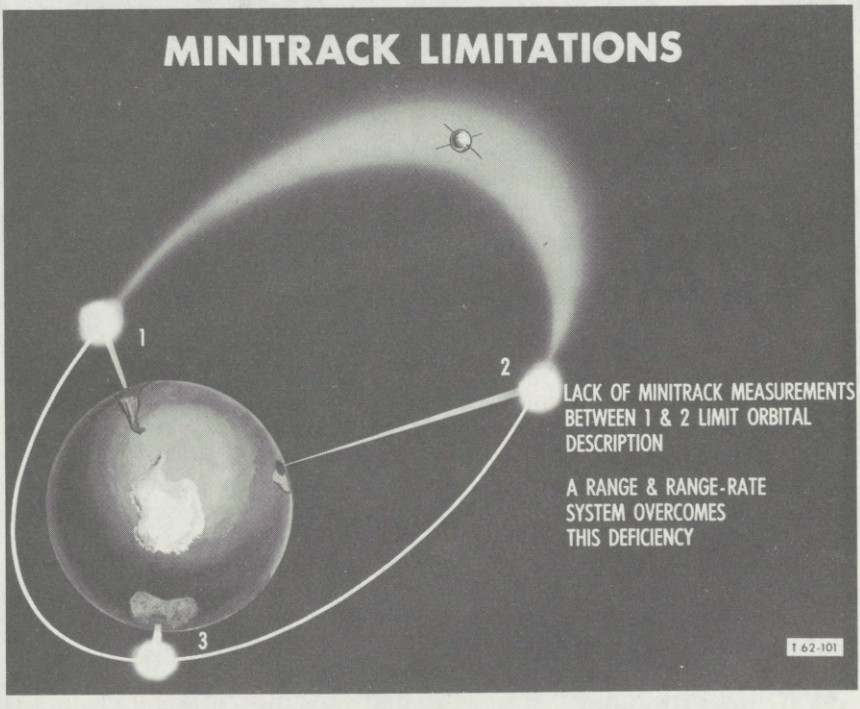

FIGURE 573

it takes a far longer time to determine an orbit, too long to be acceptable. For the purpose of the illustration, we expressed this indefiniteness of calculation that we would get from the orbit with a broad, fuzzy band of color, indicating that the orbit is not defined by the measurements since any curve within this band could represent the true path of the satellite. This means that we can know what is happening through the telemetry receivers all right but are not sure where it is happening.

We are investigating to overcome this limitation a range and range-rate system. My next chart (fig. 574) outlines that system. This

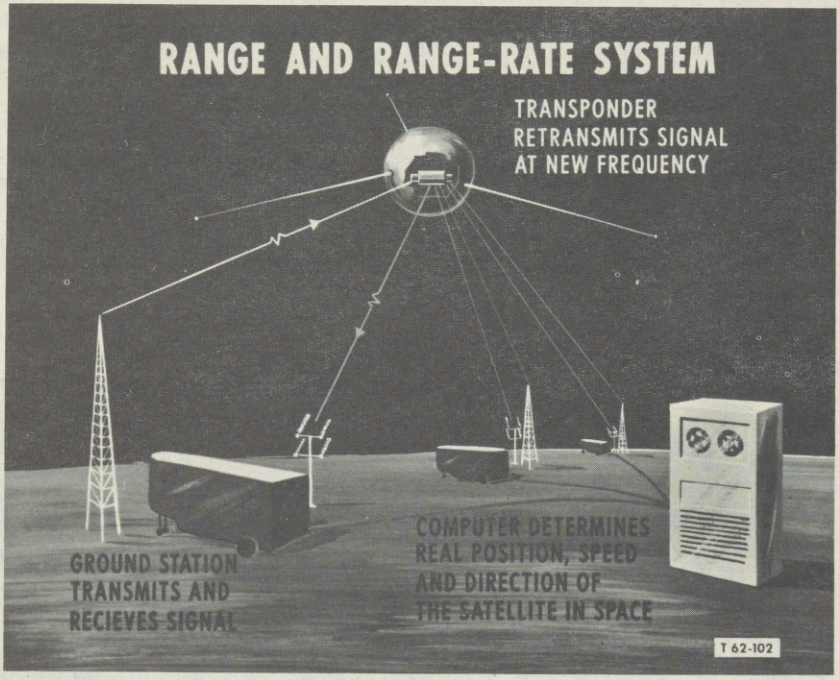

FIGURE 574

system incorporates a special transponder aboard the satellite or, in other words, a small radio device that receives a signal on one frequency and retransmits it back to the ground at another. There it is recorded at a series of three stations which we can call a range and range-rate complex. At each one of these stations the distance from the station up to the vehicle and the radial velocity component of the satellite is obtained. In other words, the distance from that station and the apparent speed of the satellite toward or away from that station. Now, as the computer in the center of the diagram receives information simultaneously from each of the three stations in the complex, it is able to compute the actual position of the satellite in its orbit, the direction it is moving, and how fast it is going in that direction. Such a system will be able to provide rapid, accurate

orbital descriptions when it is operational. We are working on experimental versions of this new tracking system now and will continue during the next fiscal year.

Mr. HECHLER. On that previous chart (fig. 574), I assume when you receive the signal as noted in the lower left-hand corner that the signal comes in better than the artist spells it?

Mr. BUCKLEY. Thank you.

Mr. PELLY. How far apart are those three stations?

Mr. BUCKLEY. We expect they probably will be roughly 200 miles apart. But, on the other hand, there may be geographic limitations. For instance, if we put them on the island of Bermuda we couldn't get them that far apart. In this case the quality of the job we can do will be somewhat limited, of course. But the answer is, roughly, 200 miles.

With the aid of the next chart (fig. 575) I would like to demonstrate that there are some interesting secondary and byproduct types of information derived when we attack some tracking and data acquisition problems. For example, the Jet Propulsion Laboratory recently conducted system tests of the deep space net. The primary objectives were to test several prototype pieces of equipment which had been developed by that laboratory, and to test the combined system and its reliability.

The Jet Propulsion Laboratory did this by setting up an experiment to track the planet Venus for an extended period before, during,

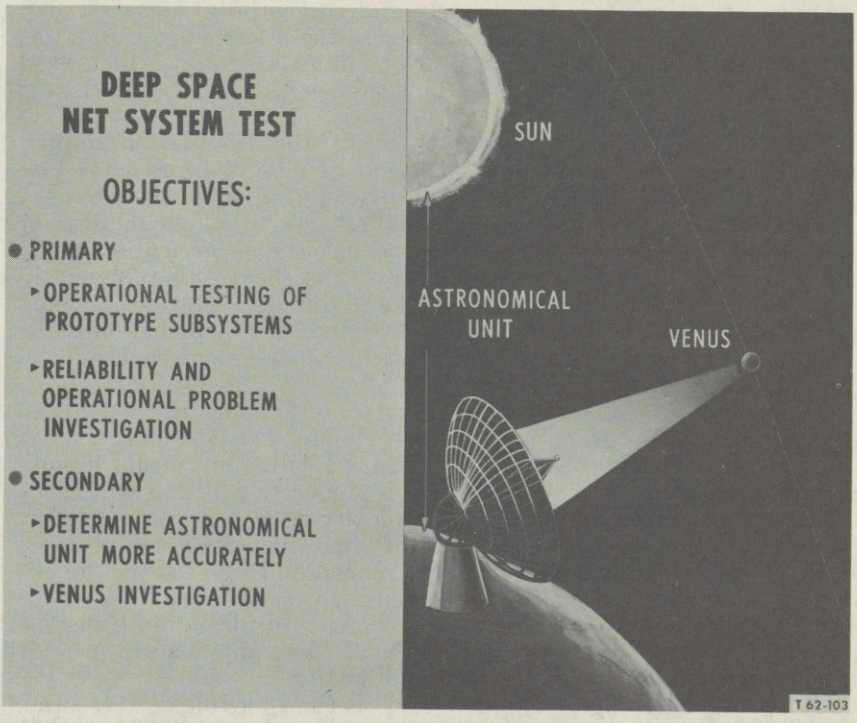

FIGURE 575

and after its closest approach to the Earth in its orbit. The actual distance, when closest, was some 26 million miles. Of course, in tracking a spacecraft far out in space, we have some cooperation; that is, the spacecraft is transmitting a signal to us. In the case of Venus, lacking any such cooperation, we used the planet as a reflector; we had to bounce the signals off its surface. This had been tried by other groups on the two previous approaches during the last 3 years, but the results as to how far away Venus was and whether or not it was rotating were questionable. It was felt that the successful use of all of these newly developed and very advanced components in the day-after-day, week-after-week tracking of Venus at that distance would be a really rigorous test.

Scientifically, there could be some very important results. A better determination of the distance of Venus from the Earth and a better determination of the characteristics of the orbit of Venus around the Sun would provide a better knowledge of what is called the astronomical unit, which is the mean distance from the Sun to the Earth—a sort of basic yardstick for astronomers in their calculations of the spacing between the Sun, the planets, and other stars. Such a result would be of great importance in helping us come close to small and faraway targets in our planetary missions. Other byproducts could be knowledge of the reflectivity of Venus and knowledge about the rotation of Venus; that is the length of the Venus day.

Briefly, I would like to report that the experiment was most successful—an engineering success because the advanced systems and components were used continuously and successfully day after day for 2 months; a scientific success because the astronomical unit was established as 92,956,016 miles, plus or minus 300 miles, which is in accuracy of 3 parts per million. This is some 200 times better than it had been known before.

Other laboratories, including those of the Soviets, attempted parallel experiments during this period of closest approach. You may be interested to know that the Soviets, after first announcing a very serious disagreement with our results, eventually announced their agreement with our values. This experiment was carried out using the 85-foot diameter antenna which constitutes the basic instrument in our deep space net. I should next like to discuss a 240-foot antenna and to explain to you why this is an important step that must be taken, and why we are proceeding with the design of such a huge antenna.

Our present facilities (fig. 576) can only support the lunar and planetary flight program through the early Mariner B launches, starting in 1964. The later spacecraft, *Voyager*, will transmit much more information back to the Earth. It is a bigger vehicle and will carry far more instruments of greater complexity resulting in more information being transmitted per unit of time, including, we plan on, low-level television pictures from the planet, and we need new facilities capable of handling this increased information flow. We have tried pictorially here to represent this increase in formation transmission and reception and the fact that the 240-foot antenna can provide the ground equipment for *Voyager* and *Apollo*.

Now this chart (fig. 577) shows that, as time goes on, our reception capability must be increase to satisfy the growth in mission require-

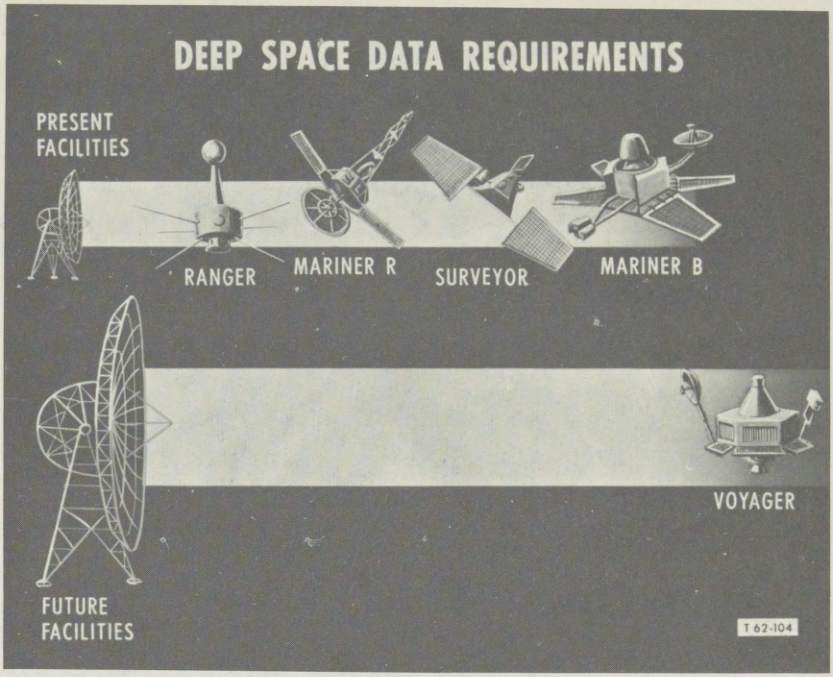

FIGURE 576

ments. The chart shows that these requirements increase by a factor of 200 over the decade. Note that during the next few years we expect to reach the maximum capability (an increase in a factor of 25 from the present) of the 85-foot antenna system. The 240-foot system, however, should provide us a capability adequate to meet the requirements of future spacecraft, including live television from the Moon and television from the planets of reduced quality.

Let me show you a pictorial representation of this very large instrument (fig. 578). The actual details are, of course, still in the design stage, but we have determined its approximate size (which will make it stand about as high as the Capitol Building) and its overall configuration. We plan to build this particular one at Goldstone, Calif., the master station of the deep space network, and have requested funding in the fiscal year 1963 budget.

You will notice that it is very similar to our existing smaller antennas except in size. However, the real differences are the improvements in the electronics, the surface accuracy, and the servo systems' performance that we are planning to get with this large instrument.

We are drawing heavily in this area on our experience with the existing 250-foot dish in Manchester, England, which we have used in our work, and the new 210-foot dish in Parkes, Australia, which we will make use of.

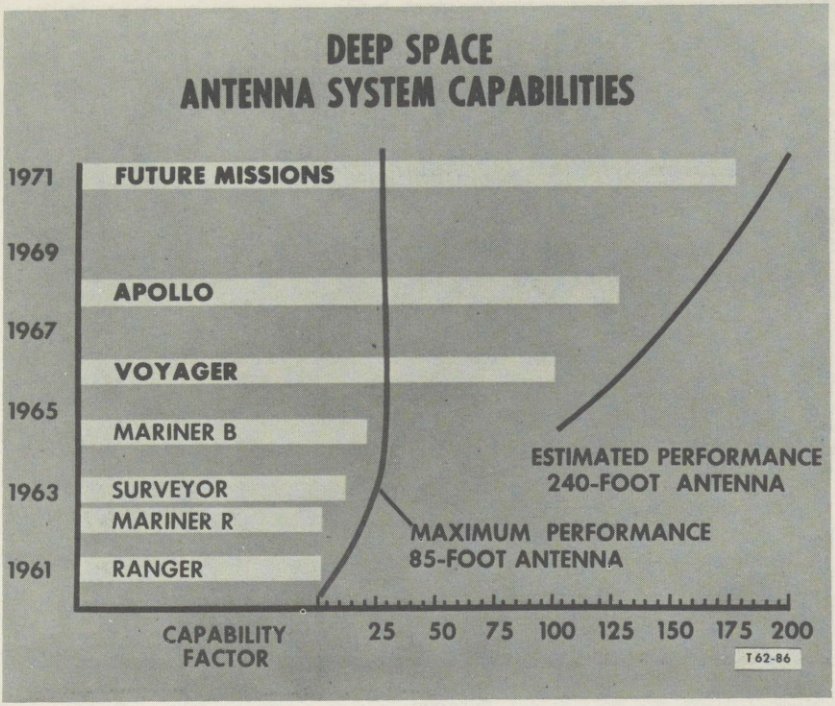

FIGURE 577

Turning to the next chart (fig. 579), let us examine the data requirements generated by the large scientific satellites, and consider a case that will be very real in the year 1964. You see circling the Earth, the Polar Orbiting Geophysical Observatory (POGO) in a polar orbit, and the Orbiting Solar Observatory (OSO), and the Orbiting Astronomical Observatory (OAO) in their near-Earth, low-inclination orbits. You will also note the Eccentric Geophysical Observatory (EGO) which I mentioned earlier, in its highly eccentric orbit. Listed on the right-hand side of the chart are other particulars of the orbit and data collection requirements for these missions. EGO makes one orbit every 42 hours. To satisfy the experimenters' objectives requires 20 hours of data collection per day. The others have a period of 1½ hours. For these, the experimenters' objectives can be realized by collecting data for 15 minutes out of every orbit. These data reception times represent a compromise between the data coverage that is technically possible, regardless of cost, and the data coverage below which the experiments with the satellite program would simply not be justified. This compromise is the result of very detailed study conducted by the tracking and data acquisition engineers and by the scientists who understand the nature and the results they hope to achieve from the experiment planned for the satellites. Knowing the amount of data that must be collected, and knowing the locations

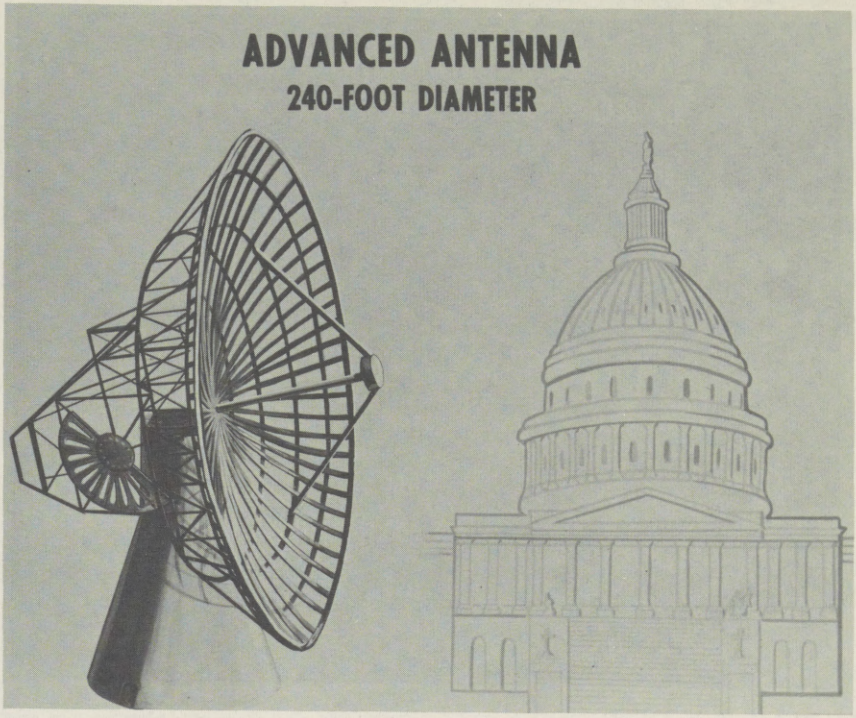

FIGURE 578

around the Earth where this data can or must be received, it is next important to determine where these new facilities should be located.

My next chart (fig. 580) shows the facilities required to support the scientific satellite program I have just mentioned—the projects listed on the left and the facilities on the right. The Rosman, N.C., North Carolina station, which now has only one antenna, is needed for all these programs. To complete the ground facilities in support of the EGO and the OAO, a Far East station is also needed. The station in Alaska to complete the support for POGO is, of course, already available, in the Nimbus station. The second station to complete the support for OSO would also be the Far East station and could therefore be the same station required by EGO and OAO. In this manner you see that the needs of the four programs, from the point of view of locations, can be satisfied with a single new location in the Far East.

Next, it is necessary to examine the workload imposed by these programs on the selected stations. At the Rosman, N.C. site, which supports all four of these large satellite programs, the data requirements cannot be met by the single antenna even if operated 24 hours a day. We therefore are asking for a second antenna at this site to share the workload imposed on this facility. The workload on the remaining two stations does not at present require that a second antenna be available for these programs.

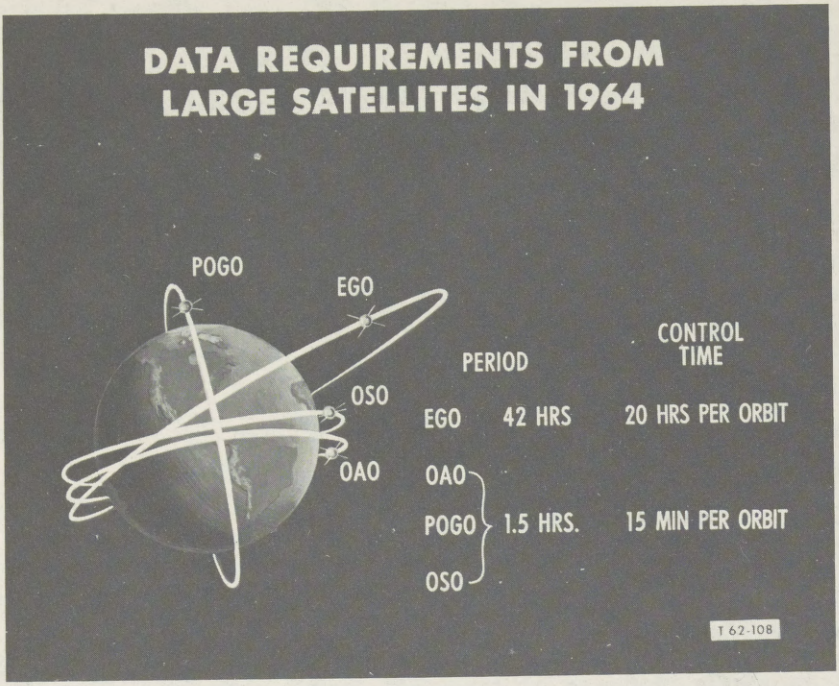

FIGURE 579

FACILITIES REQUIRED TO SUPPORT SCIENTIFIC SATELLITE PROGRAM

PROJECT	FACILITIES	
EGO	ROSMAN,N.C.	FAR EAST
OAO	ROSMAN, N.C.	FAR EAST
POGO	ROSMAN, N.C.	ALASKA
OSO	ROSMAN, N.C.	FAR EAST

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FIGURE 580

This does not complete our facilities requirements, however. We have to consider how many facilities are needed, where should they be, and when must they be operational? This chart (fig. 581) shows, by location, the present and budgeted major data acquisition facilities.

Here we show the satellite network and its expansion that I have just mentioned. In the deep space network we show the three 85-foot antennas at Goldstone, and the new 240-foot dish we are asking for. You will note that we are also requesting an additional 85-foot antenna at both Woomera and South Africa, because of the workload on those stations, as I mentioned earlier. Many parts of the program will require that we keep a continuous watch on a vehicle, if you remember me mentioning it, particularly when it is landing on the Moon or after it has landed or possibly passing through a period of solar flare we want to stay and watch it continuously. This means we would have to neglect other vehicles in the area at that time. We therefore need a second antenna at each of these sites.

You will remember that the composite schedule from the lunar and planetary flight programs is very heavy, particularly in 1964, and there are frequent occasions when more than one spacecraft must be followed from a single station. For example, we will have two Mariners going to Venus and two going to Mars during the same time period. The tracking and data requirements from these flights alone are beyond the capability of the single antenna now at Woomera and South Africa.

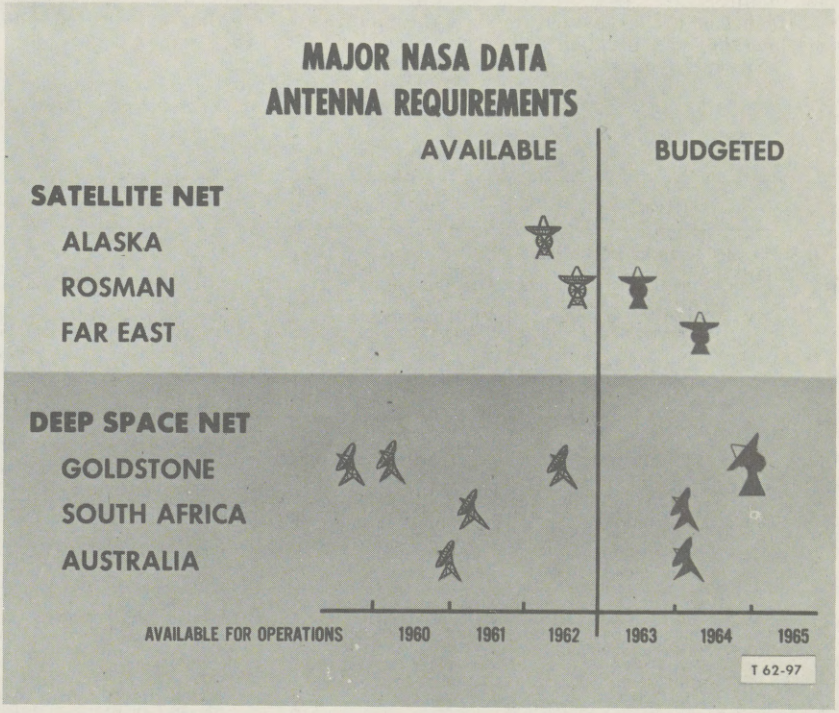

FIGURE 581

Briefly, in conclusion, let me return to my first chart (fig. 551). We have discussed the basic support, or service function, of tracking and data acquisition in my office. We have examined briefly the equipment resources we can marshal to provide this support. We have looked at some of the technical problems and have seen their potential solutions.

Thank you.

Mr. HECHLER. Thank you, Mr. Buckley. You know, you have so many of these tracking and data acquisition facilities all over the world that sometimes it is difficult even when members of the subcommittee have all their antenna out to track them and find out where they are. So we are grateful that NASA has supplied us, at our staff's request, with a list which with graphic simplicity describes exactly where these data and tracking acquisition facilities are and by whom they are operated.

This list has been presented to members of the subcommittee and without objection I would like to put it in the record at this point.

(The list referred to is as follows:)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION.
OFFICE OF THE ADMINISTRATOR,
Washington, D.C., February 27, 1962.

Mr. RAYMOND WILCOVE,
Staff Consultant, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. WILCOVE: This is in reply to your letters of January 30 and February 20, requesting information concerning NASA tracking and data acquisition facilities.

Attached is a chart which itemizes the facilities, where they are located, and by whom they are operated.

Sincerely yours,

PAUL G. DEMBLING,
Director, Office of Legislative Affairs.

Tracking and data acquisition facilities

Location	Site situation	Operated by
I. Earth satellite tracking network:		
A. Optical stations (12):		
Villa Dolores, Argentina	Argentine site	Smithsonian Astrophysical Observatory.
Woomera, Australia	Australian site	Australian personnel.
Curacao, N.W.I.	Private	Smithsonian Astrophysical Observatory.
Naini Tal, India	Indian	Indian.
Shiraz, Iran	Iranian	Smithsonian Astrophysical Observatory.
Mitaka, Japan	Japanese	Japanese.
Arequipa, Peru	Peruvian	Smithsonian Astrophysical Observatory.
Olifontsfontein, South Africa.	South African	Do.
Cadiz, Spain	Spanish	Do.
Jupiter, Fla.	Department of Defense	Do.
Maui, Hawaii	Joint Smithsonian Astrophysical Observatory—University of Hawaii.	Do.
Organ Pass, N. Mex.	Department of Defense	Do.
B. Electronic (minitrack) stations (16 [1]):		
College, Alaska	State-owned site	University of Alaska personnel.
Gilmore Creek, Alaska (85-foot antenna).	Under construction	
Fort Myers, Fla.	Leased site (private)	Bendix.
Quito, Ecuador	do	Do.
Lima, Peru	Peruvian site	Joint NASA, Bendix, Geophysical Institute of Huancayo.

[1] 2 under construction; 1 requested in fiscal year 1963 budget.

Tracking and data acquisition facilities—Continued

Location	Site situation	Operated by
I. Earth satellite tracking network—Continued		
B. Electronic, etc.—Continued		
Santiago, Chile	Chilean	Joint NASA, Bendix, University of Chile.
Antofagasta, Chile	do	Do.
Winkfield, England	British	British.
Rosman, N.C. (85-foot antenna).	Under construction	
Goldstone, Calif.	Department of Defense	Bendix.
Woomera, Australia	Australian	Australian.
East Grand Forks, Minn.	Leased site (private)	Bendix.
Blossom Point, Md.	Leased site (from U.S. Army)	Do.
St. Johns, Newfoundland.	Canadian	Canadian.
Johannesburg, South Africa.	South African	South African.
Far East Station (location not chosen).	Requested in fiscal year 1963 budget.	
II. Deep space stations (3):		
Goldstone, Calif.	Department of Defense site	Jet Propulsion Laboratory personnel.
Woomera, Australia	Australian	Australian.
Hartebeesthoek, South Africa	South African	South African.
III. Manned flight stations (16):		
Cape Canaveral, Fla.	Department of Defense site	NASA, Pan American Airways, RCA.
Coopers Island and Town Hill, Bermuda.	Department of Defense	Bendix and IBM.
Mid-Atlantic ship	Suwanee Steamship Co.	Pan American Airways and RCA.
Indian Ocean ship	do	Do.
Grand Canary Island	Spanish site	NASA and Bendix.
Kano, Nigeria	Nigerian site (leased by NASA).	Do.
Zanzibar	Zanzibari (leased by NASA)	Do.
Muchea, Australia	Australian	Weapons Research Establishment (Australia).
Woomera, Australia	do	Weapons Research Establishment (Australia) and RCA.
Canton Island	Condominium (joint United States-United Kingdom).	Bendix.
Kauai, Island, Hawaii	Department of Defense	Chance Vought.
Point Arguello, Calif.	do	Federal Electric (ITT).
Guaymas, Mexico	Mexican site (private)	NASA and Bendix.
White Sands, N. Mex.	Department of Defense	Land Air Corp.
Corpus Christi, Tex.	NASA	Do.
Eglin Air Force Base, Fla.	Department of Defense	Vitro Corp.

Mr. HECHLER. Before proceeding with the staff questions, I wonder if any members of the committee have any general questions they would like to pose?

Mr. Davis?

Mr. DAVIS. Why is it considered necessary on a Mercury flight to keep in constant communication with the capsule?

Mr. BUCKLEY. Well, first of all, it isn't quite constant. Our goal was 5 minutes out of 15 minutes.

We tried to make it 5 minutes out of 15. In some cases we had a little better than that, in some cases we couldn't quite make that, because of the geographic problem of locating the stations. With a man aboard they decided, at the time the original planning was done, that since they didn't know what effect he would have from zero gravity, and since they wanted to investigate his blood pressure and his heart rate and conditions like that under these conditions to see whether they would be affected, frequent contacts were desirable. They didn't know whether he would be bothered by head motions or

head shakes, where you get very dizzy and nauseated, as the Russian astronaut did. So the combination of the vehicle people, the spacecraft people and the doctors, plus the telemetering and tracking people agree that a proper choice for communication would be 5 minutes out of 15.

Now that we know more about it, we figure keeping in touch with him once every orbit from now on might be enough and that is the way we are planning it. I would say it hinges closely on how new the experiment is that we are attempting. That is the best way to put it, I think.

Mr. DAVIS. That is all, thank you.

Mr. HECHLER. Mr. Pelly?

Mr. PELLY. I wonder if you could give us an idea of the extent of the recent storm damage to the Wallops Island Station?

Mr. BUCKLEY. Yes, I can give you an up-to-date story on it. We can't evaluate the full loss yet. The first time we were on the island was 3 o'clock yesterday afternoon, we were on it for about an hour. The waves washed across the island and tore up the grass and reduced what little sand we had there protecting the island. It really became sort of a beach. It battered some of the buildings about but didn't seem to hurt the launch stands. It did damage to the radars. There was 2 feet deep in one radar building and 1 foot in another. Incidentally, the crew came off at 4 o'clock yesterday afternoon. There was another high tide and again the water came across the island. This time it didn't tear any buildings apart, but it deposited tremendous quantities of sand. The next high tide was this morning. We did have a man on the island but not a large crew. We kept it down, just in case anything was going wrong.

The thing that is making us slow in our evaluation is that we have had several hundred refugees brought into our mainland base, the old Chincoteaque Naval Station there. They were housed last night in the hospital area and various buildings we have there, women, children, and sick people. They were brought over by some 15 helicopters from the various parts of the armed services and our attention until late this afternoon will be undoubtedly the care and feeding of the refugees, I think. Then they will be picked up by the Red Cross.

So we know this much about it, we haven't been able to evaluate the damage yet, though.

Mr. PELLY. I take it from what you say that the damage is somewhat serious?

Mr. ULMER. A very rough preliminary estimate of the damage is somewhere in the neighborhood of $400,000 with a possible additional amount of $350,000 to $400,000 depending on the condition of the seawall, which we are unable to determine at the moment. The contractor will be at the island today to give us a better estimate.

At this point I would like for the record, Mr. Chairman, if it is agreeable with you, to thank the Congress for its wisdom in the basic NASA Act of including a provision that helps us out in an emergency of this kind. I am not sure of the exact reference to the act, I believe it is section 307(b) of Public Law 85–568; it permits any construction funds available to the agency to be used for emergency repairs in a situation of this type, merely by a determination by the Administrator that the repairs are more important than the construction of facilities for

which the funds were originally appropriated. The provision is really paying off in this case, because such a determination will, of course, be made and we will be immediately able to proceed with rebuilding and repairing the damage on the island.

Mr. HECHLER. Since you referred to the wisdom of Congress, perhaps it would be appropriate to identify your full name and title at this point.

Mr. ULMER. Yes, sir. My name is Ralph E. Ulmer, Director of Facilities Coordination in the Office of Programs.

Mr. HECHLER. Any other general questions before we get to the specifics?

Mr. Buckley, I would just like to ask you one or two brief questions to pin down with more precision your responsibilities and jurisdiction.

As I understand it, NASA has around the world these tracking and data acquisition facilities. They are utilized not only for space flight but for certain laboratory and research experiments, is that correct?

Mr. BUCKLEY. Well, Goldstone, of course, is the major center for development from JPL and that specifically is used for scientific experiments.

Actually, all these tracking stations in general, however, are responsive to the programs for the experiments they lay out with the space vehicles that they plan as part of their programs. They are also responsive to requests from DOD, as I mentioned earlier, or will be responsive to foreign countries. They, in general, are not carrying out programs directly, although I did illustrate the one that was incidental to the development and testing of a considerably complex array of equipment at Goldstone.

Mr. HECHLER. This is what I am getting at in my question. Are you responsible and is your office responsible for the tracking and data acquisition facilities that are utilized for laboratory and research experiments as contradistinguished from space flight, itself? I am trying to pin that down.

Mr. BUCKLEY. For laboratory experiments in the field of tracking and data acquisition, yes, sir.

Mr. HECHLER. I see.

Now, so far as data reduction functions are concerned, does that same principle apply?

Mr. BUCKLEY. The data reduction part should be broken into two parts, one is where you prepare the data for handing over to the experimenter, and the second part where he takes this data and analyzes it. In the course of which he may break it down and plot it one way versus another way or add it or subtract it. He does various things in the analysis of the data. The first part of this, preparing it, putting it in the form in which he wants to use it, is my responsibility.

Mr. HECHLER. Any other questions by members before we get to the staff questioning?

Mr. Hines?

Mr. HINES. Yes, sir.

Mr. Buckley, I notice that your budgets for the years 1961, 1962 and 1963 have increased each year by a factor of three or better. For instance, in 1961 it is better than $44 million, in 1962, $94 million and $158 million for this year. Do you anticipate this trend to continue, Mr. Buckley?

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Mr. BUCKLEY. The studies we have made indicate that over the next 3 or 4 years there will be an increasing trend. I don't think it will be at the rate you have found so far, however.

Beyond that, we believe that the cost of facilities will start dropping. On the other hand, the cost of operating the facilities would stay level because the facilities would stay in existence. So we would say that there would be a peak then in about 3 or 4 years.

Mr. HINES. Would you say in the years 1966 or 1965?

Mr. BUCKLEY. Yes, sir.

Mr. HINES. I see.

Could you tell us, Mr. Buckley, over the period of time that you have been building this network—who have been the prime or the outstanding contractors, both domestic and foreign? Can you tell us that?

Mr. BUCKLEY. For the Mercury network, the prime contractor was Western Electric, aided by subcontractors which included Bell Laboratories, IBM, and Bendix. Bendix itself has been a major contractor in building Minitrack stations. The Alpha Corp., Collins, and Blaw-Knox have supplied parts of the deep space network. Now these are the construction contractors, is this what you are referring to?

Mr. HINES. I am referring not only to that but also the systems designers and the equipment and component builders, too.

Mr. BUCKLEY. That would hold for that part.

Mr. HINES. I see.

Mr. BUCKLEY. There will be other contractors for operational purposes, however.

Mr. HINES. Yes. Would you name those?

Mr. BUCKLEY. Yes, sir. The Minitrack stations are operated some by Bendix and some by foreign contractors. The Mercury stations are operated some by Bendix, some by foreign contractors, one of which is the Weapons Research Establishment which is part of the Department of Supplies in Australia; and the Department of Defense groups that are helping operate the Mercury stations. They have subcontractors, which include Pan American and RCA, as you know. Chance Vought is running a station in Hawaii; Federal Electric stationed at Point Arguello on the west coast; Vitro is stationed at Eglin Air Force Base; a company called Land-Air that is operating two stations, one at White Sands and at Corpus Christi. The Bendix is operating the deep space station at Goldstone, but the other two deep space stations, the one in South Africa is operated by the Australians previously mentioned, and the one in South Africa by the South African group known as CSIR.

The optical group, as I mentioned earlier in the talk, is the—12 optical stations are operated under grant by the Smithsonian Institution here in Washington.

Have I covered them all?

Mr. HINES. Yes.

May I ask this with reference to your presentation? You mentioned spatial reference of satellites in space. What is the correlation between spatial identification and reference in space and ground reference? There must be a correlation here to get a common criteria.

Mr. BUCKLEY. I am not sure I know just what you mean, Mr. Hines, except the orbital data for all of these is collected and it is referred

to a set of coordinates based on the center of the Earth, and these are prescribed as mathematical paths around the Earth, and this is what I meant by the coordinate system that describes the position of it. That is what I meant by the spatial coordinate system.

Mr. HINES. This is what I wanted to get. It occurred to me, in reading your statement, that by spatial reference you were talking about a time reference rather than a position reference.

Mr. BUCKLEY. No, sir.

Mr. HINES. This makes it clear, that you were referring to a position reference.

Mr. BUCKLEY. Yes, sir.

Mr. HINES. That is all I have at the moment, Mr. Chairman. I would like to continue later, if I may.

Mr. HECHLER. May I ask a question about this Goldstone, this tremendous Goldstone antenna you put in? Are you going to require, after it is put in, any additional facility or development of this in order to fit it in with the Apollo project?

Mr. BUCKLEY. This particular antenna is planned and needed for the Lunar and Planetary program. On the other hand, undoubtedly when the requirements that will be forthcoming as a result of the studies now going on in Apollo; when these studies are completed I believe that the need for this dish will show up at this time.

Now, the basic dish and its electronics, the receiving equipment, would be exactly the same for Apollo, I believe. There will be additions in the telemetering details and displays. That is after the signal is received it is broken down into various parts which become the information about the various experiments or the information about the physiological details of the man's condition, and that type of component will be different between the manned space flight and the scientific program.

Mr. HECHLER. You see, one of the things we are concerned about is, if we are going to invest this much money in such a large antenna, is it going to meet all foreseeable needs in the future for the deep space probes, and for the other things that we know are going to develop?

Can't we make sure now this is developed in a way that we won't have to require expensive modification in the future?

Mr. BUCKLEY. I think in the sense that you are asking the question, sir, I can say they won't need extensive modification. They will need some additions in some detail equipment that is needed by the manned space flight that we don't need at this time for the lunar and planetary programs and we won't until the time comes that it is used for Apollo.

The basic antenna and the basic receiving equipment that goes with it will be the same in both jobs.

Mr. HECHLER. Mr. Hines?

Mr. HINES. I would like to start developing some information on construction that could be involved in your operations.

I am concerned at the moment with the Goddard Space Flight Center and the tracking and telemetry laboratory there, which I think you will find in the construction book No. 1, page CF5–G1.

First I would like to know whether the contractor for this construction has been chosen?

Mr. BUCKLEY. No, it has not.

Mr. ULMER. With one qualification, the design contractor has been picked, and the design, I believe, is completed.

Mr. HINES. May I ask you what firm that is?

Mr. ULMER. I am sorry. I don't have the firm, but we will be glad to put that in the record.

Mr. HINES. Will that be all right, Mr. Chairman?

Mr. HECHLER. Yes.

(Information referred to follows:)

The firm of Voorhees, Walker, Smith, Smith & Haines.

Mr. ULMER. I might add this is an exact duplicate of an existing structure at the Goddard Center so the design was essentially only a matter of reorienting an existing building to another site.

Mr. HINES. Your cost estimate reflects the same previous experience you have had.

Mr. ULMER. That is correct. In this building we have had very good experience.

Mr. HINES. I believe Mr. Wilcove has some questions with regard to this area that he has developed especially.

Mr. WILCOVE. Mr. Buckley, we would like to discuss with you for a while the Bendix contract for the operation of five manned space flight tracking stations. At the present time NASA has a contract with the Bendix Radio Division of the Bendix Corp. for the operation of five Project Mercury stations at Bermuda; Grand Canary Island; Kano, Nigeria; Zanzibar; and Guaymas, Mexico, plus a test and demonstration station at Wallops Island, Va.

On February 2 of this year NASA announced in a press release that negotiations would be held with Bendix and RCA Service Co. for another contract for the 1963–64 operation.

Mr. Chairman, at this point I ask permission that there be inserted in the record the press release.

Mr. HECHLER. Without objection.

(The press release referred to follows:)

[News release, National Aeronautics and Space Administration, February 2, 1962—Release No. 62–25]

NEGOTIATIONS TO BEGIN FOR TRACKING STATION OPERATION

The National Aeronautics and Space Administration will negotiate with two companies to select a contractor to operate five manned spaceflight tracking stations.

Negotiations will begin soon with Bendix Radio Division of Bendix Corp., Towson, Md., and RCA Service Co., Cherry Hill, N.J., on a 2-year contract worth about $10 million. It is for operation and maintenance of the Project Mercury stations at Bermuda; Grand Canary Islands; Kano, Nigeria; Zanzibar; and Guaymas, Mexico. Also included is the test and demonstration station at Wallops Station, Va. The Project Mercury network will also be used in Project Gemini—the follow-on program to Mercury. Gemini is a two-man spacecraft which will conduct rendevous missions (NASA Release No. 61–273).

Bendix has operated these stations for about a year and its contract will be extended until December 31, 1962. The new contract to be negotiated will cover 1963–64 operations.

The two companies were chosen from eight submitting proposals in December 1961.

NASA's Goddard Space Flight Center is responsible for technical operation of the manned spaceflight tracking network.

Mr. WILCOVE. Eight contractors submitted to NASA their estimates or proposals, rather, of costs. I would like to read them into the rec-

ord. The lowest proposal was that of RCA for $7,272,000, followed by Philco Corp., $7,379,000.

Then Federal—is that Electronics Co. or Federal Electric? I have it both ways from NASA.

Mr. BUCKLEY. Federal Electric.

Mr. WILCOVE. Federal Electric Co., a subsidiary of International Telephone & Telegraph, $7,494,000.

Pan American Airways Co., $8,099,000.

Land-Air Co., $10,705,000.

Bendix, $10,772,000.

Western Electric, $12,700,000.

General Electric, $17,210,000.

You note, Mr. Buckley, that Bendix is No. 6 on the list. I would like to ask you this: for the existing contract which became effective, I understand, on July 1, 1961, were any proposals requested from contractors for that contract.

Mr. BUCKLEY. I would like, sir, to have Mr. Williamson here, my Chief of Program Coordination, discuss this matter.

Mr. WILLIAMSON. At the time that the construction phase of the Mercury net was completed—this was the 1st of July, 1961—it was deemed advisable to go to the same people who had installed the equipment to operate it on an interim basis, pending the choice of a long-term operational contractor.

Mr. WILCOVE. What is the size of that contract?

Mr. WILLIAMSON. Approximately $8 million, I believe, at present. This is the inhouse estimate because it has not been firmed up; that is, the extension of it to December 31, 1962, has not been firmed at this moment. I can give you the actual negotiated price through June 30; including fee, it is $5,767,637.

Mr. WILCOVE. How much was the fee?

Mr. WILLIAMSON. Of that, $274,649.

Mr. WILCOVE. That is the estimated cost of the contract for the year July 1, 1961, through June 30, 1962. Is that correct?

Mr. WILLIAMSON. That is correct.

Mr. WILCOVE. According to the press release from NASA, which we inserted in the record, NASA estimated that the cost of the forthcoming contract for the 1963–64 period will be about $10 million.

In view of the fact that four of the eight proposals you received were substantially less than that amount, could you tell me why the contract was not let by advertised bidding rather than negotiation?

Mr. WILLIAMSON. Yes, I can.

The O. & M., the operations and maintenance, of a network of stations supporting a dynamic flight program that changes, that requires installation of new equipment from time to time, in fact on a fairly regular basis, and a good deal of changes—it is still in the development stage, as you recognize—these O. & M. characteristics are not susceptible to specification writing the way you could write specifications for the building of a chair or something of that sort.

Therefore, they are cost-plus-fixed-fee contracts. For that reason we find it impossible to go out on a fixed price type of bid. We go out on what is known as competitive negotiation.

The companies are requested to make their proposals and then the proposals are evaluated under the source evaluation board procedure, with which I think you are familiar already.

Mr. WILCOVE. Among the eight concerns which submitted proposals, there are some, in addition to Bendix and RCA, which have had experience in the operation of the Mercury stations. Is that not so?

Mr. WILLIAMSON. Yes, Federal Electric, Land-Air and, to some extent, Pan American, and parts of RCA as subs to Bendix are involved in a small way now in the Mercury program.

Mr. WILCOVE. Well, as a matter of fact, some of them operate Mercury network stations, do they not?

Mr. WILLIAMSON. Yes, individually. They don't direct them, however; they are not the primes.

Mr. WILCOVE. At Point Arguello, Calif., where Federal Electric Co., has a contract, is Federal Electric a subsidiary contractor?

Mr. WILLIAMSON. From our point of view, the Department of Defense, the Navy, would be the prime in that sense.

Mr. WILCOVE. But, actually, Federal Electric operates the facility.

Mr. WILLIAMSON. Then Federal Electric operates for and at the direction, if you will, of the Department of Defense.

Mr. WILCOVE. The Mercury network facilities at White Sands Station and Corpus Christi—they are also operated by Land-Air Station with DOD?

Mr. WILLIAMSON. With DOD.

Mr. WILCOVE. At Cape Canaveral, you have Pan American Airways Co., and RCA assisting or operating it for NASA and DOD?

Mr. WILLIAMSON. That is right.

Mr. WILCOVE. Well now, could you tell the subcommittee what impelled you to pick RCA and Bendix with which to negotiate? Why not Philco, Federal Electric, and Pan American Airways?

Mr. WILLIAMSON. Maybe I could describe the procedure and that might help answer the question.

The proposals come in, essentially, in two parts. There is a technical proposal which is the description on the part of the company's technical people as to how they proposed to do the job as they see it; they have had time, a good deal of time, to examine the task, visit some of the stations, if required, look at the equipment.

They know what standards of performance are required, particularly in manned flight. Then there is the business side of the proposal which is the labor cost, their proposed means of organizing their company to be responsive to the task at hand and the other business aspects of any normal proposal. These are evaluated by the source evaluation board which is picked by the Associate Administrator, and it is eva'uated in the two parts; that is to say, there is a very detailed technical evaluation and rating system for each element of the job, and there is a similar business evaluation.

The results of the evaluation are then presented to the Administrator, himself, for choice. He chooses based upon the ratings and evaluation of the board and the Administrator in this case chose Bendix and RCA to be negotiated with.

Mr. WILCOVE. According to a letter which I have from NASA in this matter, it is stated, and I quote:

> The RCA proposal, however, contains certain factors that are also appealing.

Could you tell me what these factors were that made RCA so appealing?

Mr. WILLIAMSON. I am afraid not. I wasn't on the board. I think this is a question that we would have to supply for the record, I think.

Mr. HECHLER. Mr. Williamson, how much discretion does the Administrator actually have here? Isn't he pretty much ruled by the recommendation of the board itself?

Mr. WILLIAMSON. Not in effect. He has discretion as he sees fit to exercise it. In effect, the board only presents an evaluation of each proposal, not a recommendation for action.

Mr. WAGGONNER. He can overrule the board if he desires.

Mr. WILLIAMSON. Yes, he may.

Mr. BUCKLEY. Yes.

Mr. WAGGONNER. Of how many members does this board consist?

Mr. WILLIAMSON. The board has six members.

Mr. WAGGONNER. Is it a board named at his discretion or is there an operational procedure that says certain people in certain billets will comprise that board?

Mr. WILLIAMSON. No, in this case it was named by the Associate Administrator, Dr. Seamans. He named the individuals and he has discretion, too, in the choice of individuals. Naturally the boards are made up of the best qualified technical people in the area of the proposals being described.

Mr. DAVIS. Is that board a creature of statute?

Mr. WILLIAMSON. No, it is not a creature of statute. In the terms of the procurement regulation system, it is part of the system when there is negotiated procurement as opposed to advertised procurement.

Mr. WAGGONNER. It is just NASA administrative policy?

Mr. WILLIAMSON. In this case; yes, sir. It is to assure the most competitive procurement and the best choice of the eventual contractor for any particular task.

Mr. WILCOVE. Mr. Williamson, what I have tried to bring out here is that in these eight proposals we have five proposals that are less than the proposal submitted by Bendix, some of them substantially so, and among them, with the exception of Philco, all are contractors who at the present time help operate your Mercury stations.

In other words, they are all apparently experienced. I think you will agree with me that it is important in a field as new as this to broaden as much as possible the base of experienced contractors. You would then have a larger selection from which to choose your contractors. Would you not agree with this, Mr. Williamson?

Mr. WILLIAMSON. I think that it is very fair statement, Mr. Wilcove.

Mr. WAGGONNER. Of course, it is quite possible, too, that this board would be in a position to judge the limitation of these people. It might be that they are bound to other work that they are committed to which would not allow them, because of time and other factors, to produce, in an additional capacity, what they have been producing in some previous job or in some job that might presently be underway.

Mr. WILLIAMSON. This is a critical part of any evaluation.

Mr. WAGGONNER. Their staff might be as limited as NASA's, for example, to perform a particular function. And they are actually judging RCA, Philco, Bendix, and the others as to their ability to deliver that which is proposed within a time limit.

For instance, a pertinent question in this instance would be "Do you have the organization presently available to perform this task?" The answer may be, "No, but we will." The other concern says it has a trained staff which is ready to enter into this project. Time then enters into that, in other words.

Mr. WILCOVE. In line with Mr. Waggoner's question, which is very pertinent, are all the companies which submitted proposals considered capable by NASA?

Mr. WILLIAMSON. I believe so. I would have to check that in detail.

Mr. WILCOVE. Could you supply that for the record?

Mr. WILLIAMSON. I will.

(The information requested is as follows:)

All the companies named above were solicited by the NASA and, therefore, are considered to have a competence in the field.

Mr. WILCOVE. One final question, Mr. Chairman, on the Bendix contract. Do you feel that where it is possible, an advertised bid contract would be preferable to a negotiated contract?

Mr. WILLIAMSON. That is in this case, sir?

Mr. WILCOVE. In any case.

Mr. WILLIAMSON. In this case—since we are talking about it—I would say, "No, it is not possible."

Mr. WILCOVE. Where it is possible, where all factors are the same?

Mr. WILLIAMSON. Yes.

Mr. WILCOVE. It would be more preferable than to negotiate a contract.

Mr. WILLIAMSON. It is NASA policy. In the procurement area, where it is possible without deleterious effects upon the program at hand, we strive constantly to have fixed price advertised procurement.

Mr. WILCOVE. But most of your contracts are in what category?

Mr. WILLIAMSON. In terms of numbers, or dollars, I would—I think in both cases they are probably in the negotiated category. This is the kind of business that development and research is in, when you don't have specifications that you can essentially have manufactured. You are evaluating, not the present capabilities, as much as the future capabilities of the particular individual or company to produce something successful within a time frame that we have essentially committed ourselves to the country to meet.

Mr. WILCOVE. Unlike the situation that prevailed possibly 3 years ago, we do in this instance have a number of companies which have had experience in this field. You have RCA, Federal Electric, Pan American Airways, and the Land-Air Co., in addition to Bendix. All of these have had experience in the operation of Mercury stations.

Mr. HECHLER. Of course, as always, if there is any other information on this that you care to supply for the record, you may do so.

Mr. WAGGONNER. Well, it must be assumed that all of these people who have submitted a proposal here were acceptable because were they not asked for a proposal, a bid proposal?

Mr. WILLIAMSON. Oh, yes.

Mr. WAGGONNER. So we would assume in answer to Mr. Wilcove's question a minute ago that they are satisfactory because I can't conceive of NASA asking a concern for a proposal which didn't have a record of performance.

Is it NASA's policy, either in writing or just generally understood, in cases where specifications can be written in detail, to take bids rather than to negotiate?

Mr. ULMER. This is firm NASA policy.

Mr. WAGGONNER. That is firm NASA policy?

Mr. ULMER. Yes, sir.

Mr. WILLIAMSON. Absolutely immutable, as a matter of fact.

Mr. WAGGONNER. Then that would make pertinent again, and I think it should be in the record, Mr. Chairman, if you have no objection, that NASA present an answer to Mr. Wilcove's question with regard to the appealing factors of RCA's proposal.

Mr. HECHLER. Without objection, so ordered.

(The information requested is as follows:)

Among the factors found appealing by the Administrator in his decision regarding the RCA proposal were the following:

(1) RCA was the only company to offer to absorb changeover costs. (Since the Bendix Co. is the current contractor, these costs were not involved in its proposal.)

(2) Compared to the other proposals, RCA's estimated cost was the lowest. Past experience with RCA cost estimating has been good.

Mr. PELLY. Mr. Chairman, could I ask——

Mr. HECHLER. Mr. Pelly?

Mr. PELLY. If the General Accounting Office reviews all these various items after they have been completed, have they been able to audit some of these contracts?

Mr. ULMER. They have reviewed several; yes, sir.

Mr. PELLY. It must be a very difficult task to do?

Mr. ULMER. Yes, sir.

Mr. WILLIAMSON. Particularly it is a time-consuming one because a contract that has been at large for a number of years and is then terminated has a long history of closure still to go through, as much as 6 months.

Mr. WAGGONNER. I am sure that these prime contractors are having just as much trouble expanding their organization to meet the needs as NASA, in an administrative way, has to meet the need.

So, it is a mutual problem for all concerned, it seems to me, there.

Mr. WILLIAMSON. Very difficult, sir.

Mr. WILCOVE. Mr. Chairman, I ask permission to insert in the record at this point the letter from NASA which was previously cited.

Mr. HECHLER. Without objection, it is so ordered.

(The information referred to follows:)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
OFFICE OF THE ADMINISTRATOR,
Washington, D.C., March 7, 1962.

Mr. RAYMOND WILCOVE,
Staff Consultant, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. WILCOVE: Yesterday you requested by telephone information relating to the selection by the National Aeronautics and Space Administration of companies to negotiate with NASA to operate five manned spaceflight tracking stations. In the NASA news release of February 2, 1962, it was stated that negotiations would begin with Bendix Radio Division, Bendix Corp., and RCA Service Co.

Bendix has operated these stations and its contract will be extended until December 31, 1962. The new contract to be negotiated will cover 1963–64 operations.

The two companies were chosen from eight submitting proposals. You requested the names of the other six proposers and the costs that they estimated in their proposals.

As you know, this will be a cost-plus-fixed-fee contract and therefore the costs estimated by the proposers are not prime consideration for an award. The estimated costs presented by the eight competing companies is outlined below:

Bendix Corp	$10,772,000
General Electric Co	17,210,000
Federal Electric Co. (ITT)	7,494,000
Land Air Co	10,705,000
Pan American Airways Co	8,099,000
Philco Corp	7,379,000
RCA Service Co	7,272,000
Western Electric Co	12,700,000

The Bendix proposal was considered the most realistic by the NASA people who submitted an inhouse cost estimate of $10,738,000. The RCA proposal, however, contained certain factors that are also appealing. For this reason, it was decided to extend the Bendix contractors until December 31, 1962, and to begin negotiation with the two firms. This procedure guarantees continuous operation of the tracking system.

Sincerely yours,

PAUL G. DEMBLING,
Director, Office of Legislative Affairs.

Mr. HECHLER. Mr. Hines?

Mr. HINES. Mr. Buckley, do the data operators and command facility and the telecommunication laboratory at the Jet Propulsion Laboratory come under your jurisdiction?

Mr. BUCKLEY. Yes, sir.

Mr. HINES. I would assume that the criteria that you use for the estimated amounts requested are based upon past experience, such as the cost per square foot of the buildings.

Mr. ULMER. These costs were estimated by the engineering staff at the Jet Propulsion Laboratory using their past experience in construction.

These buildings will be put out on bid, and they both are under design at the present time. Mr. Hechler, here again I would like to put myself in the position of thanking the Congress for giving us authority last year for advanced facility planning and design money. It has been a great help. We have allocated, I think, a total of approximately $6 million for this purpose. Many of the facilities for which we are requesting construction funding in 1963 are under design and will be ready for bid and in some cases ready for award when the 1963 program has been determined by the Congress and the appropriations made. This has been a great time saver.

Mr. HECHLER. We gratefully accept any suggestions as to how to move the space program forward.

Mr. ULMER. This provision has done a great deal of good.

Mr. HINES. I would like to refer to the Far East station now. Mr. Buckley, has a site been chosen for that station?

Mr. BUCKLEY. No, sir.

Mr. HINES. Are you contemplating several sites?

Mr. BUCKLEY. Yes. We have made a study here—mostly a map study and a study of the climate, study of earthquake conditions, and typhoon conditions, and a study of the acceptability of the logistics problem, and from this we have produced a series of sites in the Philippines and Japan and we are going to look at those closer.

Mr. HECHLER. If you have not yet selected a site, do you think it is premature to request $6 million?

Mr. WAGGONNER. It wouldn't be if they were going to put it in West Virginia; would it?

Mr. BUCKLEY. We have a program that we are endeavoring to supply a facility to meet; as a matter of fact, we are hard pressed to meet it, and are going over and selecting a site right now to meet this program that is coming up.

If it is delayed—if it were delayed another year, we just wouldn't meet the programs.

Mr. HECHLER. What is your timing for the selection of the site? For the people that are working on it now, what does this really mean in terms of approximate dates?

Mr. BUCKLEY. We can just barely meet the availability time now. Dave, can you help on the required date on that site?

Mr. WILLIAMSON. The required date, as was shown on the flight schedule, is for the OAO and the EGO flights. Now, EGO is in 1963 and OAO is late 1963, calendar 1963.

Mr. HECHLER. The question I asked referred not to the flight or the need for the facility, but when the site was likely to be selected.

Mr. WILLIAMSON. I think that we are hoping to select a site, and we will assume that it is in a foreign country, this next month or so. Then we have the problem of getting an agreement on the part of the host nation and developing the appropriate relationships there.

These nation-to-nation or agency-to-agency agreements have taken 4 to 6 months to arrange. In the meantime——

Mr. WAGGONNER. Generally what areas in the Far East are being considered?

Mr. BUCKLEY. The Philippines, Okinawa, and Japan.

Mr. WAGGONNER. They are three areas where you are not going to have negotiation trouble.

Mr. BUCKLEY. In a country like Japan this could get involved in whether the Japanese would build the station for us or whether the Japanese would require half use of the station, and so forth.

Actually, because of our program requirements, we will make almost full-time use of this station. We can't do what we have done elsewhere, which is allow the host country to have part use of the station. It is quite possible we could run into a problem on working this thing out.

We haven't official permission, incidentally, to go into Japan yet. We will have to go in there and meet with some of their scientific groups to see how receptive they are and under what conditions they would be willing to operate.

In the Philippines, we would envision using land that is already leased to the U.S. Government there, and that is the land we are checking.

Mr. WAGGONNER. All right. You speak about a need for this facility in late 1963. What is the estimated construction time interval for actual construction once negotiation is completed and once the contract has been let?

Mr. WILLIAMSON. Then 13 to 18 months.

Mr. WAGGONNER. Then you are behind already.

Mr. BUCKLEY. That is right.

Mr. WILLIAMSON. On a normal basis. However, we have built a similar site in Alaska and we are currently building one in North Carolina. We think we can probably shave some time. One of the

things that we have been able to do is to, as the committee knows, let the antenna portion out on contract this year, using the Administrator's emergency funding, or emergency authority.

The actual buildings and utilities for a facility of this kind take around 6 months after construction starts.

Mr. HECHLER. Pardon me. Would you repeat that? I didn't quite hear that last part.

Mr. WILLIAMSON. The actual construction of the buildings and utilities, the necessary roads, take 6 to 8 months, we figure.

The entire station, starting from the minute you just begin to the minute you are operational, runs 13 to 18 months, but we can shave this time by starting in this year as we have our site selection process, getting our agreements set up and hopefully be ready to move after the authorization.

Mr. ULMER. Mr. Chairman, if I may explain this in just a little different manner: What we are saying is that the big bulk of the funding for this station is required early because of the long leadtime required for the procurement of electronic equipment, the antenna, and other equipment. There is a relatively small amount of money, less than $900,000, that is actually involved in building on whatever site you select.

The buildings are not the critical items. The critical item is to get under contract the electronic component and the antenna itself. This should be done promptly irrespective of whatever site may be picked.

Mr. HECHLER. I recognize that, that is why it is important.

Mr. ULMER. This is why the full funding is important.

Mr. HECHLER. I was just raising the question whether it would slow you down if you didn't have enough money for the septic tanks, fencing, and other deferrable items in fiscal year 1963.

Mr. ULMER. Some of that could be deferred, but as you know, it has been our policy wherever possible to include full funding in the budget and only under very unusual cases to go into an incremental type of funding.

We would much prefer to continue the policy that your committee has established over the years, that wherever possible, full funding will be provided for NASA facilities.

Mr. HECHLER. Very wise policy.

Mr. ULMER. I think so.

Mr. HECHLER. Let me refer you to the page in this book on Far East facility, CF–14–E2. Contrasting that with the facility at North Carolina, at Rosman, figures for which are carried on CF–14–F2, I notice that on your Rosman facilities under facility construction modifications, operations building addition, 6,000 square feet at $25.60 per square foot, whereas in the Far East you have this program for $30.50 per square foot.

Now, why should that cost so much more over in the Far East than the Rosman facility?

Mr. ULMER. There is a very good possibility, sir, that this site may come within an area subject to earthquakes. Some additional funds have been added to the building estimate to take care of that contingency. That is a very sensitive building in connection with the operation of the station.

Mr. HECHLER. Things aren't any cheaper over there, earthquakes are more expensive.

Mr. ULMER. It does have an effect on the cost if you have to design for that, yes, sir.

Mr. WILLIAMSON. You will notice at the Rosman facilities it is an addition to an existing building.

Mr. HECHLER. Yes.

Mr. WILLIAMSON. And you find that those tend to be a little less expensive.

Mr. HECHLER. You would need one less wall?

Mr. WILLIAMSON. One less wall and you don't have to go back through your power system, you just expand the wiring from your existing setup.

Mr. WAGGONNER. If you were farsighted enough to start with it.

Mr. WILLIAMSON. Yes, I was agreeing with Mr. Waggonner.

Mr. WAGGONNER. Well, that is the point. Just how farsighted is this proposal? Is it going to be adequate for all foreseeable future type space probes and flights?

Mr. BUCKLEY. The one in the Far East, you mean?

Mr. WAGGONNER. Yes.

Mr. BUCKLEY. Yes, sir; for the programs we have now and we have looked quite a ways ahead. This thing will be a complete finished job for those.

Mr. HINES. In connection with Mr. Waggonner's question, may I ask what you foresee in the future with regard to larger antennas? Is the 240-foot "dish" going to be adequate for every requirement you may have in the future or do you anticipate larger ones? I am talking about really deep space flight programs.

Mr. BUCKLEY. That is rather a far-out question.

Mr. HINES. I agree.

Mr. BUCKLEY. It is beyond any program now laid down by quite a ways.

Mr. HINES. The reason I am asking this is that in selecting the antenna sites and considering the experience that you get out of these different sites, I would assume that you would anticipate their expansion for any future requirement, for instance, for larger antenna mounts, additional support buildings, and so forth. Do you anticipate beyond what you told us an expansion of the existing sites and an increase of the equipment?

Mr. BUCKLEY. In some cases we have examined the land around the area around, such as in the Alaska station, where there will be a Weather Bureau station nearby, and we took that into account. Down in the Rosman site we took it into account. So we are not neglecting it; it doesn't apply in all cases, however.

Mr. WAGGONNER. Actually, the only thing you can look forward to with any certainty there in planning for the future is land acquisition. Because if you start designing mounts, foundations, that sort of thing, for some antenna that you don't know anything about, you are going to spend money that is going to be wasted when that time comes. If you have the land, you can move over and build a new facility cheaper than you can modify the existing one.

Mr. HINES. Are you giving yourself enough latitude not only for increasing the size of the station, but also for modification to the equipment?

Mr. BUCKLEY. We are endeavoring to.

Mr. HINES. This question has to do with—if I may use an example—the Far East station. Do you anticipate contract relationships with local firms?

Mr. BUCKLEY. In the case of the Far East?

Mr. HINES. Yes.

Mr. BUCKLEY. Let me say that in every case where we have a foreign station we make it a matter of policy to have as many contracts as possible with the local people. This is without exception.

On the other hand, to get this particular facility built in time we figure that we will have to do this one ourselves.

Mr. HINES. Using our own domestic contractors?

Mr. BUCKLEY. That is right.

Mr. HINES. You wouldn't go to a Japanese electronics firm?

Mr. BUCKLEY. No. There will be a lot of local site work and naturally we will use indigenous contractors for this.

Mr. BUCKLEY. And we expect to use local people to assist in the operation and have so informed, say, the Japanese, when the thing is finished.

Mr. HINES. Thank you, Mr. Buckley.

Mr. HECHLER. Mr. Wilcove.

Mr. WILCOVE. Mr. Buckley, can we go back to the Far East station? I notice that in the budget you have no funds for the acquisition of land.

Mr. BUCKLEY. If this thing is in the Philippines, it could go on U.S. Government land that is already assigned over there. The U.S. Government apparently has quite a number of pieces of land. We have checked with the services on this. Some of the land is not in use. This is the land that the team is over there now looking at. In every case, as we work out an agreement with the foreign country, they have given us the land, assigned it to us. We assume that this would be the case in Japan. So we have not allowed anything for the land acquisition in Japan, either.

Mr. WILCOVE. Would the same be true in Okinawa, in the event you located the station there?

Mr. BUCKLEY. I believe it would, because I think there is enough land that is devoted to U.S. Government use if we go to Okinawa. We think it is a slim chance, incidentially, of going to Okinawa, because of the high intensity of other radio services in the area, that would make it difficult for us to get the quiet zone we need for these dishes.

Mr. WILCOVE. You anticipate insofar as the acquisition of land is concerned, there will be no cost to the Government?

Mr. BUCKLEY. That is right.

Mr. ULMER. I would like to add that as a matter of policy, land procurements are not requested in a facilities program unless at the time the budget is submitted there is a firm requirement for buying the land. Normally, we do not request funding for land unless we are sure we need it at the time we ask for the facility. If, after a site selection is made, it becomes necessary to buy land, we do have the emergency provisions of the authorization act that allow us to do so. We followed this procedure in connection with the expansion at the Atlantic Missile Range, and in the site selection for the Mississippi

Test Facility. We are hopeful this station will not require the acquisition of additional land.

Mr. WILCOVE. You have a survey team in the field now trying to select a site?

Mr. BUCKLEY. Yes, sir.

Mr. WILCOVE. How large is it?

Mr. BUCKLEY. Three people.

Mr. WILCOVE. Could you put the names of the survey members of the team in the record?

Mr. BUCKLEY. Yes, sir; I will do that.

The survey team members are Messrs. Brown, Fletcher, and Kerrigan of the NASA.

Mr. WILCOVE. Since you had no specific site in mind when you made your estimates on the cost of your site development and utility installations, could you tell us what they were based on?

Mr. WILLIAMSON. Actually, these estimates are based on our experience in Alaska. Alaska is a remote and not terribly easy place to work in. We feel that the Pacific would make a Far East site equally remote. And these are essentially estimates expanded from the Alaska experience, carried over from the Alaska experience.

Mr. WILCOVE. You have $100,000 in your budget estimates for the cost of preparing the site and paving access roads. How would you equate that with your Alaskan experience, seeing as how you haven't picked a site yet in the Far East?

Mr. WILLIAMSON. You try to locate a major facility of this sort, as Mr. Buckley pointed out, in a radio quiet zone, but you try also to locate it near enough major communications lines that you are not completely isolated; these are roads, telecommunications lines, sometimes even the sea could be a communication link to your stations, so that you are not completely isolated. You also have to do intrasite road and paving work and there is a normal amount of roadwork that you have to do between your site and the major highway, for example, to get equipment in.

Mr. ULMER. This is a nominal estimate.

Mr. WILLIAMSON. Based on what we have done before.

Mr. ULMER. Yes, it is a rough estimate based on what we did at other stations. It may well come out 80,000 or 110,000.

Mr. WILCOVE. Or 150,000.

Mr. ULMER. Could be, yes. In our authorization bill you have provided a 5-percent leeway that allows us to make adjustments upward or downward between various NASA centers and stations depending on what the actual prices might be.

Mr. WILCOVE. You might refer to your estimates as educated guesses.

Mr. ULMER. In this case it is probably more than an educated guess because we have built some stations before. If this were our first station I think your term would apply.

Mr. WILCOVE. I presume the same would be true for the $20,000 you have estimated for the water supply and water tanks.

Mr. ULMER. I think your statement would be true for all the utility systems. Mr. Wilcove.

Mr. WILCOVE. Not knowing in advance what the water supply is.

Mr. ULMER. Right.

Mr. WILCOVE. And the same I presume for your fencing?

Mr. ULMER. Correct.

Mr. WILCOVE. For your antenna foundation you have estimated $100,000. Isn't it rather difficult to make any estimate for that if you don't even know the type of ground on which you are going to build?

Mr. ULMER. It is.

Mr. WILCOVE. Where did you get the estimate?

Mr. ULMER. Again, this is a nominal estimate based on the average of similar foundation costs in the stations that we have built.

Mr. WILLIAMSON. There is the other side of the story, too, that you would not locate your station in a marsh or something with underwater—underground streams, rather, because the soil conditions would not allow you to put down a foundation. So to some extent these kinds of prices, the kinds of estimates here, reflect limitations on our choice of sites.

Mr. WILCOVE. Do you have any estimate of what the facility will cost to operate?

Mr. WILLIAMSON. I would like to supply that for the record, if I might. I don't think I have one off the top of my head.

Mr. WILCOVE. I think that would be just as easy to furnish as the other estimates.

Mr. WILLIAMSON. I don't have it with me at this time.

(The information requested is as follows:)

The annual operating cost is estimated at $1.3 million.

Mr. WILCOVE. Those are all the questions I have, Mr. Chairman, on the Far East station.

Mr. HECHLER. Are you still available for a few minutes?

Mr. BUCKLEY. Yes.

Mr. HECHLER. Continue, Mr. Wilcove.

Mr. WILCOVE. In the NASA budget estimate book on page CF14–E1 there is a reference to, and I quote:

Provision for subsequent modification to Cassegrain feed to improve performance as single frequency operation.

I believe you will find it in the third paragraph.

Mr. BUCKLEY. Yes.

Mr. WILCOVE. First, could you give us a definition of what is meant by "Cassegrain feed"?

Mr. BUCKLEY. That is a term from the astronomical world, and describes how the reflectors converge the signal to a focal point. The Cassegrainian system involves a dual reflector system, the large dish plus a smaller one that then brings the receiving point back through a hole in the main dish, rather than having it out in the air at the end of a quadripod. This is what is referred to as a Cassegrainian type of configuration.

Mr. WILCOVE. I gather that represents an improvement in the type of facility when it is added?

Mr. BUCKLEY. It is being experimented on by MIT, in this country; it has been by Bell Laboratories, and others. It allows the complex

electronics to be placed back behind the main dish near the center of gravity of the whole system rather than suspended out in the air at the end of the quadripod. And as you go to more and more advanced electronics, such as the parametric amplifiers, why, it becomes necessary to have this more complex equipment, heavy equipment, back at this basic structural point rather than suspended out in the air. Very advanced electronics use a device called Masers, in which you have liquid nitrogen or liquid helium and so forth circulating past them; it is a very difficult problem to handle that type of environment way out at the end of the quadripod. It is much easier to go to this advanced electronics if it is back behind the main antenna, the center of gravity of the whole system.

Mr. WILCOVE. In your reference to the 85-foot dish you propose to build at the Rosman, N.C., installation, you have a similar reference to provision for subsequent modification Cassegrain feed.

Why don't you incorporate the modification at the present time instead of putting it in later?

Mr. BUCKLEY. There is experimental work going on in various places in the world on the Cassegrainian modification.

Right at the moment, to get this done we would rather build it in the way we know how to build it and not incorporate an experimental device in a thing that we want to have operational and then have to run through an experimental period.

Mr. WAGGONNER. The Cassegrain feed is not operational at the present time?

Mr. BUCKLEY. I know of only one that is operational at the present time. It is being experimented with by a number of universities and industrial firms. So it actually would slow this equipment down if we try to build it in at the moment.

Mr. WAGGONNER. But—excuse me.

Mr. BUCKLEY. Excuse me, sir.

We can and are designing this so that it is not a major change. We are making provisions in the design as we go, so that the cost of putting in this Cassegrain would be about one-seventh of what it would be if we neglected the anticipation of it. We are anticipating it this far.

Mr. WAGGONNER. But it will still cost more to put it in later than to incorporate it now, would it not?

Mr. BUCKLEY. Yes, sir; but we have to meet an operational date with the equipment, too, at the same time.

You would be gambling on the fact that your experimental work would come up with the proper solution in adequate time.

Mr. WILCOVE. I appreciate that, but I notice in your backup budget book that you are including it in the 240-foot dish at Goldstone. I quote: "a folded Cassegrain radio frequency system" is being incorporated into the dish.

If it can't be incorporated in an 85-foot dish because it is so experimental, why are you putting it in the 240-foot dish?

Mr. WILLIAMSON. There is a point, from the text, which I would like to read. [Reading:].

* * * subsequent modification to Cassegrain feed to improve performance at single-frequency operation.

This is one of the critical points. The Cassegrain system, although it improves your performance, improves it only at a given frequency and to develop something that can change frequency quickly, because the various satellites transmit at different frequencies, and that is Cassegrain at the same time, is pushing the state of the art considerably.

Now the deep-space dishes operate at the deep-space frequency. I think that is 2,290 megacycles right now, and also the leadtime on that big dish is about 3 years.

Mr. HINES. In other words, you have a tuning problem.

Mr. WILLIAMSON. It is a tuning problem. Now with the 85-foot dishes that we are proposing here, the non-Cassegrain, the prime-focus-fed, we do have the capability of changing from one frequency to the other, with a minimum workload, particularly work stoppage, shutting down the station and starting up again.

Does that answer——

Mr. WILCOVE. Well, if I understand your explanation correctly; it is more feasible and possibly easier to incorporate it into the 240-foot dish at Goldstone than in the smaller one, the 85-foot dish at Rosman.

Mr. WILLIAMSON. It is also the operational requirements for the Rosman dish and Far East dish. They are closer upon us and they will be at different frequencies for the satellites they will be supporting. With longer leadtime of the 240-foot Goldstone dish, and the single-frequency operation of the deep space missions, we can go ahead and design in the Cassegrain from the start.

Mr. WILCOVE. Mr. Buckley, I would now like to discuss briefly with you the communications net to which you referred in your prepared statement. Could you tell us what the cost was in 1961–62 and your estimated cost for 1963 for the overall operation? That would include your teletype, telephone, and microwave installations.

Mr. BUCKLEY. Do you have that handy?

Mr. WILLIAMSON. If I may refer to the backup book, on page RDO–23–8, we show the line, "Network Communications," for the 3 years.

"Network Communications" is the fourth line down showing the cost in 1961 as around $6.9 million; it jumps in 1962 to $12.3 million approximately, because so many stations become operational during this fiscal year and a slight increase to $13.2 million in fiscal 1963 is estimated.

Mr. WILCOVE. I have estimates furnished me by NASA of $4,720,000 for 1961 and $9,046,000 for 1962.

Mr. WILLIAMSON. Those are the direct contract costs. These are the total operations costs.

Mr. WILCOVE. Mr. Chairman, at this point I would like to insert in the record a list of the contractors from whom the various facilities are leased. They are all leased, are they not?

Mr. WILLIAMSON. They are.

Mr. WILCOVE. And the estimated costs for 1961–62.

Mr. HECHLER. Without objection it is so ordered.

(The document referred to is as follows:)

COMMUNICATIONS NETWORK FOR NASA TRACKING AND DATA ACQUISITION FACILITIES

Fiscal year estimates of payments to contractors for telephone, teletype, and microwave facilities furnished NASA

	1961	1962
Radio Corp. of America	$1,205,000	$2,123,500
Western Union Co	353,000	588,000
Chesapeake & Potomac Telephone Co	93,600	94,600
American Telephone & Telegraph Co	1,348,000	2,673,700
Southern Bell	52,000	81,200
National Telegraph Co. of Spain	24,000	24,000
OTC-Australia (Australian Government agency)	503,000	571,600
OTC-Canada (Canadian Government agency)	87,000	133,800
Australian Department of Supply		600,000
British Post Office	238,000	175,800
Trans-Radio Espanola, Madrid	47,000	20,400
Cable & Wireless		320,000
Western Electric Co		298,000
Bendix Corp	431,000	701,000
Other (miscellaneous contract services)	338,400	640,400
Total	4,720,000	9,046,000

NOTE.—Estimate of contract cost for 1963 fiscal year, $10,000,000.

Mr. HECHLER. Mr. Buckley, and gentlemen, there may be other questions that we would like to submit to you in writing the answers to which you may supply for the record.

We are as anxious as you are to help move the program forward by letting you get back to your jobs, and I think that we have covered the ground sufficiently so that it won't be necessary for you to return on Monday.

Mr. Wilcove?

Mr. WILCOVE. Mr. Chairman, in connection with the costs of the site preparation for the various facilities for which NASA is asking funds for the 1963 fiscal year, and the cost for various parking areas, I ask permission to insert in the record various data gathered by the staff.

Mr. HECHLER. Without objection, so ordered.

(The information referred to will appear in the testimony before the Subcommittee on Applications and Tracking and Data Acquisition of April 10, 1962.)

Mr. HECHLER. Mr. Williamson, you mentioned two of the requirements for establishing these tracking facilities are quiet and the location of the sea. We don't have any sea in West Virginia, but we have a great deal of quiet, we have a lot of experience, and our mountaineers having tracked other things in the wilderness. I make this not as a suggestion but merely to extol the virtues of the State of West Virginia.

Thank you very much, Mr. Buckley, Mr. Ulmer, and Mr. Williamson, for being with us.

The subcommittee stands adjourned until Monday morning at 10 a.m.

(Whereupon, at 12:16 p.m., the subcommittee adjourned until Monday, March 12, 1962, at 10 a.m.)

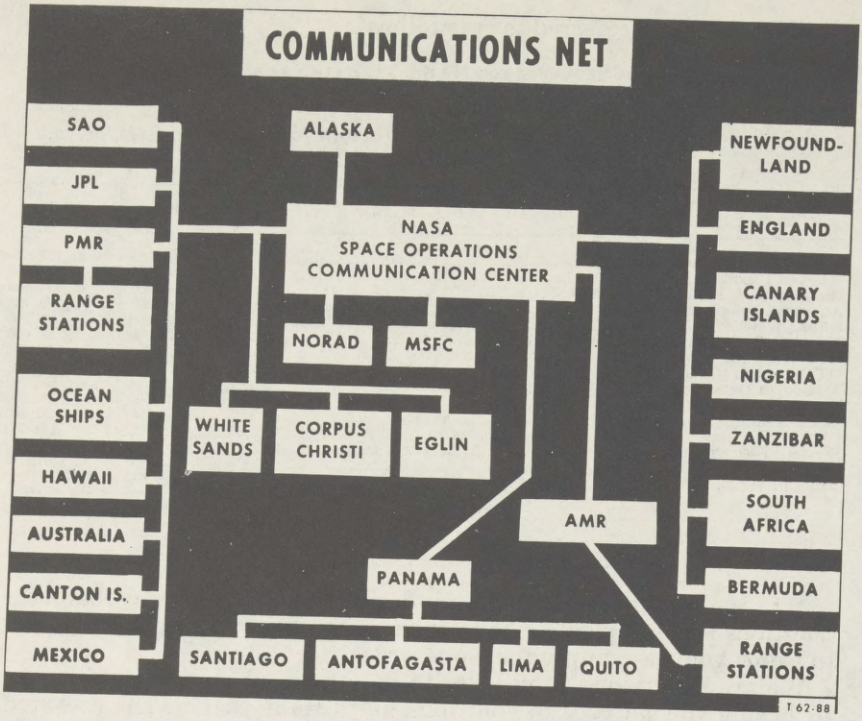
COMMUNICATIONS NET
SAO
JPL
PMR
RANGE STATIONS
OCEAN SHIPS
HAWAII
AUSTRALIA
CANTON IS.
MEXICO
ALASKA
NASA SPACE OPERATIONS COMMUNICATION CENTER
NORAD
MSFC
WHITE SANDS
CORPUS CHRISTI
EGLIN
AMR
PANAMA
SANTIAGO
ANTOFAGASTA
LIMA
QUITO
NEWFOUND-LAND
ENGLAND
CANARY ISLANDS
NIGERIA
ZANZIBAR
SOUTH AFRICA
BERMUDA
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FIGURE 582

1963 NASA AUTHORIZATION

MONDAY, MARCH 12, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON APPLICATIONS AND
TRACKING AND DATA ACQUISITION,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10 a.m., in room 214–B, New House Office Building, Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. The subcommittee will come to order.

This morning we are very pleased to have before our subcommittee the Chief of the U.S. Weather Bureau, Dr. Francis W. Reichelderfer, accompanied by Mr. D. S. Johnson, Director of Meteorological Satellite Activities of the U.S. Weather Bureau.

STATEMENT OF DR. F. W. REICHELDERFER, CHIEF, U.S. WEATHER BUREAU; ACCOMPANIED BY D. S. JOHNSON, DIRECTOR OF METEOROLOGICAL SATELLITE ACTIVITIES, U.S. WEATHER BUREAU

Dr. REICHELDERFER. Thank you, Mr. Chairman and members of the subcommittee, I am very happy for the opportunity to talk again about what has happened since I appeared before this committee the last time in this very revolutionary advance in viewing, measuring, and reporting what is going on in the atmosphere, the meteorological satellite program.

If it is agreeable to you, Mr. Chairman, I will make some general remarks and then I would like to have Mr. Johnson, the director of our satellite activities, speak to one or two visual aids, posters, and since Mr. Johnson is directly in touch with the many things that are going on in our satellite activities perhaps he can assist in answering some of the questions.

Things are moving rapidly in meteorological satellites in our cooperative program with NASA and with DOD and it is indeed quite a problem to keep in touch with all that is going on, not only in Government but in the private cooperating agencies.

In general, the meteorological satellites have functioned remarkably well. We have had four launchings and four successes. That is an excellent batting average.

We are now in the sixth week of obtaining pictures and infrared data from TIROS IV. The sensors and the reporting machinery are functioning very well.

In my last testimony I spoke about what a revolutionary advance this is for meteorology. The meteorologist has been plagued from

the beginning of the science by lack of data of the atmosphere and now is expected to report and predict atmospheric conditions about which there is little or no information.

I want to emphasize this fact because in fact we have less than 25 percent of the coverage, the reports that we need to provide the information required for aviation, for agriculture, and the warnings that the public and the business community really need.

The satellite, by giving, eventually—we haven't attained it yet—by giving a complete picture of the clouds all over the globe and by measuring other things, the infrared radiation and eventually other things that the satellites are capable of measuring, will make up most of the deficiencies that now confront us in trying to give the information of the atmosphere and the weather and climate that is required.

Specifically, one of the principal things that has come out of the use of TIROS satellites in the last year has been new infrared data which gives hope of new factors in forecasting which we can only guess at the present time.

We find, for example, that on successive passes of the satellite, the measurements of infrared radiation from the clouds and from the ground retain certain peculiarities, certain features in the lines of equal values, the isopleths which are undoubtedly significant.

They undoubtedly have hundreds of applications. One illustration is that they may show breeding spots for tornadoes. To give another example, they may help in locating warm waters, pools of warm waters in the oceans that will be of value to fishermen in finding bodies of water most favorable for certain kinds of fish and most likely to have fish.

Another important development is a sharpening of the information about ice features in polar regions. Of course, TIROS satellites do not cover the polar regions completely, but they get close enough to show that they will give us information about leads, open water in the ice packs that cannot be obtained adequately in any other way. This is of great interest to our Canadian colleagues.

One of the major problems of Canada in opening up and using the Far North is to know where they have open water, and the satellites show this immediately. We are now engaged in a close cooperative project with Canada in trying to correlate what they have been able to see from aircraft photographs with what TIROS shows, so that eventually this will mean a great economy in their operations and a great improvement in their knowledge of ice conditions in the Far North.

This has economic implications and we have hopes that Canada will join us in providing some of the ground facilities necessary to make the best use of satellite information.

Still another development in the use of satellite information, and I mentioned this I believe last year, in surveying snowfields, in telling hydrologists how much snow has accumulated for the use of hydrologic engineers and for forecasting the runoff in lands that depend on irrigation. This can be very, very helpful.

Still another new development is the use of the infrared and cloud information, together, over the wide-open spaces of the oceans to determine the heights of clouds. Now, this is important not only for air navigation but also in forecasting and determining how storms are developing.

Heretofore it has been quite impossible to have sounding devices, ocean station vessels, or aircraft reconnaissance facilities, to cover large portions of the Earth's surface. This can now be done by the satellite in a very effective way, not as accurate as we would like, but far more accurately than anything we have ever had before.

Finally, in my general remarks, I would point to the United Nations resolution adopted by the General Assembly in December, sponsored by the United States, in which President Kennedy has taken a very direct personal interest, looking to development of outer space for peaceful purposes but pointing up the program by specific suggestions for the development of international cooperation in the use of satellite information and other atmospheric information for advancing not only knowledge of the atmosphere in the scientific sense, but methods and techniques for long-range weather forecasting and for determining, on a global scale, more about the primary causes of unusually cold seasons, droughts, and so on, and then looking to that more distant day, in general, when there may be greater possibilities of weather control, weather modification.

Of course, at the present time we do know something about small-scale weather modification, but we feel quite sure that this field has not been developed as much as it can be, and that it will not be possible to develop it until we know more about the mechanisms of the atmosphere for the globe as a whole.

Thank you, Mr. Chairman.

Mr. HECHLER. Would you care to have Mr. Johnson proceed?

Dr. REICHELDERFER. Yes.

Dave, would you go ahead with your remarks?

Mr. JOHNSON. I have a number of TIROS IV pictures here that I thought you might be interested in seeing, if you wish, and I could describe a little bit about what is in these pictures.

I think it helps to illustrate further some of Dr. Reichelderfer's remarks regarding the potential of meteorological satellites and actually the use that is now being made of the TIROS satellites.

Would you care to have me describe these?

Mr. HECHLER. Yes.

Mr. JOHNSON. We have all heard much about Colonel Glenn's flight. This particular photograph which I am passing out is a picture taken by the TIROS IV satellite a few hours before Colonel Glenn impacted; it includes the impact area.

A number of sequences of TIROS IV pictures were used directly in preparing forecasts for the space flight. It assisted materially in building up the knowledge of our Mercury forecast team in the meteorology of data-sparse areas over which Colonel Glenn was to fly. Then as the flight came closer to reality, it assisted them in filling in some of these data-sparse areas that you have heard so much about.

Actually, Colonel Glenn was briefed using some of these TIROS IV pictures preparatory to his mission.

I think as we look forward to increased space activities we recognize the increasing scope of the U.S. activities in meteorology that will result, because we certainly are going to be expected to continue forecasting for these space missions.

Mr. HECHLER. Commander Shepard remarked that he hoped the day would arrive when it would not be necessary to hold a flight because of the weather. I wonder if you care to comment on that?

Mr. JOHNSON. Well, I can certainly appreciate his hope for this, and this actually has been a hope in aviation for many years. But so far, it is still necessary to have considerable knowledge of the weather, even to fly within the atmosphere.

I think it may be some time before one can have both aircraft and spaceships where you do not have to worry about the weather.

Giving an example of some of the international applications, this picture was taken by TIROS IV in the vicinity of Malagasay Republic and Mauritius, east of Africa.

It is a picture of a fairly well developed storm taken by TIROS IV. As a result of obtaining this picture, as soon as the forecaster at the TIROS data receiving station saw it, a message was prepared and sent to both the Malagasay Republic and Mauritius giving them the coordinates of this storm and its general nature.

This storm existed in an area which could threaten both these localities, but also an area where there are few, if any, weather stations that would give them a warning of this storm.

This type of information has been sent to many countries in the world, in both the TIROS III and TIROS IV program. If you wish, we do have a very short summary of the TIROS III applications, including the international applications.

Mr. HECHLER. Without objection, that will be placed in the record.

(The information above referred to is as follows:)

SUMMARY OF OPERATIONAL USE MADE OF TIROS III PICTURE DATA, U.S. DEPARTMENT OF COMMERCE, WEATHER BUREAU, JULY 12 TO OCTOBER 12, 1961

An experimental, operational-use program has been in effect since the launching of TIROS III on July 12, 1961. The aims of this program were to make use of the picture data on a real-time basis, to furnish information for incorporation into daily analyses based on meteorological data acquired by conventional means, and to provide warnings of unusual or previously undetected weather to all concerned both in the United States and abroad. TIROS III was also called the hurricane hunter satellite; how well it succeeded in this task is common knowledge.

On more than 50 separate occasions, TIROS III photographed tropical cyclones in all stages of development. Five hurricanes and one tropical storm were seen in the Atlantic; two hurricanes and a tropical storm were seen in the eastern Pacific. Typhoons Kathy through Tilda, nine storms in all, were followed in the central and western Pacific. A total of 50 advisories on these storms, easterly waves, and other significant circulations were phoned, radioed, or otherwise transmited to Guam, Honolulu, San Francisco, Miami, San Juan, Fuchu and the Japanese Meteorological Agency, Mexico City, New Orleans, Manila, Hong Kong, and Taipei. The Japanese Meteorological Agency and Manila acknowledged these advisories with thanks and both requested continued advisories. On July 23 the remnants of hurricane Madeline, still having a significant circulation, were seen off the west coast of Mexico 48 hours after the final bulletin had been issued. This information was sent to Mexico, the hurricane office in San Francisco, and was used by the National Meteorological Center to revise the surface analysis in the area.

Hurricane Esther was discovered by TIROS III in its formative stages at 11° N., 30° W., on September 10. San Juan and Miami were notified, and at 6 p.m., A.s.t., September 12, with reconnaissance and ship reports confirming, bulletin No. 1 on Hurricane Esther was issued by San Juan. Thus Esther became the first hurricane ever discovered by a meteorological satellite.

The National Meteorological Center used information contained in TIROS III pictures as a basis for reanalysis of surface and upper air charts on 17 days during this period of operation. On July 19, the position of tropical storm Liza was moved 4 degrees of latitude on the surface charts to agree with TIROS III pictures. On July 14, a vortex seen over Baja California was used to locate a low on the surface analysis. On the 15th the orientation of cloud bands seen

on the satellite picture was the basis for relocating a surface front in the Atlantic. The day-to-day observations by TIROS of hurricane, typhoons, tropical and extratropical vortices, cloud bands, and other large cloud formations were used for relocating fronts and pressure centers, reanalysis of isobaric fields, and for confirming analysis in areas of scarce or doubtful data.

In one case (September 6) a squall line extending from Lake Huron to western Texas was discovered in TIROS photographs and entered on the surface chart on this evidence. This was a case where conventional observations over a dense network failed to uncover a severe weather situation.

In all, during this 3-month period, TIROS III viewed 60 significant vortices, discovered a hurricane, saw 18 tropical storms, and 6 easterly waves. Actions resulting from TIROS observations included reanalysis on 17 days including relocating 2 fronts and locating 1 squall line, and reanalysis of surface isobars in 2 cases; plus 50 telephoned, radioed, and telegraphed advisories on tropical cyclones to weather centers in United States and abroad.

APPENDIX

The following typical excerpts from a letter, telegrams, and advisory messages are a measure of the impact of TIROS III on daily operations.

1. Weather advisory on hurricane Debbie:

"San Juan Weather Bureau advisory No. 14: Hurricane Debbie, 12 midnight Ast., September 11, 1961. Vessel reports and pictures from the weather satellite, TIROS III, gave definite information this evening on the location of tropical storm Debbie and indicated it had probably attained hurricane force. * * *"

2. Message from the Japan Meteorological Agency:

"Attention: Chief, U.S. Weather Bureau:

"Thank you for your telegram of 25, 0536, a.m. U.S. Government PD position of tropical depression 998 MBS was fixed. * * * Please continue to send us tropical vortex information."

3. A message of thanks and request for further fixes on tropical storm Sally was received from Manila, P.I., in acknowledgment of a USWB message sent on September 25, 1961.

4. Memorandum from supervisory forecaster, International Aviation Forecasting Service, Weather Bureau Airways Station, New York International Airport, N.Y.

"A copy of the depiction (TIROS nephanalysis) was used in lieu of any weather depiction field normally prepared" for the route between New York and Dakar, Africa.

"The response from crew members on these procedures[1] has been enthusiastic.

"There is absolutely no question that the TIROS fields are an invaluable aid in our daily activities."

5. Operations Analysis Unit, MSL, summary for night of August 29–30, 1961:

"A vortex * * * followed for several days was located at 24.5° N. and 151° E. * * * showed indications of increased circulation. Our (TIROS) position was phoned to the typhoon duty forecaster on Guam through the SAC hot line in Det. 28 (4WG). They had just received a recon fix at 04Z of 24.7° N., 153.2° E. The phone connection was excellent and the nephanalysis was discussed in detail."

6. Operations analysis unit, MSL, summary for July 23, 1961:

"Another nephanalysis from PMR showed a rather large but weak vortex centered at 24.5° N., 136.5° W. * * * distinct spiral bands were visible. This may be the remains of tropical storm Liza, which was seen 3 days earlier." (The last bulletin No. 22, was issued by San Francisco on July 19.) "This storm has been dropped from analysis in the meantime, but on this information * * * current analysis was altered to show an inverted trough over that area. This vortex position and related essentials were given to Crooks at SFO via fax phone."

7. On July 20, a tropical depression, Madeline, was observed by TIROS III. Tropical depression advisory No. 4, based solely on the satellite pictures, was issued by the Weather Bureau office in San Francisco. This advisory, locating the storm near 14.1° N. and 111.5° W., proved to be especially valuable to the tuna fishing fleet that operates off the coast of Mexico and southern California. This was the first time that a tropical cyclone advisory was issued on the basis of satellite photographs alone.

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[1] "I.e., the use of TIROS III nephanalyses in place of conventional weather depiction charts."

Mr. JOHNSON. Generally it is always interesting to see a few landmarks, and we do have some of those from TIROS IV, although the meteorologist isn't quite so interested. This particular picture is taken off the coast of Somaliland, taken before Colonel Glenn probably saw it, on his third orbit I believe. It indicates the cloud distribution in that vicinity. But also you can recognize the coastal features quite clearly.

The next picture shows the Mediterranean and north Africa. You see the Nile River as a dark line against the brighter ground of north Africa and you can see also rather clearly the Nile River Delta.

This is one of the best quality pictures of this particular area that has been obtained in the TIROS series. I think it is quite dramatic.

While we are still in Africa, this next picture is of interest. It also has considerable scientific significance. This is a picture primarily of Lake Victoria. You will see the bright area which is the specular reflection of the Sun off the lake surface.

This leads us to ask the question: Can we use the nature and characteristic of this specular reflection as a measure of the sea-surface conditions?

We are carrying on now some theoretical studies to determine whether this may be possible, that we could at least get a fair measurement of the roughness of the sea surface. This, of course, would be of considerable value to shipping interests, Navy interests, and also I trust to the recovery of space capsules. So far this work looks quite promising.

Regarding the snow problem mentioned earlier, this is a picture of the eastern part of the United States after one of our recent snowstorms. The large white area that you see near the bottom of the picture is the edge of the storm as it moved out into the Atlantic, and the clearing behind.

North is to the right. You can see the dark outline of the Chesapeake Bay against the snow background, the Delaware River, and on the lower right, the outline of Long Island. The dark area near the top of the picture on the right-hand side is Lake Erie.

This points up one of the potentials for satellites, and that is in hydrology, where we have very few observations, particularly of the snow depth and snow extent. While at the moment we do not see any technique by which we can determine the snow depth from the satellite, it seems quite reasonable that we can determine the area of the snow cover.

By using this in conjunction with some automatic snow depth instruments, at strategic places, a better estimate could be made of the total snowpack.

The development of surface temperature measurement equipment to be used on satellites, which is well underway now, would allow us to make surface temperature measurements over the snow which would be a clue as to the rate of snowmelt. From this added information we would be able to predict more precisely the resulting runoff.

You will recall a few weeks ago that there was a large storm off of the California coast. This is the TIROS IV picture of this storm, which in something like 2 days gave 6 inches of rainfall to Los Angeles.

Mrs. WEIS. Did you have any warning or any pictures of the storm that devastated the east coast last week?

Mr. JOHNSON. No, ma'am. At that time TIROS IV was obtaining coverage in the Southern Hemisphere. We were not receiving information from the Northern Hemisphere.

This points out dramatically the reason we are pushing for the Nimbus satellite system, using a polar orbit, so we can get coverage at least once a day of the whole Earth and these storms would not form without being under the eyes of the satellites.

Mrs. WEIS. If satellites had been covering this area, could you have given early enough warning to these people to at least enable them to save some of their possessions?

Mr. JOHNSON. We certainly would have been able to give better service, yes, because it is again in an area where we have few observations. Off the coast, there are many fewer observations on which to base our forecasts.

Mr. WAGGONNER. How far off the coastline did this particular east coast storm develop?

Dr. REICHELDERFER. May I answer that?

This points up what I said in the beginning, that we don't have enough observations. The very high tides were undoubtedly due, not only to the strength of the winds, but to the long fetch. It just had a—it blew long enough in distance and in time that it just literally piled up the water along the coast.

Now, we don't have enough observations over the oceans to tell exactly how far east the strong east and northeast wind existed. If we had satellite coverage, we could have told by the clouds what the general structure was, and then the normal procedure would have been to send reconnaissance aircraft out to take further observations exactly in the places where we needed them most.

The best answer I can give is that the storm apparently extended, the center extended between 300 and 500 miles east of the coast.

Mr. HECHLER. Do I gather from your observation that when you do have Nimbus that these things will be more nearly possible to predict?

Dr. REICHELDERFER. Yes, sir. The Nimbus will be launched in a polar orbit which will give us—it will make two passes per day, one will be during the night when we cannot get pictures, over every point on Earth, so that at least once a day we will have a photograph of every point on Earth.

Mr. HECHLER. I would like to ask a few questions concerning the use of weather satellites in international cooperation.

There are two things involved here it seems to me. In the first place, we have a very strong weapon so far as making friends among uncommitted nations and among nations of the free world in the dissemination of our information to those nations that do not now possess it.

In the second place, I believe we have a chance to extend peaceful cooperation with the Soviet Union in the area of exchange of information on meteorological satellites.

Now, taking the first of these, isn't it true that there are large areas in the world where there is a very scanty amount of weather information available?

Dr. REICHELDERFER. This is quite true. The Southern Hemisphere is the best example where the oceans occupy relatively larger portions of the Earth than in the Northern Hemisphere. It is surprising that the countries of South America can provide weather forecasts at all, they have such very inadequate coverage.

It seems to me they have almost no shipping or air traffic in the South Pacific, or even in the South Atlantic, to report the conditions that they need to know in order to draw a weather map. The meteorological problems down there are very difficult.

We had a good illustration of what happens in the Indian Ocean 2 years ago, when in quick succession two hurricanes, they call them cyclones over there, they are the same phenomenon, approached the coast of Pakistan and caused loss of life by drownings, by high tides.

The official figure was 17,000 drownings. The unofficial figure was much higher, it may have been as high as 50,000. And there was very little warning.

The example that Mr. Johnson quoted about Mauritius and the hurricane sighted there shows how little information they have.

So you are quite right; all over the Southern Hemisphere they are in urgent need of more weather information, and this is true also in many large areas of the Northern Hemisphere.

Mr. HECHLER. I feel that meteorological satellites are a very powerful weapon of freedom.

What is your philosophy on the use of this information among uncommitted nations as a weapon of freedom?

Dr. REICHELDERFER. It has been the policy of the U.S. Government to regard the information from meteorological satellites as completely open and available for everybody. This has been true right from the beginning and we have been at liberty to offer the information to any and all nations.

Last November, we had an international meteorological workshop sponsored by NASA and the Weather Bureau with endorsers, quite a number of scientific agencies, the World Meteorological Organization, National Academy of Sciences, and many others.

And in that workshop there were some 60 participants——

Mr. JOHNSON. Thirty countries.

Dr. REICHELDERFER. Thirty countries were represented and about 40 representatives from these 30 countries. There was a great deal of enthusiasm. In fact, some of them who came with doubts as to whether satellites had yet advanced to the stage where they could be of practical benefit, went away very enthusiastic about the immediate uses.

As a regular thing we transmit to a considerable number of countries, notably New Zealand, Australia, Canada, and the countries of Western Europe, coded messages giving the principal features from the TIROS satellite when they are of significance.

Eventually, of course, the world should have facsimile circuits so that the complete cloud map can be transmitted to all interested countries.

We have regular daily contact with many countries at the present time as regards satellites.

Of course, for meteorological cooperation in general there is a worldwide exchange four times a day, so that the cooperation has always been very close. It has to be; we can't get the information we need from other countries unless we have this daily exchange of weather reports.

Of course, our forecasts of cold waves, severe storms, and so forth, are based to a considerable extent on the reports we get from countries and ocean areas beyond our shores.

Mr. HECHLER. I think a good example of how these meteorological satellites are a weapon of freedom is the violence of the Soviet reaction against TIROS which has been exhibited on one or two occasions.

I would refer, for example, to a statement of the newspaper of the Soviet armed forces, which was printed in the New York Times last July, which compared the orbiting of TIROS III with the U–2 flights and Midas III, and tried to lump those together, which indicates, I think, the fact that the Soviet recognizes that weather satellites may be a threat to communism.

Dr. REICHELDERFER. Yes. Since the results of our TIROS, our meteorological satellites have been open for all countries from the beginning. I have been at liberty each year to discuss present status and prospects in the meetings of the World Meteorological Organization in Geneva.

There have been Soviet representatives and they have seen what we have published. They have always shown an interest, but if I can guess their reactions, they have always felt that the meteorological satellite could be used for purposes other than meteorology.

But the fact of the matter is that the resolution of the photographs for meteorological purposes is not sufficient for identifying objects on the ground, so we can show that we are using this satellite for meteorological purposes, for scientific purposes. I am glad to say that in recent months there has been some evidence that the Soviets would like to cooperate in the meteorological satellite.

This is not very tangible yet, but in any event some of the questions, as evidenced in the quotation you referred to, apparently have been satisfied, and the U.S.S.R. scientists are thinking now about cooperating with us in extending study of the atmosphere.

Mr. HECHLER. Just one final question now.

Would you elaborate on these evidences and relate them to the possibility that this might be a weapon, also, toward international cooperation and world peace with reference to the Soviets?

Dr. REICHELDERFER. With reference to the Soviets?

When the United Nations resolution was under consideration in November and December there was indifference at first, on the part of the Soviets, in fact, some opposition.

But a representative visited us and was shown what we do in meteorological satellites in a completely open manner, for all purposes, for all uses in meteorology, and the U.S.S.R. eventually endorsed the U.N. resolution, voted for it. That was one evidence.

We have had correspondence since then, not committing themselves but indicating that they are thinking about cooperation.

I should add that Poland and Czechoslovakia have cooperated in the TIROS program by taking supporting observations, coordinating observations from the ground at the same time the TIROS was taking observations from above.

The Soviets have indicated their plans to attend international meetings in April and May, specifically the Commission for Synoptic Meteorology which meets here, and the COSPAR Committee, the Committee on Space, and there are indications that they will attend and participate.

Mr. HECHLER. We are honored, as always, to have an ex officio member of the subcommittee, the chairman of the full committee, Mr. Miller, with us again this morning.

Mr. MILLER. Thank you, sir.

Happy to see you here, Doctor.

Dr. REICHELDERFER. Thank you, Mr. Congressman.

Mr. HECHLER. Are there any questions from the members?

Dr. REICHELDERFER. Would you like Mr. Johnson to proceed?

Mr. HECHLER. Mr. Davis?

Mr. DAVIS. I don't think Mr. Johnson has finished. Wouldn't it be a good idea to let Mr. Johnson finish before we get into our questioning?

Mr. HECHLER. Yes.

Mr. JOHNSON. I have one more picture. This is a picture taken on the first orbit of TIROS IV and shows the Great Lakes area.

Mrs. WEIS. Which is the right way to hold these photos?

Mr. JOHNSON. We find that most people are psychologically happier if they view the pictures with the horizon at the top, without regard for which direction is north. In this picture you are looking generally west with the horizon at the top of the picture.

This is Lake Nipigon in Canada, which is completely covered by ice, probably with snow on top of the ice.

The next white area is Lake Superior, which is almost completely ice covered, but there is what ice people call a lead, this dark line running through the ice, which is an area of open water and points out the potential of using satellite observations of a large area to point out where one can navigate during ice conditions.

The large black area at the bottom of the picture is Lake Michigan, which is almost entirely ice free.

This type of information is being used in conjunction with Project TIREC, which Dr. Reichelderfer mentioned earlier, in which various United States and Canadian agencies are cooperating in a joint program, utilizing the TIROS satellite as well as ship and aircraft observations to see to what degree satellites can be used for ice reconnaissance. The preliminary results are most encouraging.

The second phase of Project TIREC will start about the first of April when the satellite will once again obtain pictures in these northern latitudes. It represents a significant example of cooperative programs with other countries.

There is a document which has been passed out to you, I will have to say, this was prepared in some hurry a few weeks ago, which is an attempt to present some of the ideas, some of the work going on in the development of operational uses of satellite data.

I mention this at this time because on page 7 of this document you will note two pictures of ice in the Gulf of St. Lawrence area taken with TIROS II approximately 1 year ago. These two pictures are of the same area in the vicinity of Anticosti Island and show the changes in the ice features in that area over a 1-week period.

The people who are now studying data of this type think that there is a strong possibility of studying pictures from the satellites of this type and being able to actually forecast the breakup of ice or where it would be easiest to go through with an icebreaker to open up the ice for shipping.

Mr. HECHLER. I think it would be appropriate to put this in the record if it is agreeable with you, Dr. Reichelderfer.

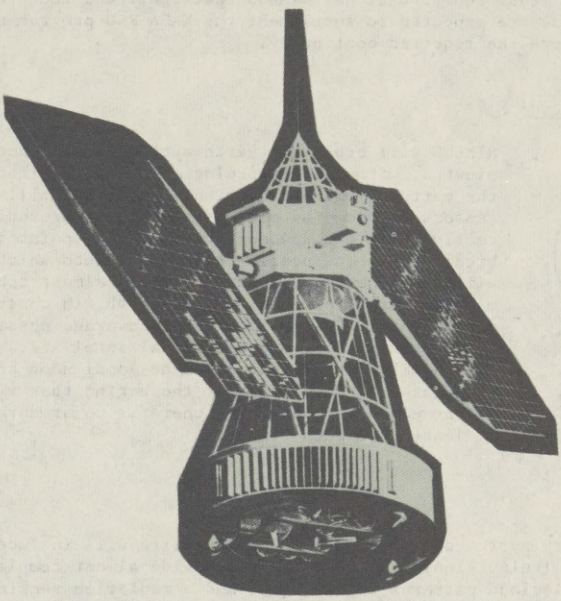
Dr. REICHELDERFER. Yes, sir.

Mr. HECHLER. Without objection.

(The document above referred to is as follows:)

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, Secretary
WEATHER BUREAU
F. W. Reichelderfer, Chief

NATIONAL OPERATIONAL METEOROLOGICAL SATELLITE SYSTEM



The
NIMBUS
Meteorological Satellite

Washington, D.C.
January, 1962

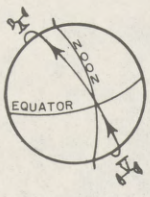
(2181)

The NIMBUS Advanced Meteorological Satellite

NIMBUS and the National Operational Meteorological Satellite System (NOMSS)

The NIMBUS artificial satellites are advanced meteorological spacecraft that will obtain a large part of the information needed for the National Operational Meteorological Satellite System to provide "for the continuous observation of worldwide meteorological conditions...."[1] The National Aeronautics and Space Administration plans to launch the first NIMBUS satellite in mid Fiscal Year 1963. Data from this research and development spacecraft will also be used for operational purposes. NASA plans to launch a total of four research and development NIMBUS spacecraft during the period 1963 through early 1966. These will not provide the continuous observational capability required for the NOMSS, so the Weather Bureau plans to fund procurement of at least four additional NIMBUS spacecraft and four launch vehicles. These are expected to supplement the NASA R&D program sufficiently to assure the required continuity.

Orbit and Attitude



NIMBUS ORBIT

NIMBUS will orbit the earth approximately once every 100 minutes, with its meteorological sensors directed toward the earth. This earth-oriented attitude will permit the sensors to view the earth's atmosphere or surface directly below the spacecraft from every point in its orbital path. The nearly polar orbit into which NIMBUS will be launched will make possible almost total daily meteorological coverage of the earth, in contrast to the approximately 20% maximum daily coverage possible with TIROS, the present meteorological satellite. The first NIMBUS will cross the equator at local noon and local midnight on each circuit of the earth; thus every part of the earth, except where there is polar darkness, will be seen in sunlight at least once each 24 hours.

Sensors

The sensory system of the first NIMBUS satellite will include an improved vidicon (television) camera system to provide almost complete coverage of global cloud patterns in daylight, and a radiation sensing system to provide measurements of atmospheric and terrestrial radiation, from which nighttime cloud cover can be derived.

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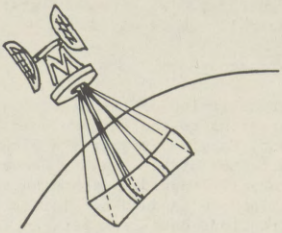
[1] from Pub. Law 87-332, 9/30/61

Pictures

The camera system will consist of three cameras, one pointing straight downward, and two flanking cameras pointing sideward at a slight angle from the vertical. These cameras will take pictures simultaneously during daylight at about 100 second intervals. This will provide three side-by-side pictures; the pictures from each of the side cameras will overlap the pictures from the central camera by about 5%. Each set of three pictures, covering an area about 400 miles by 1200 miles, will slightly overlap the preceding set.



NIMBUS PICTURE AREA
APPROXIMATELY 400 X 1200 MILES

Radiation

NIMBUS will carry a high resolution infrared system to measure, during the night part of each orbit, the approximate temperatures of cloud tops or, in cloud free areas, the ground or ocean surface temperatures. The measurements will be used to obtain nighttime cloud maps and to approximate the height of the cloud tops. This sensor will be the "eye" of the satellite during the time the area beneath it is in darkness, but will not be used to obtain daytime data. A lower resolution radiation sensor to obtain heat balance measurements will be included on future NIMBUS satellites.

Future Experimental Sensors

The modular design of NIMBUS will permit the addition of new or improved sensory systems. As these systems are developed they can be tested as part of the R&D program. Some of those contemplated are electrostatic tape cameras for continuous picture strips, spectrometers for measuring atmospheric temperatures and constituents, image-orthicon cameras for nighttime photography, and radar to detect precipitation. New sensors will be included in the operational spacecraft when proven to be of operational value.

Data Acquisition

Two Command and Data Acquisition (CDA) stations are planned for operational purposes during FY 1963-66. Control signals are sent to, and data are received from the spacecraft at these stations. The data are processed into a form suitable for transmission to the Weather Bureau's Meteorological Satellite Activities (MSA) organization at Suitland, Maryland. One of the stations will be located at Fairbanks, Alaska; the other at a northerly latitude on the east coast of North America.

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Data can be received at Fairbanks from only nine of the nearly fourteen orbits per day. With two CDA stations in operation, data from all orbits will normally be received.

Communications

Transmission of the picture and radiation data from the data acquisition stations to the Meteorological Satellite Activities organization at Suitland, Maryland requires a high quality wideband communications system. An indication of the quality needed can be gained by comparing the desired 96 kilocycle bandwidth with high quality telephone circuits, which operate at 3 kilocycle bandwidth. Initial operational plans call for a wideband communications data-link between Fairbanks, Alaska and Suitland, Maryland.

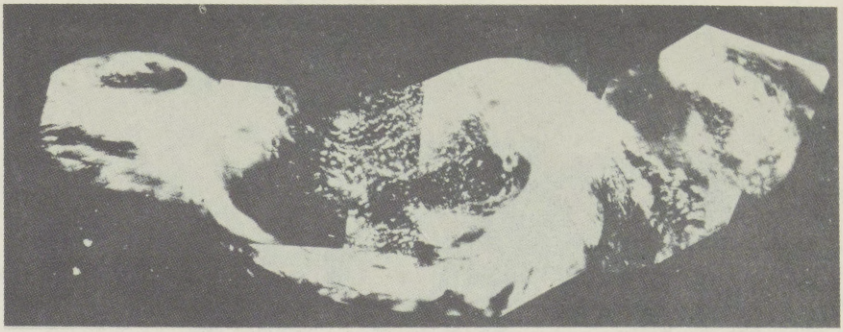
Central Data Processing

Central data processing and analysis procedures will be used by the Meteorological Satellite Activities organization to convert data from NIMBUS into forms suitable for meteorological purposes, such as their use in daily analysis and forecasting operations. These data also will be placed in the archives in formats suitable for rapid retrieval to facilitate their use in research and development in the fields of forecasting, atmospheric circulation, physical meteorology, and for climatological study.

Processing will include computer preparation of geographic (latitude-longitude) grids for pictures, computer processing of radiation data, and picture processing. A computer will be used to prepare maps showing cloud cover, heights, and types, and maps of snow and ice cover. These products, after checking by professional meteorologists, will be turned over to the National Meteorological Center, co-located with the processing center at Suitland, Maryland for operational use. These data also will be used to produce a storm detection and tracking chart. All products will be distributed to using meteorological agencies by the most expeditious means. Maps and pictures will be transmitted in original form by facsimile, and in coded form by radio and teletypewriter. Distribution will be made to users in the United States and abroad, it being understood that all data are freely available to the world community.

Meteorological Uses of NIMBUS Data

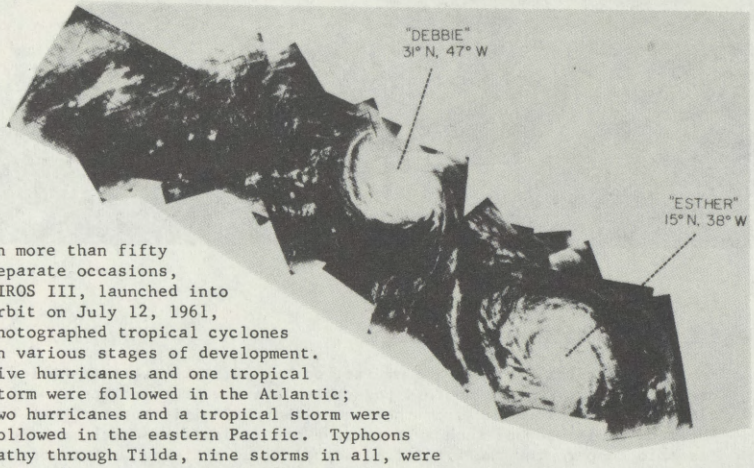
The meteorological uses of NIMBUS data must of necessity be discussed in terms of the experience with TIROS, an earlier version of a meteorological satellite. In general NIMBUS picture data will show more detail; the best resolution will be 0.5 miles in contrast to a best TIROS resolution of 1.5 to 2.0 miles. The constant attitude of NIMBUS will keep variation in resolution small, whereas the changing attitude of TIROS results in large variations in picture resolution. The characteristics of the NIMBUS radiation sensors will show a similar improvement over the TIROS sensors.



Seeing Broad-scale Weather Patterns

Pictures from six TIROS I orbits, on May 20, 1960, were assembled to make the picture mosaic on this page which shows a broad-scale view of the cloud patterns extending from the central North Pacific to the Great Lakes. The remarkable view of such an extensive area allowed research meteorologists to compare for the first time actual cloud patterns with theoretical cloud distributions. Prior to TIROS I, broad-scale cloud patterns were surmised on the basis of observations made from widely spaced ground stations. Over ocean areas, of course, even fewer reports are available. Thus meteorological satellites which make possible daily, operationally useful observations over wide areas, help to fill the gaps in standard observational networks, and furnish the observations needed for advanced meteorological research. Despite the demonstrated capability of TIROS, NIMBUS satellites will furnish greater quantities of higher quality data. While the TIROS looks at the earth at varying angles, NIMBUS will look directly down at the earth. Thus the problem of rectification, or adjusting cloud pictures to fit a map, will be greatly simplified. The area shown in this cloud mosaic will be seen by three orbits of NIMBUS as compared to the six needed by TIROS; and finally, NIMBUS will see the changing weather patterns of this area day after day, while TIROS can see it at most for only about ten successive days, after which about thirty days go by before the area can be seen again.

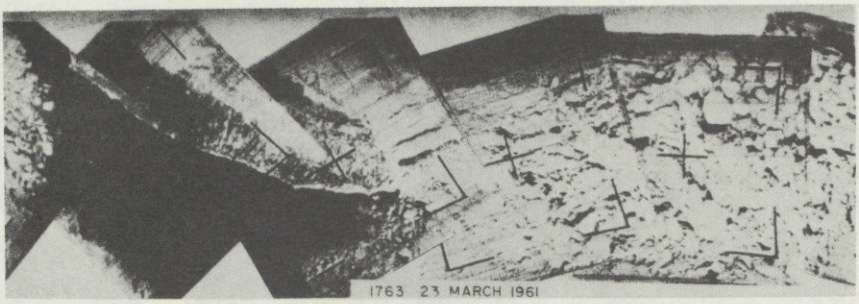
Hurricane and Typhoon Detection and Tracking



On more than fifty separate occasions, TIROS III, launched into orbit on July 12, 1961, photographed tropical cyclones in various stages of development. Five hurricanes and one tropical storm were followed in the Atlantic; two hurricanes and a tropical storm were followed in the eastern Pacific. Typhoons Kathy through Tilda, nine storms in all, were followed in the eastern Pacific.

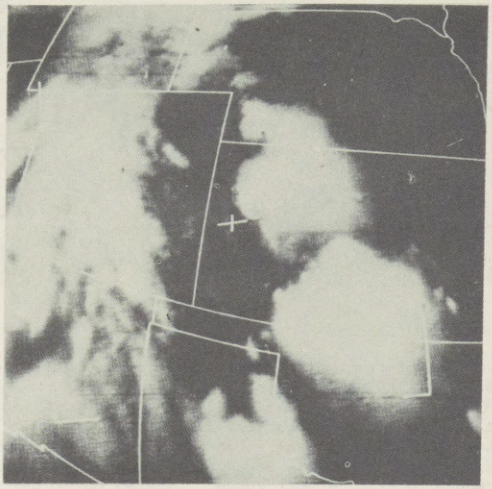
Hurricane Esther, shown here with hurricane Debbie, was the first hurricane discovered by means of meteorological satellite pictures alone, in time for operational use. The information was used to direct aerial reconnaissance to the area to confirm the location of the storm and to gather detailed data. Post analysis of satellite pictures showed that hurricane Anna, also, might have been discovered in its formative stages had meteorologists had experience in recognizing satellite pictures of these storms. It is expected that, during future hurricane seasons, many hurricanes will be discovered by use of meteorological satellite pictures, and followed from day to day in the pictures. When this becomes routine, reconnaissance flights can be directed to each storm to obtain necessary detailed measurements, thus making scheduled, time-consuming surveillance flights unnecessary.

The weather of the tropics, like that of the great oceanic areas of the world, is observed inadequately by conventional means, but NIMBUS will see it on a daily basis. Satellite pictures from TIROS are now being used by research meteorologists for intensive studies of tropical weather. NIMBUS pictures and radiation data will furnish more complete and more continuous data for both operational and research uses.



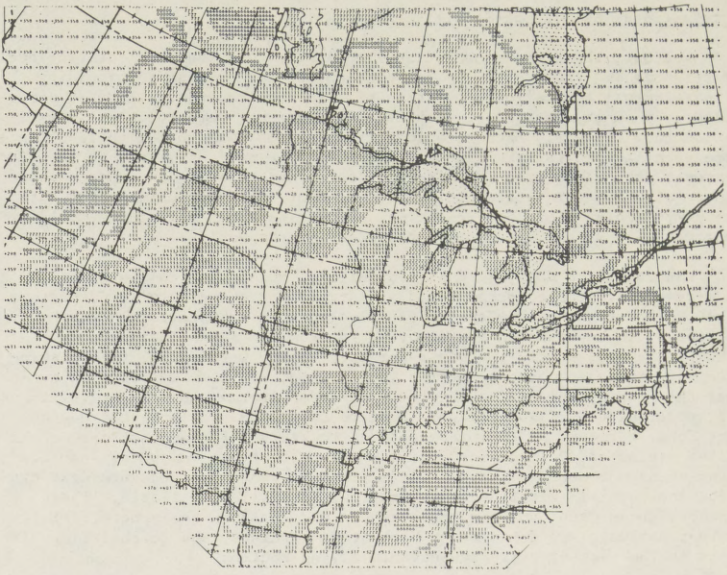
Ice and Snow Reconnaissance

The picture mosaics on this page show ice in the Gulf of St. Lawrence photographed from TIROS II in March 1961. Ice floes, cracks in solid ice fields, and areas of unfrozen water are all easily seen. Use of satellite pictures to show the condition of ice fields over navigable waters will greatly decrease the need to use reconnaissance aircraft and patrol ships for this task, and will provide more frequent information over much larger areas than would be possible otherwise. Snow on the ground also can be seen in satellite pictures. The accurate survey of snow cover possible with satellites will provide information for estimates of water availability and for forecasts of spring flood potential.



Severe Storms

The cloud picture on this page was taken by TIROS I on May 27, 1960. The very large isolated clouds over the southwestern tip of Nebraska, western Kansas, and the Texas Panhandle were identified as areas of severe weather. At the time this picture was taken, hailstones as large as baseballs were falling over western Kansas. As these clouds moved eastward, hail continued and within three hours a tornado developed in the cloud seen over Texas. Large, bright isolated clouds have been seen in other satellite photographs, and in the few cases that have been thoroughly investigated, severe weather, such as heavy thunderstorms, hail, or tornadoes, was reported at or shortly after the time the pictures were taken. It is hoped that information of this type will be available in time to assist in the preparation of forecasts of severe weather.



Radiation Data

The radiation sensors of NIMBUS will measure the temperatures of the earth's surface, except where there are clouds, in which case the temperature measured will be that of the tops of the clouds. The sensors will also measure the water-vapor content of the atmosphere, the reflectivity of the earth, the long wave (heat) radiation from the earth to space, and the incoming radiation from the sun.

Radiation measurements will be mapped by computers, in the form shown on this page. Areas of warm and cold surfaces can be detected; the cold areas generally representing cloud tops and the warm areas the ground surface. Thus maps such as this can furnish information about cloud cover on the night side of the earth. Improved sensors should provide nighttime radiation maps that will approximate the television cloud pictures now available from TIROS.

International Aspects of Satellite Data

Weather, which knows no national boundaries, is the most international of sciences and requires close cooperation between nations in providing meteorological advice for protection of life and property. This was recognized over ninety years ago, when the International Meteorological Organization (now the World Meteorological Organization) was formed to facilitate free exchange of weather information between the nations of the world. The pictures from TIROS gave immediate evidence that here was an unprecedented source of weather intelligence, especially for areas for which other data are unavailable. For the first time, weather patterns and storms could be followed over oceans and unpopulated areas of the world.

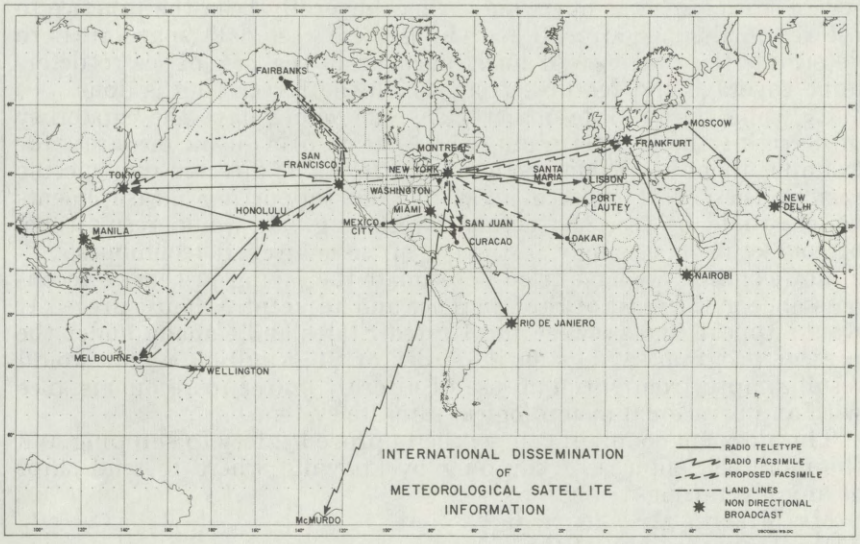
The satellite data, just as conventional meteorological information, is made freely available to the world at large. For example, a TIROS picture taken in the southern hemisphere was used to warn the Australian weather service of an unsuspected storm moving in from the South Indian Ocean. TIROS III pictures were the basis for an advisory warning the tuna fishing fleet off the west coast of Mexico that a tropical storm was being spawned over the fishing grounds. Fifty advisories on storms and other significant weather tracked by TIROS III were sent to Japan, the Philippines, Mexico, Hong Kong, Formosa, and Guam, as well as to Weather Bureau stations in the United States and Puerto Rico. Maps showing the types, amounts, and locations of clouds seen in the satellite pictures were given the broadest distribution possible with the communications facilities available. These maps have been used, both in the northern and southern hemisphere, for weather analysis and forecasting, for storm warnings, and for briefing aircrews on the weather over transoceanic flying routes.

During the operational life of TIROS III, approximately thirty countries conducted intensified observational programs to coincide with the passage of the satellite overhead. These programs were initiated in response to a joint Weather Bureau-NASA invitation to participate in the experiment by comparing special supplementary observations with those taken by the satellite.

In November of 1961, an International Meteorological Satellite Workshop was sponsored jointly by the Weather Bureau and NASA. Thirty five participants from 27 nations attended, and expressed enthusiastically their satisfaction and thanks to the United States for sharing the results of the satellite experiments. Subsequent correspondence reveals greatly intensified interest on the part of the national meteorological services, and contains requests that satellite data be transmitted as quickly as possible for use in daily operations.

This reaction by the nations of the world to the value of the limited observations available from TIROS satellites is an indication of how much more in demand will be the worldwide daily observations from NIMBUS. The Weather Bureau is taking steps to assure the widest possible flow of information when the NIMBUS satellites are in orbit. Communications facilities are being expanded; as each link becomes available it will be used to transmit data from TIROS satellites until NIMBUS data are available.

The map below shows present and proposed communications arrangements. These will be expanded as necessary through collaboration of national and international efforts.



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Mr. JOHNSON. This document also points up another application which has come to the fore since we last appeared before this group, that is, the tracking and identification of hurricanes.

A dramatic illustration is shown on page 6 in which during a single 15-minute period of TIROS III both Hurricanes Esther and Debbie were seen. In this particular case this was the first view that we obtained of Hurricane Esther. Its existence was determined from the pictures reproduced here and shows up the potential of satellites with respect to severe storms.

Subsequent research using TIROS III data have shown that we could have detected the existence of Hurricane Anna some 4 days before it was determined by conventional means.

Now, in addition to the improved forecasting and the increased safety from having this global weather eye, there are other savings which can result. In the past both for ice reconnaissance and for severe storms such as hurricanes it has generally been the practice to use reconnaissance aircraft searching these vast data space areas to determine the existence of hurricanes, or in the case of ice to determine coverage and features from which the forecasting is done.

By using the satellite observations one would have the capability of detecting these, determining the location of a suspicious area, for example, then the reconnaissance aircraft can be directed to a specific spot in these vast isolated areas to take supporting measurements which would be used in further forecasting. It would result then, of course, in an economy in the use of these aircraft techniques.

For example, we have tried to estimate the saving just in ice reconnaissance in the Gulf of St. Lawrence and adjacent Atlantic area. It would appear that between the United States and Canada under the present program savings on the order of $1¾ million a year would result simply from optimum use of aircraft and ship reconnaissance with an operational meterological satellite system.

This does not count, of course, the improved safety to shipping and the more efficient use of shipping by knowing where to send ships at any given time.

Mr. MILLER. Mr. Chairman.

Mr. HECHLER. Mr. Miller.

Mr. MILLER. Are you through, Mr. Johnson? Excuse me.

Mr. JOHNSON. I would just mention that these two charts I have here pertain to the development of a data-handling system for the Nimbus operational satellite system and I didn't know whether you, Mr. Chairman, would like me to discuss this now or later on in discussing the operational program.

Mr. HECHLER. Mr. Miller might have a question.

Mr. MILLER. Perhaps you have already answered this, but for my own information, the pictures that you show here are pictures that have been obtained by experimental satellites. As we go on in this field, we will develop, perhaps better techniques in getting and recording pictures. This is to be hoped for.

Now, as this progress takes place do you feel that with the sophistication of the satellites, there also will be more sophistication in interpreting these pictures?

Today, aren't we novices in a new era and 10 years from now we can anticipate that the interpretation of greatly improved pictures will give us a lot more data than we can possibly get today?

Dr. REICHELDERFER. One of the surprises with TIROS I was the extent to which this supposedly experimental satellite was operational. That is, we began to use the data——

Mr. MILLER. Immediately, that is right——

Dr. REICHELDERFER. Almost from the beginning.

You are quite right, we will get more data as time goes on, but the primary problem now is that we have so much data already that we have not yet developed the ultimate means of processing and transmitting. We are concentrating on this.

This is a meteorological problem, we are concentrating on it and are tying the data from the satellite right into the reservoir of meteorological data from other sources, rockets, sounding balloons, surface observations, so that it all, even now, goes into the National Meteorological Center at Suitland, and serves all civil and military purposes.

So that what you say is quite right, we are already far into the operational phase.

Mr. MILLER. You are far into it, but there will be, naturally, increased sophistication as you go along.

Dr. REICHELDERFER. Undoubtedly.

Mr. MILLER. You can do this more hurriedly; you will know what to discard and what to accept.

Dr. REICHELDERFER. I don't think we can imagine the hundreds of applications that will come out of the satellite data as they become more fully developed, as they are processed more quickly and we find more sophisticated ways of using the data, getting them out.

An important thing, of course, in meteorological data is that the information for most purposes is "perishable." You have to use it now, within an hour or two of the observation, or it loses value because the weather changes and one must then have a new set of observations.

We are trying to develop the whole system so it can be used just as promptly as possible.

Mr. MILLER. I want to compliment you, Doctor, on the work that you have done and the progress you have made in this new field. I have followed it, as you know, in another committee and was at one time very much interested. Unfortunately, I had to give up my position on the Subcommittee on Oceanography.

I am familiar with the work that you are doing, and I would like to compliment you and the Bureau on the very fine job that you have done.

Dr. REICHELDERFER. Thank you, sir.

Anything as new and challenging, as pioneering as this is, attracts many competent people, and we are fortunate in having not only in the Weather Bureau but in NASA some of the finest scientists and technicians that one could wish and they are doing a magnificent job in pushing ahead.

Mr. MILLER. I should warn you that on this committee you have a member who, by avocation, follows astronomy. I know he is very much interested in this. So you be careful of Mr. Davis over there. He likes to play with astronomy, you see.

Dr. REICHELDERFER. These atmospheric and space things are all tying more and more together. The very high atmosphere even out to the heavenly bodies, perhaps not quite as far as astronomy usually

takes up, but at the other extreme our studies go into oceanography. These phenomena are all somewhat interrelated.

I remarked earlier that the infrared patches of warmer areas over the oceans may have an application to fisheries, to the fishing industry.

Mr. MILLER. Isn't that true where your storms are actually small?

Dr. REICHELDERFER. Many of them do originate as small cyclones, yes.

In connection with some of the questions, one point that occurred to me that I believe would be of general interest, is the fact that this early detection of where a hurricane is breeding, before it has really taken form, if satellites can reveal the breeding places as we have good reason to think they will, then this will be the easiest stage for modification of the storm, perhaps dissolving it, wiping it out.

Once a hurricane becomes fully formed and starts its destructive course, the forces involved are so great and the coverage, the area, is so large, that it would take almost superhuman forces to counteract it.

But if one can get to it in the beginning when it hasn't developed the cyclonic, the hurricane circulation—some cyclonic circulation but not the full hurricane circulation, then if we can find ways to foil the circulation and relieve the instability perhaps by distributing it in several places instead of having it concentrated in one place, then there may be hope of doing something about these storms.

This, of course, is extremely challenging in its possibilities. These weather phenomena are so interrelated that one of the links in the chain or sequence is that if we are successful in destroying hurricanes, and I must say this is highly speculative, I wouldn't want to mislead, if we are successful, then we will be confronted by another problem because hurricanes build up the moisture aloft and the circulation carries drought-relieving conditions westward over New Mexico and sometimes into Arizona. So that one source of the moisture for the semiarid regions would have been cut off.

I mention this to show you how all of these things in the atmosphere are interrelated and we need a much fuller understanding of the whole mechanism. The satellite program offers more promise to understanding of the whole global mechanism than anything we have had since the beginning of meteorology.

Mr. Chairman, perhaps I should mention this published article. Mr. Johnson is one of the coauthors. It summarizes some of the accomplishments in meteorological satellites, and I thought that you might like to glance through it.

This is an article on meteorological satellites published in the Bulletin of the Atomic Scientists, the article by Wexler and Johnson. It points out some of the international possibilities that may be of more detailed interest, sir.

Mr. HECHLER. Thank you.

Mr. Johnson, did you want to proceed with your charts?

Mr. JOHNSON. If you would like.

One of the problems which has already been mentioned here is that of data processing.

Actually in the past year, with the later TIROS satellites we have used essentially every picture which had meteorological use in preparing these nephanalyses or cloud analyses that have been distributed for operational use.

This does not mean to say that we have exacted the full potential of these pictures, but we at least are able with our present system to review all of the pictures and pick out the major significant pictures for meteorology.

But as we look forward to the establishment of the national operational meteorological satellite system based upon the Nimbus polar orbiting satellite, we are again faced with essentially a quantum jump in the quantity of data that are available.

Therefore it is necessary to devise a data-handling system to cope with this on a current basis to provide further forecasting information.

The charts are designed to give you a thumbnail sketch of what we are now devising in this area. The present status is that the subsystem design is nearly complete. We expect to start procuring the equipment that is required to operate this system. We hope to have it completely operational by the end of this year.

The Nimbus meteorological satellite transmits its data to the ground receiving stations. At that point we will obtain daytime cloud pictures (fig. 583) similar to those from TIROS. We will also obtain infrared observations which can be converted to picture form.

Initially these will be much fuzzier pictures than the one shown here on this chart (fig. 584), but as the program develops and improvements are obtained we expect that before very many years quality such as shown on the chart can be obtained.

There are other radiation data which Dr. Reichelderfer has mentioned. One of particular importance is the measurement of the heat budget of the Earth, which we believe will contribute to extended forecasting.

Much information, such as temperatures in the satellite, the attitude of the satellite, which are necessary to process the meteorological data, as well as the picture and radiation data would be transmitted by wide band communications from the data-receiving stations to the processing complex at Suitland, Md., the National Meteorological Center, and Meteorological Satellite Activities, where the actual processing and first utilization of the data will take place.

There will be a rather extensive computer installation and photoprocessing equipment to handle the millions and millions of bits of information that will come in every 2 hours and to present analyzed observational data that can be interpreted by the meteorologist and applied to various user needs.

For example, cloud maps will be produced indicating the types of cloud, location and distribution, somewhat similar to the nephanalyses which we showed you last July, but of improved quality based on subsequent research.

We have touched upon the snow cover for hydrological applications and ice cover for marine interests. We plan to produce special maps for these interests. A team of specialists who will have at their fingertips all of the data processed in this center, the digital information, pictorial information, and maps, will integrate all the information produced in the proper format to meet the user needs. This information will be transmitted to all users, both nationally and internationally, civil and military.

One of the typical examples of output products is a map of the storm tracks of hurricanes from the first time they are sighted by the satellite.

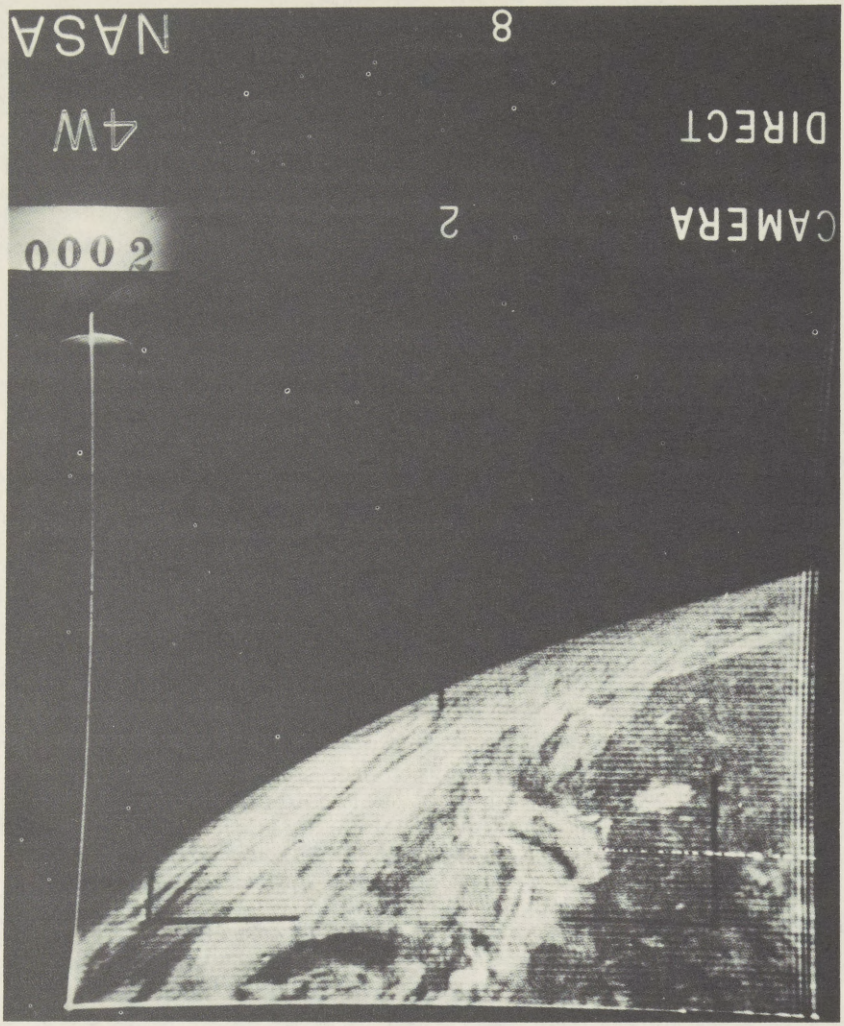

FIGURE 583

The second chart (fig. 585) indicates essentially the major block components in the data-processing system. Of course, there is the Nimbus satellite which basically provides the observations, the 85-foot-diameter tracking or receiving antenna, and the data acquisition station where the basic raw information is first recorded.

The wide band data link sends the information to the data-processing center at Suitland described more fully on the first chart (fig. 584). The output of this data-processing center is provided to the National Meteorological Center for the global and hemispheric analyses, then distributed to Weather Bureau stations and U.S. military services, and also to international weather organizations by an international communications network.

This is part of an overall meteorological service organization with which this system will be integrated to make it a fully integrated weather service, including meteorological satellites.

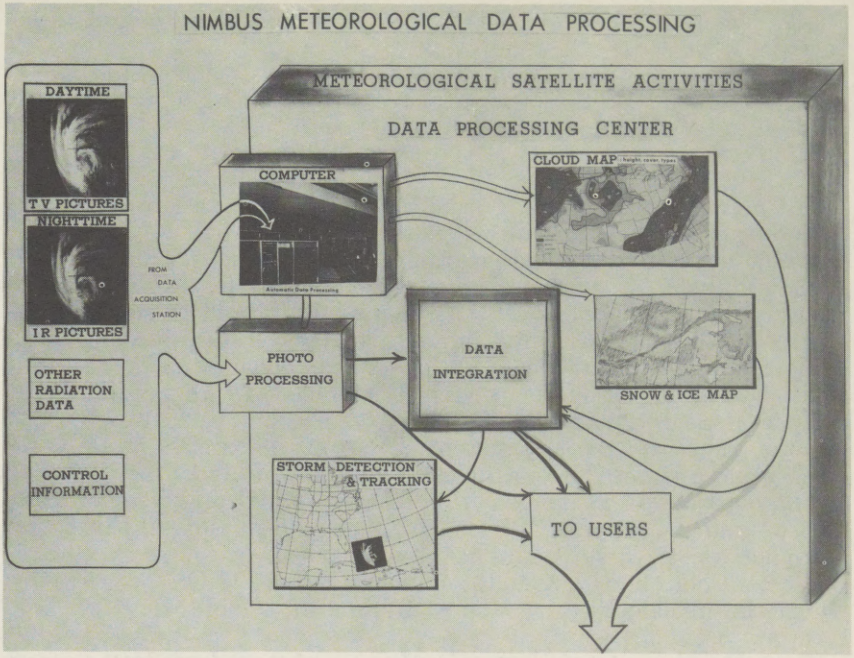

FIGURE 584

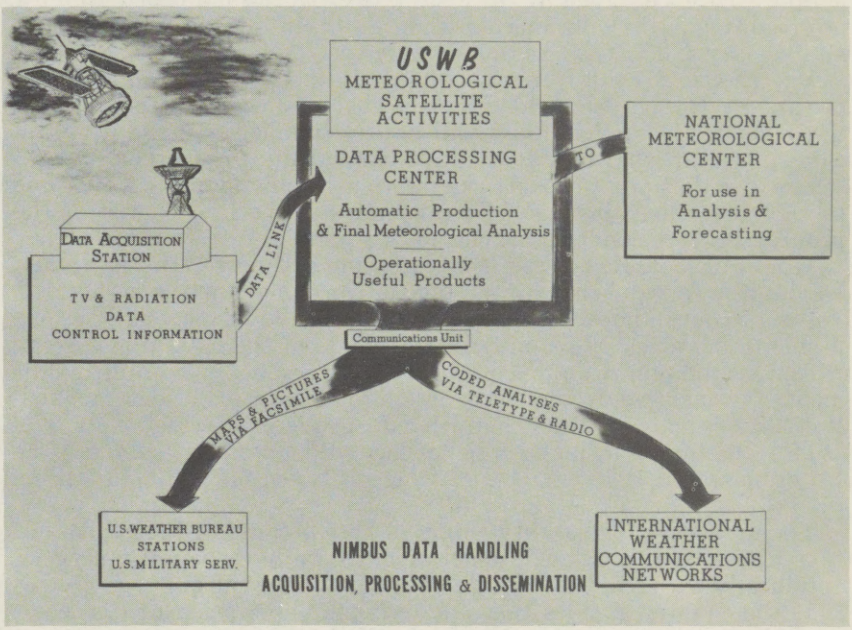

FIGURE 585

That is all I have.

Mr. HECHLER. Our ever-thirsty record desires these charts to be included also.

Mr. JOHNSON. Fine. We will have copies, black and white.

Mr. HECHLER. Do the members have any questions before we proceed to staff questioning?

Mr. DAVIS. I have one.

Mr. HECHLER. Mr. Davis.

Mr. DAVIS. Mr. Johnson, I would like to ask if you have any idea how long a weather satellite will last, or what its life will be? Are you able to predict that? For example, what about Nimbus?

Mr. JOHNSON. Nimbus is being designed initially for a 6-month lifetime. This gets into questions of probability and when you consider a satellite of that complexity, or even the complexity of TIROS, there are certain components where one component can go out and cause a whole subsystem or perhaps the whole satellite to fail.

There is a very intensive reliability program on the part of NASA and the principal subcontractors of NASA in the Nimbus program to come as close as possible to assuring a minimum of 6 months' lifetime.

The objective is to increase this to a minimum of 1 year of life. But, of course, it is pretty difficult to anticipate for sure at this stage when not even the first Nimbus has been launched.

We can look, however, at the history of the TIROS program in which the initial objective was a lifetime of 3 months, which has certainly been surpassed.

There have been 4 out of 4, and a number of these have lasted more than 3 months, providing useful meteorological data.

So we are encouraged by the history of what has happened up until now. In fact, I become amazed when I stop to think that the second anniversary of TIROS I has not occurred yet.

Mr. DAVIS. As this program comes to the floor of Congress, of course, one of the principal questions that will occur to the mind of the membership of the House will be: How much will the program cost? And of what benefit would it be economically to the country?

I realize that you probably can't give a specific figure to either one of those questions, but could you comment on both as to cost of the program and the resultant benefits?

Mr. JOHNSON. Regarding the cost you are perfectly right, Mr. Davis; it is very difficult at this stage of the game to indicate this.

We, of course, hope that the costs will come down materially as one is able to more nearly fix on the components of the observing system.

Also, right now we are going through very heavy capital investment; for example, in the construction of the command data acquisition stations and the rather complex data-processing system.

If I am forced to make a somewhat wild guess, I would say the program would level out at somewhere between $50 and $75 million per year.

The question of reliability enters in here because of the expense of the spacecraft and launch vehicles; until we have better experience specifically with Nimbus it would be hard to judge this.

If the country decides that one daytime observation of the whole earth is sufficient, only one Nimbus satellite would be required in operational condition at all times.

If the lifetime is 1 year per satellite on the average, it is obvious that the yearly cost comes down rather sharply.

As far as the meteorological benefits are concerned, again you are perfectly correct in stating that it is difficult to attach a dollar value to this. Many of the things we mentioned before this group last year and again today, I think dramatically point out the economic value in a general sense. Simply through better forecasts substantial savings to the economy of this country will result and certainly savings of life. If we can provide better long-range forecasts, which we think are completely possible with the use of the heat budget information and some of the new numerical techniques now being developed, this will be of substantial value to public utilities as one simple example, where the utilities program their production and distribution of fuels based upon the expected weather conditions. This can result in direct dollar savings if they can do this more precisely and more accurately.

The same thing is applicable to agriculture. If one can forecast more precisely, say, for a month in advance, the agricultural people are better able to plan their operations to take advantage of the weather, and also to preclude crop damage due to weather. If they could anticipate freezing weather or heavy rains they may change their harvesting schedule as a result.

I mentioned earlier ice reconnaissance; I don't think that we could come up with a realistic dollar figure here, but I suspect it could be in terms of millions of dollars, just simply due to more economical shipping operations by knowing when and where shipping can go, during the spring in particular when the ice is breaking up.

Also in the seaways, particularly lake areas, paths could be made through the ice by knowing better where the weak spots in the ice are.

I think there are a number of examples of this nature. I am quite confident that the overall saving to the economy and contribution to the well-being of our people will be quite significant, and we haven't yet touched on the international applications where there are many countries that do not have services as well developed as that of the United States.

With the increased technology and expansion of the level of these countries, they are themselves going to need and be able to capitalize on better weather information.

Dr. REICHELDERFER. There is good reason to believe also that other countries will be willing to share the cost after the Nimbus satellite system gets going. This has already been indicated by—I shouldn't name the countries, but by three or four countries.

Mr. DAVIS. Thank you.

Mrs. WEIS. That was the question I wanted to ask.

You referred earlier to the great value to Canada of your reconnaissance on the polar ice pack. Do we get any benefit from that directly?

If we don't, shouldn't Canada contribute something toward this great economic benefit she is going to derive from this program?

Dr. REICHELDERFER. They have already come forward. I am not at liberty to discuss the details, but this is—this I am sure will be accomplished within the next year.

Mrs. WEIS. Would that be any value to us? Will we benefit economically directly from that research?

Dr. REICHELDERFER. Well, we will benefit, of course, the United States will, because we have many operations in the far north, but I feel quite sure that Canada will contribute to the operation.

Mrs. WEIS. Thank you.

Mr. HECHLER. Dr. Reichelderfer, would you care to place in the record any more extensive discussion of the economic benefits that could be realized along the line Mr. Johnson touched on? Are there any further things that you think should be pointed out?

Dr. REICHELDERFER. Yes, Mr. Chairman. I think we could develop something more.

Both NASA and the Weather Bureau tried 2 or 3 years ago to get some firm figures, and as someone remarked, it is always difficult to estimate damage that didn't occur. So the figures are necessarily just estimates, but we will furnish something more definite and can go a little further than we have been able to do in the remarks this morning.

Mr. PELLY. If the chairman would yield.

Mr. HECHLER. Yes.

Mr. PELLY. I might suggest that in the retail field, merchandising organizations certainly have very large expenditures for advertising, for sales, and for promotions. They are willing to pay money to get good forecasts of the weather so that they don't waste a lot of money because of poor weather conditions.

I am sure the savings to merchandising organizations would be vast.

Dr. REICHELDERFER. Yes; they would be very great.

One runs into some academic questions in assigning values. For example, many years ago a rather careful survey of cold wave warnings in the Middle West brought out that the savings to livestock owners who were able to get their cattle under cover, amounted to at least—well, the livestock that probably would have been lost was estimated at $8 million.

Well, if one saves the livestock in January and saves them again in February, is it $8 million that you save or $16 million? Obviously definitions are needed.

Mr. HECHLER. I think in making your cost assessments that it wouldn't be necessary to try to pin these down with any precision, but merely to give what you can on cost estimates and then go on and generalize other economic benefits that you feel might accrue.

Dr. REICHELDERFER. I am sure we can provide some figures on that, Mr. Chairman.

Mr. WAGGONNER. I think those economic benefits that you mentioned are important. But the fact that you might have saved 9 out of 10 of these lives that were lost in this recent storm far exceed those things. That is a factor that has great appeal.

Mr. HECHLER. Yes.

(The information requested is as follows:)

ECONOMIC BENEFITS TO BE EXPECTED FROM METEOROLOGICAL SATELLITE INPUT INTO NATIONAL STORM WARNING SYSTEM

The Nation's growth in population, economy, and technology has brought about increasing dependence on weather information. For weather forecasting for the United States it is necessary to have synoptic reports from all over the globe. At present our data for the vast ocean areas which cover 70 percent of the earth's surface are limited mostly to points along the principal sea and air lanes. These data limitations permit only the broadest kind of hemispheric weather charting and this only for the Northern Hemisphere. Very little is known of the relationship between the weather of the two hemispheres and the effect of the high atmosphere on the weather observed in man's present environment.

Earth satellites serve as global weather observing platforms. The satellite makes possible for the first time a truly worldwide survey of clouds and storms.

Clouds are visual indicators of atmospheric motion and make possible the detection and location of most high- and low-pressure areas and storm centers. This information will contribute greatly to weather forecasting, particularly over the important ocean and sparsely populated land areas from which few observations are now received, and in coastal areas.

Satellite observations furnish a wealth of new data in blindspots, blank areas where we now need information and do not have it. Weather satellites have already discovered and fixed locations of tropical disturbances (hurricanes) more accurately and pictured their configurations and movements more clearly than could be done by any other available means.

There are many benefits to be gained through space satellites that cannot be evaluated in dollars. In the past, scientific research has improved forecasting techniques so that warnings of hurricanes have reduced the average annual loss of life from such storms in coastal regions of this country to less than one-fiftieth of the average losses two decades ago. Property losses have been greatly reduced by advanced preparations made possible by earlier warnings. In most parts of the world these methods of storm detection and warnings are not yet available. In the United States much more will be gained through protection based on further advances in forecasting other weather anomalies and atmospheric disturbances. Satellite observations will contribute much to these advances. Eventual benefits will depend also on the extent to which weather modification may be found possible. Although no firm estimates of cost-benefit ratio can be given now for meteorological satellites, surveys of the many uses of weather reports and forecasts in this country show that reduction in losses from storm and bad weather damage by virtue of preparedness based on forecasts in this country, now exceeds a billion dollars annually in addition to large savings in human lives, and it is reported that more definite forecasts longer in advance would double or treble the benefits. These figures refer to this country. The total would be many times greater if technical advances were applied to meterological services all over the world which would gain from satellite observations.

The international aspects of meteorological satellites have been stated by President Kennedy and others responsible for international relationships. The significance of these matters with respect to human welfare and national prestige is incalculable.

Examples of economic benefits: (1) Recent studies show that the value of improvements in forecasts can be very large. In one case history, a 100-day study concluded that full use of currently available weather information could cut losses caused by weather for a trucking company by a third, while improved forecasting could cut remaining losses another 80 percent if the information were supplied efficiently.

(2) Research studies of the heat budget of the Earth and of the atmosphere would be greatly helped by satellite radiation observations. The development of longer range, including seasonal, forecasts is believed to be dependent upon an improved knowledge of this heat budget. Long-range weather forecasts would have practical applications in so many hundreds of activities and occupations that the benefits and savings are incalculable. They would certainly run into the billions each year.

(3) Airline operations would be greatly assisted by improved forecasts. Use of weather data to compute minimal flight paths can provide appreciable savings. As an example, a recent flight path from Wake Island to San Francisco was planned for a decided departure from the great circle route, but with a savings in estimated flight time of 1½ hours with a resulting estimated savings of $1,350 for this one flight. Planning by use of weather data can also reduce the number of flights circling and awaiting instructions to land. Acceptance rates can be geared to the weather at a given terminal and takeoffs at origination points controlled accordingly.

The planning of airline schedules so that large numbers of planes are not grounded in areas of widespread inclement weather is also an important economic factor.

(4) Improved weather forecasts for agriculture can provide very large reductions of costs. In 1959 it was estimated that 312 million acres were under forms of cultivation that could require spraying or dusting schedules. The saving of only one application of spray or dust each season to this overall area through improvement of shower probability forecasts would result in savings of many millions, probably hundreds of millions of dollars a year for the world as a whole. Of course, many agricultural activities other than spraying would be served through an improved weather service. Seasonal forecasts could lead to very large savings in seed, fertilizer, and equipment costs in years when crops

are destroyed by late freezes, spring flooding, etc. Seasonal forecasts would serve optimum use of multiple-purpose dams, and more efficient use and realistic planning for storage of fuels.

(5) Direct use of satellite observations to measure snow cover in mountainous areas where data are extremely sparse could help improve estimates of snow and future release of water for power, for agricultural purposes, etc. The measurement of surface temperatures by satellites also appears feasible and could contribute to estimates of snowpack melt and runoff.

(6) Satellites give information about ice coverage in polar and subpolar navigational waters. Through complete ice reconnaissance by satellites it has been estimated that the United States and Canada together could save $1¾ million per year in aircraft and ship reconnaissance operations.

(7) The complete picture of weather over oceans would improve ship routing techniques. The Military Sea Transportation Service tentatively estimates that each hour saved in cargo ship operation is a saving of $200 to them. On the basis of average savings of 14.5 hours for both oceans combined, these figures would result in an average saving of $2,900 per ship crossing. On passenger ships the cost of meals for passengers, etc., would be added to this estimated savings.

(8) Global observations by Nimbus satellites will provide a better record of storm tracks. These would help support better estimates of probability of storms along coasts. This information used together with estimates of roughness of the seas derived from satellite observations of spectral images of the sun reflected from the sea surface, could provide improved estimates of storm surges on coasts. Lives as well as economic factors are at stake here.

(9) The locating of tropical storms in sparse data areas is one of the most important contributions that is available for improvement of weather services through use of satellite observational data. Of special significance are the areas in western Gulf of Mexico, off the west coast of Mexico, and in the vicinity of the Hawaiian Islands. Other areas where great loss of life occurred in recent years with undetected typhoons includes the Bay of Bengal and Indian Ocean. There would be reductions in the present expenditures for aerial reconnaissance to discover hurricanes.

(10) Since the Armed Forces must operate in the air, on land, and on and under the sea, they are particularly interested in 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 damages, 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.

These are only a few examples of the many possible economic contributions. Ahead lies new knowledge of the atmospheric environment that will lead to great economic gains.

Dr. REICHELDERFER. With reference again to the storm circumstances, the conditions that gave rise to the very high waters and high waves are relatively simple, and we were unable to tell more about them because we were uninformed of the conditions at sea.

If we have the observations, there is no question that we could give advance warning because we have been successful in the last few years in developing excellent methods of forecasting the height of waters in connection with hurricanes, when we have had knowledge and the storm itself moved slowly enough that we could set up—use the techniques.

So the problem will be relatively simple if we get the information.

The satellite—we will try to bring this out in the additional information we furnish.

The satellite, of course, could not be given credit for all of the savings because it is part of the system, and in connection with the storm some of the credit would have to go to the observations we already have along the shore and from ships at sea.

But I will try to point out in preparing the figures that this is a part of an integrated system of the National Meteorological Service.

Mr. HECHLER. Mr. Wilcove?

Mr. WILCOVE. Doctor, I was interested in your statement regarding the possibilities of controlling large storms, such as hurricanes. I assume that you would first have to find where the storm was gathering?

Dr. REICHELDERFER. Yes.

Mr. WILCOVE. And then, if possible, use some method to break it up before it gathered brute force and went on to the mainland.

Could you give us some idea—I realize this is highly conjectural—could you give us some idea of what methods you are contemplating using to break up these storms?

Dr. REICHELDERFER. Last fall, in connection with one of the hurricanes that passed north of Puerto Rico we conducted a cloud-seeding test. This was just a preliminary test to see whether we could observe any real lasting effects. This weather-modification subject is a long and complex story. I will try to brief it.

Many years ago cloud-seeding tests were conducted on a hurricane that changed course. We had partial evidence at that time that the change in course came before the seeding. But there was no way to prove it. It was a so-called post hoc facility. Post hoc ergo propter hoc. It happened afterward, therefore it was caused by the first thing.

Further studies showed that there was no reason to believe the seeding in that case did change the course of the hurricane, but we couldn't afford to take the chance with very large-scale seeding until we knew more about what would happen. So the seeding last fall was preliminary.

The seeding did clear out the water droplets in the wall of the cloud. The cloud was of the order of 20 or 30 miles across the center of the storm, and the cloud seeding, as we fully expected, changed the supercooled cloud droplets, cloud droplets below freezing, into snowflakes, ice particles.

The storm did not change course and its intensity was not affected so far as we know. Next year, this year, rather, this fall, we hope to conduct larger scale cloud-seeding tests. Now, this is one possibility.

Other possibilities had been suggested years ago, that bonfires be started at sea in the vicinity of a circulation that is expected to build into a hurricane. The bonfires would start convectional cells, it is true they would be pretty large fires, but this could be done by setting fire to oil on the surface of the water, setting up convectional cells that would interfere with the cyclonic circulation just as you can break up a vortex in a dust whirl, or a vortex in water by a foil of some kind.

Mr. WAGGONNER. One moment. In the path of it or all around?

Dr. REICHELDERFER. Right in the circulation.

If you have the circulation you would put these foil cells right in the circulation, so as to interfere with it, deflect it, much as you break up a smoke ring by putting your finger through it.

Still other even more speculative proposals are that a chemical that inhibits evaporation be spread over the waters.

Now, we don't think this will work because we think that the waves, the sea, would break it up. But this is a possibility that needs testing.

Mr. HECHLER. It is pretty dangerous for the fellow that has to go and drop the match.

Dr. REICHELDERFER. Well, yes, I think this can be controlled all right.

Still another method is the use of explosives like bombs. This has been suggested many times. The Weather Bureau has many, many files of letters from—mostly from residents in the hurricane belt, who want to know why we don't shoot hurricanes down or bomb them out of existence.

This also is strong medicine, but we can't rule out the possibility when we are dealing with something as destructive as a hurricane.

So we should test all of these things.

Mr. WILCOVE. Doctor, if you have a hurricane forming, let us say, in the South Atlantic Ocean, where you don't have any shipping, could you possibly use nuclear power to dissipate it? I know there has been some talk of this.

Dr. REICHELDERFER. Well, I think there is no doubt, if one used a sufficiently powerful bomb one could put that particular vortex out of existence. The cure might be worse than the disease. We have to look into the consequences of a bomb powerful enough to wreck a hurricane circulation.

It seems quite evident that if it is put in the wrong place one could intensify the hurricane.

Mr. WAGGONNER. Or if you didn't wreck it you really would be ruined, by fallout and other effects.

Dr. REICHELDERFER. There are also the side effects from the bomb. So in general when we have talked about bombings, we talked about conventional bombs, not hydrogen or atomic bombs. This sort of thing has to be approached with care.

Mr. WILCOVE. Of course, anytime you dissipated a hurricane, the benefits would be tremendous.

Dr. REICHELDERFER. Yes.

Mr. WILCOVE. Just about every hurricane does some damage, if not to the United States, then to some other country.

Dr. REICHELDERFER. Yes, this is usually true.

Mr. WAGGONNER. Wind is not the worst damage of a hurricane. It is the tidal effects of the water that really cause damage. You can take the pounding of 100-knot wind, or 135, or 40, or 50 knots. But when that water moves in, something gives.

Dr. REICHELDERFER. It is the flooding that does most of the damage. In a tornado the winds are violent enough and the central core with reduced pressure is violent enough so that the destruction is a wind effect or a pressure effect. But with hurricanes, most of the loss of life is by drowning as it was in the case of the severe storm off the east coast last week.

Mr. WAGGONNER. Doctor, money being available, wouldn't we be better off with a Nimbus in polar orbit and one in east-west orbit, coordinated to give us a 12-hour coverage rather than 24-hour coverage?

Dr. REICHELDERFER. What we hope to do eventually is have another series, another system called Aeros, which would be in orbit above the Equator at an angular speed equal to the speed of the Earth, so that it would appear to stand still.

Mr. WAGGONNER. It would be stationary?

Dr. REICHELDERFER. It would appear to be stationary. Then you would have continuous-use 24-hour surveillance, if you had four of them equidistant around the globe.

If the satellites show the value that we expect them to show in meteorology and have the worldwide applications that we are confident they will, then certainly an Aeros satellite system will be the eventual plan.

Mr. WAGGONNER. Really, the technical problems of photography present bigger difficulties now than anything else; don't they, for instance, the infrared photography?

Dr. REICHELDERFER. Certainly, we need development in sensors. Of course, we have been amazed at the information we have gotten from the television photographs now. The sensors have worked very, very well.

We do need improvements, and there will be other things we will measure eventually. We hope eventually to get not only a cloud census, but a census of precipitation by measuring the precipitation with radar. This has been done on the surface of the Earth, it hasn't been done aloft, but the technical capabilities are there. It is simply a matter of engineering and development.

Mr. WAGGONNER. By contrast, how far is Russia behind us in this program?

Dr. REICHELDERFER. In the meteorological satellites, I probably can't do any better than to quote the reply that I received to that question when I asked it last June of a Soviet representative. He said:

> Well, we haven't done much in meteorological satellites, we have been devoting our satellite efforts to other things.

Insofar as we know, this is correct.

Mr. WAGGONNER. The reason I asked that, Mr. Chairman, goes back to the question or statement you made earlier about Russia being violently opposed to it.

I think that is just a matter of emphasis. To me it is the Soviet attitude that the Russians are behind us and they are trying to belittle our accomplishments there.

Dr. REICHELDERFER. This could be.

Mr. HECHLER. They are not only trying to belittle our accomplishments, it seems to me that they recognize the power of the weather satellite as a weapon of freedom.

Dr. REICHELDERFER. Yes.

Mr. WAGGONNER. Well, of course, I think our entire program has developed through an approach completely different from anything they have. Ours is just based on a different set of values.

Dr. REICHELDERFER. That is true, sir.

Mr. HECHLER. Mr. Hines?

Mr. HINES. I would like to ask Dr. Reichelderfer to define the limits of responsibility of the Weather Bureau in relation to the NASA satellite program. What is the Weather Bureau input into the program?

Dr. REICHELDERFER. The working arrangements with NASA, in fact this was the concept with which the whole plan has been approached right from the beginning, is that the initial basic research and development for the R. & D. phase of the satellite will be carried on by NASA.

There are the phases of research and development of sensors, meteorological sensors and meteorological services that the Weather Bureau is engaged in, but there is no duplication because we work very closely together.

Once any system of satellites becomes operational—and recall that the TIROS became operational right from the beginning—then the Weather Bureau, as the national meteorological agency, is the organization to carry on research and development in the application of satellite data to our meteorological problems. And this division of responsibility has been rather clearly defined.

I think it is an excellent complementary way to operate. I think it represents the strongest use of the facilities and staff, scientific staffs, we have available in both agencies.

Mr. HINES. Are you happy with the funding?

Dr. REICHELDERFER. Sir?

Mr. HINES. Are you happy with the present funding of the weather satellite program? Do you think it is adequate?

Dr. REICHELDERFER. Except that it wasn't quite enough.

It was somewhat below the original estimates. We think this is the best, the most practical way to operate. Then the user—well, in the first place, then the Congress says how much it thinks should be used for meteorological satellites.

The funds are given to the meteorological agency. Then as the user, we work with NASA; and we, of course, make full use of their capabilities. We don't duplicate them.

Most of our appropriation has been transferred under proper contract arrangements to NASA. And this seems to me to be the most practical balance in fixing the responsibility where it should be and making a clean-cut division between the responsibilities of the user, the service agency, and the research agency.

Mr. HECHLER. The obvious question, of course, arises when you said it was not enough. What more could you do if you had what you considered to be enough? Precisely what specific activity has been reduced or delayed by not having what you call "enough"?

Dr. REICHELDERFER. With the appropriations authorized, we have no leeway for any failures.

Now, because of the 100-percent success, so far, NASA is confident and we feel very hopeful that this can be continued. The operation is carried on very carefully.

But failures do occur. In that case, instead of being able to carry out the schedule, the launch schedule that is planned, we would just not have enough funds to provide an alternate, a second trial, on any of these Nimbus satellites that are not successful.

Mr. HECHLER. In other words, up to date there has been no delay or crimp put in your activities by reason of not having the amount which you requested originally?

Dr. REICHELDERFER. Yes, sir; that is the case.

Mr. HINES. Mr. Chairman, may I say this is? I perhaps detect or sense in this a contradiction to the testimony in which representatives of NASA did talk about their backup to their meteorological flight program.

I assume that the Weather Bureau would be funding, not only the actual flight, but also the cost of the backup vehicles.

Dr. REICHELDERFER. That is what we should do; yes, sir.

Mr. HINES. I would like to inquire a little further of NASA, if I may, at a later time, about the apparent contradiction, because I think this is important to our hearing and to our position.

If I may sum up, Doctor, at present the cost of gathering worldwide meteorological information is borne by all the countries participating. With regard to the weather satellite system, the costs as envisioned now will be borne by the United States initially, though perhaps later contributions from other countries will be realized.

I would assume that our weather satellite system is not going to supplant any existing system; is that not so?

Dr. REICHELDERFER. In general this is so. It is quite possible there will be a change in emphasis, for example, on surface observations or on radiosonde operations depending on how we develop the satellite.

But in general it seems that the needs of the country, the needs of business, industry, and the military, are to know everything everywhere all of the time in the atmosphere.

Mr. HINES. Yes.

Dr. REICHELDERFER. That means that we are just adding to our capabilities and not replacing what we now use.

Mr. HINES. I think this is important to bring out because we mustn't envision any curtailing in any other area just because we have a satellite system going.

Dr. REICHELDERFER. Yes.

Mr. HINES. One last question, if I may, at this moment.

What liaison do you have with the Department of Defense? How do DOD representatives communicate their meteorological desires to you?

Dr. REICHELDERFER. There are essentially two, to some extent three, interdepartmental bodies that take care of that.

One is the JMSAC Committee—I will have to ask Mr. Johnson for a translation.

Mr. JOHNSON. Joint Meteorological Satellite Advisory Committee.

Dr. REICHELDERFER. This Committee is chaired by NASA, primarily for the coordination of the R. & D. aspects.

The committee of the Joint Chiefs of Staff that is responsible for direct coordination with the military is the Joint Meteorological Group; Army, Navy, Air Force, and Weather Bureau are the members of that committee.

There is a third committee which takes care of military and civil requirements in meteorology insofar as they are not classified and confined to JMG, the Joint Meteorological Group. This is the National Aviation——

Mr. HECHLER. National Coordinating Committee for Aviation Meteorology——

Dr. REICHELDERFER. Yes; that is the trouble with using these abbreviations, you forget what they originally were, in full—the National Coordinating Committee for Aviation Meteorology.

Mr. HINES. Thank you, Doctor.

Mr. ROUSH. No questions.

Mrs. WEIS. No questions.

Mr. HECHLER. Mr. Waggonner, any questions?

Mr. WAGGONNER. If some component of the Nimbus satellite became inoperative, would you consider it more or less useless? Would you want another one in orbit if some major component became inoperative?

Are you going to build in backup components in the future so that you can utilize one component if another goes bad?

Dr. REICHELDERFER. There is a great deal of interchangeability. I would like to have Mr. Johnson amplify my remark.

Mr. JOHNSON. If, Mr. Waggonner, you are referring to a Nimbus satellite in orbit——

Mr. WAGGONNER. Yes.

Mr. JOHNSON. Let's say it started operating totally as expected: it would depend to a great extent on the particular component which would fail. Many of the components are in duplicate to provide for such failure.

There is only one set of solar paddles. If for some reason these were damaged, we would be essentially out of business because of lack of power.

However, if a certain tape recorder went out, it would be possible in many cases to switch to a spare tape recorder by remote control from the ground and continue operating.

If we consider the overall sensory systems where there may have been television cameras for cloud cover in the daylight and a variety of radiation sensors, the decision as to whether the failure was of major significance would be determined by which of these systems went out.

I am reasonably sure for the coming few years at least that if the principal TV camera system went out, we would recommend another launch to replace it.

Mr. WAGGONNER. What developments have been made now, if traffic is going to be getting rather heavy up there and complex, to remove from orbit an inoperative satellite?

Mr. JOHNSON. I am not in a position to answer this. I would imagine that NASA or the DOD would be in better position.

Mr. WAGGONNER. It is going to get rather confusing in time to come if that isn't done, too.

Dr. REICHELDERFER. Yes; that is one of the problems.

Mrs. WEIS. There is an awful lot of room up there, Mr. Waggonner.

Mr. HECHLER. Mr. Wilcove?

Mr. WILCOVE. Doctor, have the satellites helped you in locating some of the breeding centers where storms are found?

Dr. REICHELDERFER. They have helped very definitely in determining where particular storms were forming. The general breeding places of storms have been known from climatological studies, but there is an element in what you say. They have helped us to fix the breeding place of storms individually.

In particular, with reference to hurricanes, during some of the orbits last summer, we had six tropical cyclones in view at one time. There were three in the Atlantic, two typhoons in the Pacific; one that later struck Japan and caused great damage, and then a relatively minor tropical cyclone that did not reach hurricane stage off the west coast of Lower California.

We could not possibly by any other means, practical means, have known that all of these storms were in existence at that time.

Mr. WILCOVE. Are there some definite fixed areas where these storms usually originate?

Dr. REICHELDERFER. Yes; although they are pretty broad. Some hurricanes have been tracked even from a wave that developed in central Africa and have been tracked westward right across the Atlantic to the Gulf of Mexico.

But in general hurricanes develop, primarily, in the Atlantic, North Atlantic, and North Pacific along about latitude 15 or 18.

In one season of the year there is a preference for them to originate in the western gulf. Usually they occur, they develop east of the West Indies, someplace in the Atlantic between the West Indies and the African coast.

In the Pacific, much the same general pattern occurs, they develop several hundred miles south of Hawaii, anyplace from there on to the area of Yap, and even to the Philippines. I refer to the island of Yap. Then they move westward and curve northwestward.

Other types of storms, I have been talking about hurricanes, it has been known since sailing vessel days, Cape Hatteras has been considered the graveyard of ships, and the situation that developed last night is typical in its evidence of one breeding place.

The situation I refer to is that when we have a well-defined storm over the Great Lakes and when there is an old front, an inactive front along the Gulfstream, along Hatteras and extending south and south-southwestward, then there is a strong tendency for the development of a new storm off the Hatteras coast. That is what happened in this case.

We have learned to look out for that sort of development and it can happen very quickly.

Mr. WILCOVE. Of course, with the coverage provided by satellites, you will know exactly where to look.

Dr. REICHELDERFER. Not only know exactly where to look, but we will know the extent of the storm. This is very difficult to get at sea. We often do not know whether it is a very large storm or whether it is just a small storm. These come in assorted sizes.

Mr. WILCOVE. Doctor, this has nothing to do with what we were just discussing, but did you ever determine why the Russians failed to attend that weather gathering you had here recently after they had already made plans to do so?

Dr. REICHELDERFER. Not really. We do know that often they plan to attend and then something comes up, some bona fide reason comes up and they just don't inform us as we would naturally do if we were the absentees.

Of course, I am sure in some cases it is political, but we do know in some cases it is apparently nonpolitical.

In the particular case you referred to, I asked one of the leading scientists in the U.S.S.R., and he said that he was surprised they had not attended, that they should have, and he would see what he could do about it.

Mr. WILCOVE. Do the Russians have any benefits to gain by participating actively in the program?

What additional benefits would they gain over and above what they would otherwise get without participation?

Don't we furnish them, along with all the other nations, all the information that we obtain from satellite coverage?

Dr. REICHELDERFER. Yes; this is difficult for us to tell.

By the nature of things the exchange of meteorological information has to be in the clear. Even during the war when we tried to censor it, we understand that through neutral countries much information reached the enemy.

It is not evident to us just how extensive the benefits are that the U.S.S.R. would gain by participation. The fact remains they have continued their exchange of information, they have kept their contract insofar as weather broadcasts is concerned, ever since it was opened up after the war. They did not interrupt during the cold war.

Mr. WILCOVE. Is there any participation they could engage in satellite coverage that would benefit this country outside of possibly some financial benefit by contributing to the cost?

Dr. REICHELDERFER. There are the financial benefits and then there is a great deal of territory under U.S.S.R. control, and the coordination of information, surface observations, and satellite observation itself. In order to get the most from it on understanding the mechanics of the atmosphere as a whole, we would receive a good bit of benefit from this.

Mr. WILCOVE. Have we asked them for such cooperation?

Dr. REICHELDERFER. Yes, we have, and we have received nothing special to date, if I recall correctly.

Mr. JOHNSON. Nothing has been received from the U.S.S.R. We have received cooperation and exchange of data from both Poland and Czechoslovakia.

I may point out if I may, Mr. Chairman, that with the present TIROS system, the number and location of data-receiving stations, we get very little coverage over the U.S.S.R.

Mr. WILCOVE. In other words, if they would cooperate and set up some receiving station, we could obtain additional information?

Mr. JOHNSON. Yes; in principle this would be true.

Dr. REICHELDERFER. But TIROS doesn't go far enough north.

Mr. WILCOVE. I am thinking of Nimbus.

Dr. REICHELDERFER. Yes, it will cover northern regions.

Mr. WILCOVE. Did we ever receive a reply from them to our request that they participate in the program?

Dr. REICHELDERFER. Not directly. Of course, we did receive information that they would attend the workshop and then they didn't show up.

Mr. WILCOVE. Thank you. That is all, Mr. Chairman.

Mr. HECHLER. Just two quick closing questions.

You have signed a formal agreement with NASA delineating the responsibilities between the Weather Bureau and NASA?

Dr. REICHELDERFER. We have; yes, sir.

Mr. HECHLER. Now, are you completely satisfied, or do you, as a predicter of storms, foresee any possible storms, disagreement?

Dr. REICHELDERFER. We are very well satisfied with the agreement, Mr. Chairman. In any cooperative undertaking of this kind there are, of course, day-by-day problems to work out. But we are able to work them out and we think the agreement is a very fair and a very workable agreement, and we anticipate no serious difficulty. We would work almost as one agency between NASA and the Weather Bureau.

Mr. HECHLER. Thank you very much, Dr. Reichelderfer and Mr. Johnson for your good testimony this morning.

The subcommittee stands adjourned until Wednesday at 10:30 a.m.

(Whereupon, at 12:06 p.m., the subcommittee adjourned, to reconvene at 10:30 a.m., Wednesday, March 14, 1962.)

1963 NASA AUTHORIZATION

WEDNESDAY, MARCH 14, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON APPLICATIONS
AND TRACKING AND DATA ACQUISITION,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10:40 a.m., in room 304, Old House Office Building, Hon. Thomas M. Pelly, presiding.

Mr. PELLY. The meeting will come to order.

The subcommittee chairman, unfortunately, is detained and has asked that I open the meeting and that we start the testimony and questioning. I think that when he gets here, Mr. Hechler will probably have a statement for the record.

But, in the meantime, I just want to say personally that we appreciate very much having you here, Mr. Rubel, to start the testimony and then later when the other members of the committee are able, I know that they will have an opportunity to read the first part of your statement and any questioning in the meantime.

So, if you will, then proceed.

Mr. RUBEL. Thank you very much, Mr. Chairman.

The statement that I have here is divided into two parts. The first part concerns the national meteorological satellite program and the second part concerns the national communication satellite program; and if you wish me to, then I can read the first part of the statement or if you would prefer, we can go directly to questioning, whatever your preference might be.

Mr. PELLY. Well, I think it would be better, possibly, to proceed with the first part of your testimony.

Mr. RUBEL. All right, fine.

STATEMENT OF JOHN H. RUBEL, DEPUTY DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

BIOGRAPHICAL SKETCH OF MR. JOHN H. RUBEL

Mr. John H. Rubel was appointed Deputy Director of Defense Research and Engineering on April 1, 1960.

Mr. Rubel had been Assistant Director of Defense Research and Engineering (Strategic Weapons) since May 19, 1959.

Mr. Rubel, who was born in Chicago, April 27, 1920, received his B.S. in electrical engineering with honor from the California Institute of Technology in 1942. Following his graduation he was associated with the General Electric Co. for 3½ years in the GE research laboratories, briefly with Lockheed Aircraft Co., and then joined Hughes Aircraft Co. in 1946.

While with Hughes, Mr. Rubel contributed to the development of one of the earliest successful automatic celestial navigation systems in this country. He also was associated with the development of the Falcon family of missiles. In 1952 he joined the radar laboratories later renamed the airborne systems laboratories of which he was named director in 1955. It was from this post that Mr. Rubel came to the Defense Department on May 19, 1959.

Mr. Rubel's industrial experience encompassed the field of airborne systems including radar, digital and analog computers, guidance and control systems, communications subsystems, etc.

With the Department of Defense, Mr. Rubel's responsibilities have included research, engineering, and engineering management aspects of long-range strategic strike forces currently in being, under development, or contemplated for future development. He has also been concerned with related matters including operations analysis relating to the design of strategic weapons systems.

As Deputy to the Director of Defense Research and Engineering, Mr. Rubel's responsibilities encompassed the entire field of military systems. Mr. Rubel served as Acting Director of Defense Research and Engineering during the several months of Dr. Herbert F. York's recovery from his illness in the summer and fall of 1960. For his service as Deputy Director of Defense Research and Engineering and Acting Director of Defense Research and Engineering, Mr. Rubel received the Secretary of Defense Meritorious Civilian Service Award on January 16, 1961.

On May 11, 1961, the President nominated Mr. Rubel to the Senate to be Assistant Secretary of Defense. Following confirmation by the Senate, Mr. Rubel's appointment became effective on May 19, 1961, with the specific duty being Deputy Director, Defense Research and Engineering.

Mr. Rubel is married and has three children. They were residents of Los Angeles, Calif., before moving to Washington, D.C.

Mr. RUBEL. Mr. Chairman and members of the committee, it is my pleasure to appear before your committee today on the subject of the national meteorological satellite program and the national communication satellite program. I will address myself first to the former.

This program is, of course, primarily the responsibility of the Weather Bureau of the Department of Commerce, but both the National Aeronautics and Space Administration and the Department of Defense have been active participants for several years in the development of this program and NASA continues to have the major responsibility for research and development in the meteorological satellite area.

The interdepartmental activities of the past several years have been concerned with the development of satellites, with the development of techniques for making optimum utilization of weather data produced through use of these satellites and with the establishment of a system for making use of meteorological satellite data on an operational basis.

In the remarks which follow, I will outline the principal organizational mechanisms which exist within the Department of Defense and between the Department of Defense and other agencies, particularly NASA and the Weather Bureau, for effecting coordination of research and development activities, for the formulation of plans for the achievement of an early operational capability, and for policy level coordination.

The requirements of the Department of Defense for an operational meteorological satellite program have been developed by the joint meteorological group, of the Joint Chiefs of Staff.

This group is composed of representatives of the three military services and the Weather Bureau of the Department of Commerce.

These requirements were approved by the JCS on April 6, 1961. The Director of Defense Research and Engineering forwarded these

requirements to the Administrator of the NASA, for guidance in the research and development of meteorological satellite systems.

Comparison of the observational requirements stated by the JCS and the capability of the national meteorological satellite systems indicates that—

(*a*) The military requirements have been included in the overall national requirements and

(*b*) These requirements will be satisfied by the system when it becomes fully operational in calendar year 1964.

The Department of Defense looks to the Interdepartmental Committee on Atmospheric Sciences of the Federal Council for Science and Technology for overall coordination of research and development activities in the atmospheric sciences area.

This group does not, however, concern itself with the detailed coordination of programs as complex and as narrow as the meteorological satellite program, but rather concerns itself with the broad policy decisions concerning areas of atmospheric sciences needing emphasis, and so forth.

We depend on the Joint Meteorological Satellite Advisory Committee for detailed coordination of research and development activity in the meteorological satellite area.

I think I should pause at this moment and clarify that paragraph, because these things are so long it is easy to get mixed up. In fact, I sometimes get mixed up myself. But the Federal Council for Science and Technology brings together various committees which, among other things, overlook the research activities in a variety of fields and what is referred to here, is the surveillance that this group, the inner departmental Committee on Atmospheric Sciences exercises over the research aspects of the scientific part of the job.

But when it comes down to a program such as TIROS or Nimbus or any other program, for actually doing a job for which funds are appropriated in a project sense, then we do not depend on them.

Rather, we depend on the Joint Meteorological Satellite Advisory Committee which is called JMSAC and which I'll talk about in a little more detail.

But I think it's important to distinguish again; these people help the scientists get together in making sure we are getting the day-to-day job done to operate in the upper atmosphere; things of that sort, on one hand and then actually getting the projects done.

The initial TIROS development program was conducted by the U.S. Army Signal Corps under the technical supervision of the Advanced Research Projects Agency until the spring of 1959 when the entire program was transferred to NASA. Through fiscal year 1959 the Department of Defense had expended almost $12 million on this effort.

The results of this program have been most successful as is evidenced by the succession of impressive TIROS launches to this date.

I have with me individual pictures taken from TIROS II, III, and IV, which are outstanding examples of the excellence of the work being done with this program.

The entire research and development program leading to the operational satellite and including the interim operational use of data is coordinated through the Joint Meteorological Satellite Advisory Committee, the JMSAC.

The NASA member is chairman and the membership includes representatives from the Office of the Director of Defense Research and Engineering, the Weather Bureau, and the three military departments.

The actual expenditure of funds by the Department of Defense in this area has been nominal, but the contributions through participation in various aspects of the program have been substantial.

Specifically through coordination in JMSAC, joint participation has involved the following:

(*a*) Provision of facilities for command acquisition and data readout: This is accomplished by the NASA at Wallops Island and by the Department of Defense at the Pacific Missile Range.

NASA plans to increase the number of command acquisition and data readout stations for the Nimbus satellite and has established a station at Fairbanks, Alaska, and is in the process of selecting a site for the establishment of a station in the northeast North American continent.

There is a reason for wishing to delete that phrase there.

Mr. PELLY. Off the record.

(Discussion off the record.)

Mr. PELLY. You may proceed.

Mr. RUBEL. To date, personnel from Army, Navy, Air Force, NASA, and the Weather Bureau have participated in this activity as members of the readout teams located at each of these stations. A team consists of 12 meteorologists plus supporting technical personnel.

We are still talking about our participation in the program on JMSAC.

(*b*) Processing and rectification of the master film: This is accomplished by the naval photographic interpretation center located here in the Washington area.

(*c*) Collection of supplementary data for research and development of interpretation techniques and procedures: This activity includes photo reconnaissance flights, scheduled to coincide with passage of satellites, the collection of special surface weather observations, the collection of "in flight" pilot reports as well as hurricane reconnaissance and ice reconnaissance.

The agencies participating in these activities are the Army, Navy, Air Force, Weather Bureau, and Federal Aviation Agency.

And I might interpolate here, to make sure it's clear; by making these farflung observations both on the ground and in the air, by a variety of means and correlating these observations from what we see from the satellite looking above, with these ground observations, we will enable ourselves to make much better use of the satellite data in the future.

Because it is not always obvious looking down a great number of miles, in the several hundreds, to make sure what those photographs are in terms of conditions on the ground.

By noting what the condition is on the ground at the time the photographs and other data is being read out, we can learn how to use that data for the purpose.

Mr. HINES. In other words, Mr. Rubel, reconnaissance aircraft would time their flights with the passing of the satellite overhead?

Mr. RUBEL. Yes, that is correct.

(*d*) The interim operational use, application, and evaluation of cloud analyses. These functions are performed by the Weather Bureau, Navy, and the Air Force.

This effort has increased substantially as the number of successful TIROS launches have increased.

The Air Force and Navy are particularly interested in supporting research in this phase of the activity.

Such research is essential to meet their own specific operational requirements.

The National Coordinating Committee for Aviation Meteorology was established in November 1960 under the chairmanship of the Chief of the United States Weather Bureau.

Membership on NACCAM includes the Army, Navy, Air Force, Weather Bureau, Federal Aviation Agency, Civil Aeronautics Board, and Bureau of the Budget.

This committee is very active and the Department of Defense is pleased to be represented and will continue to cooperate in this effort.

In recognition of the importance of meteorological satellites an ad hoc panel on operational meteorological satellites (POMS), often called the POMS committee, was formed early last year to develop a plan for a meteorological satellite system which would satisfy the requirements of both the civilian and military components of the Government.

This ad hoc panel has since been formalized and made a permanent panel of the committee effective this month. Its continuing function is much the same as was its function as an ad hoc panel because plans in this area must keep pace with the growing technological capabilities of the agencies involved and the changing requirements growing out of recognition of these capabilities.

In addition to meeting requirements the panel is also concerned with achieving an operational system at the earliest possible date.

The plan was completed in April 1961 and distributed to all interested agencies giving guidance in the areas of management, funding, launch schedules, ground facilities, communications, and payload configuration.

The Department of Defense endorsed the plan strongly and will do all it can to support the conclusions and recommendations contained therein.

The Aeronautics and Astronautics Coordination Board has overall responsibility for the coordination of activities involving the Department of Defense and the National Aeronautics and Space Administration.

I would like to amend that statement also by pointing out, the Aeronautics and Astronautics Coordination Board was originally established in about May or June of 1960 and we've testified to the organization and functions of this board before your committee and others, on numerous occasions in the past, but since the expansion of the NASA program beginning last spring and the establishment of the national goal for a manned lunar landing and return in this decade as part of our national space objectives, the requirements for coordination between the NASA and the Department of Defense have, of course, been correspondingly expanded so that we have really found ourselves

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supplementing the operations of the AACB by the establishment of other mechanisms.

Some of these have not yet been fully formalized, but they really exist and I expect within the next very few weeks if not sooner, perhaps the next few days, some of these will be formalized to the point where that will be documentation giving description of them in somewhat more detail, specifying in detail those aspects of the manned lunar effort, for which the NASA requires DOD support.

We have had recently issued, a directive signed by Mr. McNamara which specifies the manner in which responsibility for such coordination will be assumed within the Department of Defense and it does have the effect of somewhat supplementing and going beyond the responsibilities which formerly were discharged through the mechanism of the AACB.

Mr. PELLY. Is this going to suggest that if the documents become available within a relatively few days, that the record would be open and that you could have these as part of the record?

Mr. RUBEL. Yes, that is a very real possibility and we'll bear that in mind and try to get that in the record if we can.

The thing I have in mind is the specific form of organization the Air Force will establish under General Schriever's command for actually carrying out certain motions of their support of the man lunar program.

I think we are very close to the point now where that will be definitised in writing. If it is in time to put it in the record, we certainly will be very pleased to do so.

One of the subgroups of this Board, the AACB, the unmanned spacecraft panel, concerns itself with the meteorological satellite program as well as all of the other unmanned satellites to insure effective coordination, the prevention of undesirable duplication and the free and complete exchange of information.

Mr. RUBEL. Good morning, Mr. Chairman.

Mr. HECHLER. You may proceed.

Mr. RUBEL. Mr. Chairman, we had begun reading the first part of my statement which concerns meteorological satellites and we are almost through with it.

Mr. HECHLER. You may proceed.

Mr. RUBEL. The meteorological satellite program is an important example of how such coordination can be effected.

The unmanned spacecraft panel leans heavily on the joint meteorological satellite group for technical competence in the meteorological satellite area and takes action only in cases where policy is involved and a decision cannot be reached by JMSAC.

In all of the coordinating activities mentioned, the basic aim of the people involved is to arrive at a truly national program wherein the needs of each agency are given thorough consideration and the requirements of no agency are overlooked.

It is our opinion in the Department of Defense that the existing mechanisms have done and continue to do this task in a most effective manner.

The Department of Defense recognizes the importance of the peaceful use of space in the establishment of better international relationships and is happy to cooperate with the establishment of in-

ternational programs which will lead to the understanding of the environment in which we expect to operate.

The Department of Defense has and will continue to have a keen interest in the national meteorological satellite program.

We are pleased with the progress to date and will do all we can to keep the program moving forward.

Adequate weather information of the type required by the military departments is most difficult to obtain over inaccessible areas of the world and satellites can be most useful in obtaining such information.

Let me turn now to a consideration of the national communication satellite program.

Mr. HECHLER. I think in the interest of continuity it will be better if we pause before you get into the discussion of communication satellites and take up questions by the subcommittee on the meteorological satellite.

But before we proceed with any staff committee questions, I'd like to ask you to furnish for the record various items that you have mentioned in the course of your prepared statement, namely:

The requirements of the Department of Defense for an operational meteorological satellite program, you mentioned on page 2. The precise membership of the Joint Meteorological Group of the Joint Chiefs of Staff you mention on page 2.

Membership of JMSAC which you mention on page 3 and likewise the text of the plan for the meteorological system prepared by the ad hoc panel and membership of the ad hoc panel which you mention on page 7.

Would this be possible?

Mr. RUBEL. Yes, sir; we will be very pleased to do that, Mr. Chairman.

The POMS report you referred to, we submitted last year and also the classified addendum thereto, but we will be pleased to give you another copy, if you would care to have that.

The JCS requirements are classified. The rest of the material that you've asked for can be put into the record.

Mr. HECHLER. We'll put in the record the unclassified items, then.

Mr. RUBEL. Yes; and we'll supply you all the other information including the classified material.

(The information requested will be found in the committee files.)

Mr. HECHLER. Before we proceed, do any of the members have general questions prior to staff questions?

Mr. Hines?

Mr. HINES. Mr. Rubel, under an operational meteorological system, wouldn't the Navy Photographic Center in Washington continue to handle the processing and rectification of the films for both military and civilian agencies?

Is that planned?

Mr. RUBEL. To the best of my knowledge, that's the case. I'd like to ask Mr. Foster here on my right, and incidentally who is our Defense representation on the JMSAC, if he would back me up on that, or correct me if I am not right.

Mr. FOSTER. That is right, they do plan to continue.

Mr. HINES. That is also a Weather Bureau installation, is it not?

Mr. FOSTER. No; it is not. That is a Navy installation.

Mr. HINES. It is?

Mr. FOSTER. Located right next door to the Meteorological Center there.

Mr. HINES. I see.

May I ask what is meant by making use of the meteorological satellite data on an operational basis?

Does this get into a classified area?

Mr. RUBEL. Well, I don't think it necessarily would. There would be features of a military portion of the operational portion that would be classified, but I think the general meaning of operational use would not be classified.

The military departments have an obvious need for weather data of several types.

Certainly, they would like to have the best weather forecast that can be made available and much of the data which will be collected and utilized and interpreted for commercial, for civilian as well as for military purposes, will form a basis for forecast information and be available to the military departments as well as to civilian agencies.

Military departments always have use for information as to the status of the weather on a real time basis for potential operational purposes—for potential military operational purposes in areas which are of little or no immediate interest to civilian agencies and also outside the continental limits of the United States.

Mr. HINES. Yes.

Mr. RUBEL. This kind of operational information is obviously much more unique to the military departments than it would be to our own American citizens located in the continental United States, and the systems that do design the information could be made available to the military departments for that purpose.

Mr. HINES. I see. When did the Army begin work on the TIROS? You didn't mention that in our statement.

Mr. RUBEL. Will, you know when they begin this?

I might have that here.

Mr. FOSTER. The actual date of the beginnings, I do not have.

Mr. HINES. Can you tell me the year?

Mr. FOSTER. About 1958.

Mr. HINES. Thank you. On page 4, you mentioned something about the nominal amount. How much is the nominal amount? This is on page 4 of your statement. Is nominal below a million dollars?

Mr. FOSTER. The nominal amount is, in fact, about $800,000.

Mr. HINES. I assumed it was less than a million dollars.

Mr. HECHLER. May I ask a question here, Mr. Rubel. On page 5 I note you say on lines 2 and 3 that the Department of Defense has established a read-out station at the Pacific Missile Range and we are, of course, concerned here about any independent activity or duplication.

I wonder whether your future plans and whether the Department of Defense intends to establish stations elsewhere or are you going to rely on NASA facilities?

Mr. RUBEL. I think, Mr. Chairman, that for operational use the military departments will establish a read-out station in many other places.

Mr. HECHLER. What is the principle that would cause you to establish independent read-out stations?

Mr. RUBEL. The principle there, Mr. Chairman, relates to the need for the military departments to acquire real time current weather information.

For example, a force located in a remote area such as the southeast Pacific, might have a need for real time weather information, relative to that area and its general vicinity which could only be acquired through a read-out station that would be located somewhere in that general area and for which weather stations—read-out stations located on the continental United States, for the North American Continent, would not suffice.

Mr. HECHLER. Let me follow up to be sure I understand.

Who is going to operate the stations after the meteorological satellite system becomes operational?

Would this be the Weather Bureau, DOD, or NASA?

Under what circumstances again would DOD get involved after the meteorological satellite system becomes operational?

Mr. RUBEL. Mr. Chairman, it's my understanding that the Weather Bureau will be responsible for the operational system.

The Weather Bureau will operate those stations which are necessary to acquire and utilize the data for civilian purposes and partly to satisfy military needs from the operational system; but that the military departments will also operate independently of the Weather Bureau.

But at those stations which are uniquely required for military operational purposes, the design of the system permits the utilization of the same basic system to provide data for both purposes simultaneously.

Mr. HECHLER. Are there any further questions on meteorological satellites?

Mr. Wilcove?

Mr. WILCOVE. Mr. Rubel, does the Defense Department now have its own installations for obtaining weather information or do you rely entirely on the Weather Bureau?

Mr. RUBEL. I think we call it phase 1. At the present time we are exploring, insofar as we can, the vehicles of devisees that are conceived and deployed for research and development purposes.

The read-out facilities we have are operated both by the Department of Defense and by the Weather Bureau.

We have a read-out station or command and acquisition station at PMR.

The Weather Bureau has one at Suitland.

The Navy Department in conjunction, or in physical conjunction therewith, provides for the rectification of photographs that come from the satellite, as I mentioned earlier.

In this R. & D. phase we have a mixture of ground facilities all working together to utilize the data which is acquired during this operation, during this research and development phase 1.

Mr. WILCOVE. What I primarily had in mind, Mr. Rubel—perhaps I didn't make myself clear—is this: What system did you have before the satellites were put up?

Did you obtain all your weather information from Weather Bureau facilities or did you have some of your own?

Mr. RUBEL. No; we have many sources of weather information including reconnaissance flights that are made by Army—I mean by Air Force and Navy aircraft.

There are balloon soundings that are made by the Weather, also made available to the Department of Defense. There are rocket soundings that are also utilized by all the services and by the Weather Bureau as a source of meteorological data. All of these are pooled by all the services in the acquisition and utilization of weather data.

There also are sitings, reports from ships at sea. From observation positions in military installations around the world, which also feed data in for the creation of meteorological reports of various systems.

Mr. HECHLER. I was just going to say, meteorological conditions in this room are not very well controlled.

Mr. WILCOVE. But are all those activities centralized by the Weather Bureau?

In other words, your satellite flights, aren't they carried out as an adjunct to Weather Bureau activity?

Mr. RUBEL. It is my understanding—I'd like to ask you to back me up on this, Will.

We furnish the data which we get to the Weather Bureau, but that observation is for strictly tactical purposes, unique to a military operation and are acquired by the military departments on an ad hoc basis as necessary.

For example, observations and soundings are made at the Atlantic Missile Range prior to and in connection of space shots of various kinds in order to get a more refined and complete understanding of weather conditions as they would effect such a shot and these are supplementary to and are not furnished, nor are they under the supervision of the Weather Bureau.

Mr. WILCOVE. To sum it up, all weather activities are not centralized in the Weather Bureau?

Mr. RUBEL. That is correct.

Mr. WILCOVE. In your prepared statement, Mr. Rubel, you say that the meteorological satellite system will become fully operational in calendar year 1964.

Is that the estimate of DOD, or is that someone else's forecast?

Mr. RUBEL. I think it represents an agreed-upon estimate that everybody shares.

I don't think we have any difference between our DOD estimates and those of the Weather Bureau or of the NASA and represents an appraisal of the status of the system and the progress that's being made on that.

Mr. WILCOVE. In other words, it is the thinking of all the groups involved in the program, that it will become operational in calendar year 1964?

Mr. RUBEL. Right.

Mr. WILCOVE. What type of system do you anticipate will become operational in 1964?

Mr. RUBEL. That is the Nimbus system.

The satellite stabilized with respect to the local vertical on the earth.

In other words, keeps looking down to the earth as it goes around the earth.

It is in such an orbit it passes the Equator at noon at all times. Of course, that is the Nimbus system.

It has, of course, a great many other factors, in fact.

The ability to look at a lot of information with a wide-angle lens. The ability to focus on more detailed features. The ability to pick up infrared information and make other various observations that are necessary and useful in understanding the weather.

But it is the Nimbus system that we contemplate.

Beyond that, people have other thoughts, but not approved programs at the present time.

Mr. WILCOVE. And how many Nimbus satellites is it anticipated will be aloft at one time for an operational system?

Mr. RUBEL. Well, one at a time in operational use would provide ample data and the system is designed so that, as I understand it, the life of the system that is the life of a satellite in orbit and the rate at which satellites will be launched will be such as to insure that you would always have at least one satellite in full operation at all times.

Mr. WILCOVE. With reference to the photoreconnaissance flights handled by Army, Navy, and Air Force aircraft, how is this activity coordinated.

In other words, who determines who flies where and at what time?

Mr. RUBEL. Why don't you answer that question?

Mr. FOSTER. This particular activity is coordinated through the Joint Meteorological Satellite Advisory Committee.

The Air Force flights are actually controlled through the geophysics research directorate of the Air Force, Cambridge Research Laboratory, and they have membership on the Joint Meteorological Satellite Committee and it is coordinated in that activity.

Mr. WILCOVE. And the Weather Bureau is represented on this group?

Mr. FOSTER. Yes.

Mr. WILCOVE. Will this system be continued in the satellite research program?

Mr. FOSTER. Yes; for the research and development it's hoped to continue.

There are also, of course, flights made by local commands in which case the Weather Bureau, of course, is informed and the information is then transmitted to the National Meteorological Center and JMSAC is informed.

Mr. WILCOVE. Then, of course, it gets to the Weather Bureau and they circulate it?

Mr. FOSTER. Right.

Mr. WILCOVE. With reference to the interim operational use, application, and evaluation of cloud analyses by the Navy and Air Force—to which you refer, Mr. Rubel, on your prepared statement, on page 6, is this done individually by each agency?

Mr. FOSTER. Well, the answer is yes and also jointly.

The Air Force carries on an activity of its own at Cambridge in which they are doing research on the use of these cloud analyses.

The Navy's carrying on a similar activity in response to Navy requirements at their weather facility at Norfolk and the Army is doing

a little of this in connection with some of their ballistic work at Fort Monmouth.

Mr. WILCOVE. Who coordinates this?

Mr. FOSTER. This again is coordinated in JMSAC.

Mr. WILCOVE. Will the same setup be continued when the satellite system becomes operational?

Mr. FOSTER. Yes.

Mr. RUBEL. I think that the burden of this paragraph, however, is aimed at the effort that is going on now to correlate ground observations with the data which one gets back from the satellites in such a way as to enable the very rapid and the highly accurate interpretation of satellite data in the operational phase without the necessity for continuing a research activity per se, so that, for example, the folks in the Army when they look at data which comes back from an operational satellite can interpret that data and know what that means in terms of the weather conditions they are going to have to confront, and their interests in those weather conditions is different than the interests that the Air Force, for example, would have or than the Navy Department would have since flying through the weather is different than walking through it or driving through it.

So that the reason for the decentralization of these research activities, is understandable and the necessity for it, I think clear, in that context.

Now, when one gets to the operational phase, we fully expect you are going to have to continue this sort of thing, but presumably at an ever-increasing level.

Hopefully we'll finally get to the point we'll understand what those pictures mean or what that data means so it won't be necessary to do any more research with the correlation of that material with respect to terrestrial and atmospheric conditions.

Mr. WILCOVE. When a satellite takes a picture of the cloud coverage below, you also take pictures below the cloud, do you not?

I presume the clouds look different from below than above.

Mr. RUBEL. That's the kind of observations they are doing here. They do more than that, too. They report in detail what the operations are. The idea being you must look at the pattern, look at the wind measurement and precipitation, humidity, look at formations as they appear from the ground and correlate from what one sees from the satellite and the measurement, infrared, measurements, things of that kind that one makes from the satellite.

Mr. WILCOVE. Could you outline for us, briefly, the recommendations of the ad hoc panel on operation—just a brief outline of the recommendations.

Mr. RUBEL. Are you thinking now, Mr. Wilcove, of the recommendations as they relate to the military?

Mr. WILCOVE. No; on page 7 of your prepared statement, Mr. Ruble, you stated that a plan was developed for a meteorological satellite system which will satisfy the requirements of both the civilian and the military. That is what I had in mind.

Mr. RUBEL. There are two sets of recommendations in the POMS Committee report. One is in this unclassified document and the other in this much smaller classified one relating to military securities, development of the meteorological system.

With respect to the first general conclusion and recommendations they are that the United States undertake to develop a national operational meteorological satellite system at the earliest possible date. Of course, that recommendation is being followed up; that this document be accepted as the basis for initial planning and implementation of such a system.

That recommendation is being followed up also and has been done by all the interested departments. That funds be made available in early fiscal year 1962 to begin implementation of the system.

And there have been funds even beyond those contemplated at the time this report was written, to accelerate the work, the development work, and also the interim exploitation of the intersatellite development.

There were $22 million added to the NASA budget, for example, in the last budget add-on in May 1961 for the purchase of four additional TIROS satellites, one as a backup and three to provide additional satellites in orbit during this year and the early part of next year, so that we would continue to have those TIROS satellites in orbit even while deploying the Nimbus because of the great amount of material we are getting from that satellite.

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. There was a great deal of testimony last year relative to who has responsibility for what.

I don't believe any legislative changes were made, but I think the assignment of responsibilities is very clear between NASA, the Department of Defense, and the Weather Bureau and all of us recognize responsibility for the development of these devices in orbit is the responsibility of NASA, and the responsibility for the operational phase is the Weather Bureau.

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

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 postlaunch 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.

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

That applies, of course, for the Department of Defense, since we are one of the major users and all of these organizations are staffed on a multiservice basis and multiagency basis.

That the operational—that the satellite data users participate in gram, 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.

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

Not only have those recommendations in essence been followed, but in addition, we have, as I said before, acquired more TIROS satellites so that we would get earlier operational utility from this very successful R. & D. program.

Well, that really covers the points I just made.

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

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 phaseout; and

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

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

Those were the recommendations in here.

There were two recommendations or conclusions in the confidential report which I testified to last year and which I think are germane in the context of this overall recommendation, and it said the following.

The observational requirement stated by the Joint Chiefs of Staff were the requirements and capabilities described in the main portion of this report.

That's what I was just reading from.

Demonstrates that (1) these requirements are included in the overall national requirements and (2) these requirements will be satisfied by the system—the military requirements, in short, by the total system.

Mr. WILCOVE. That is fine, Mr. Rubel.

I have just one more question, Mr. Chairman.

The Department of Defense, to sum up what has been said here today and previously, apparently sees no need then for a meterological satellite system of its own.

Mr. RUBEL. Yes, sir; that is correct.

Mr. WILCOVE. Thank you, Mr. Rubel.

Mr. HECHLER. Mr. Rubel, on top of page 9, when you discuss international relationships, with reference to meterological satellites, I had a feeling you are a little bit low key here. You said you'd be glad to cooperate with efforts.

I had a feeling that the Department of Defense didn't want to assume any real strong position toward the use of the meteorological satellites as a weapon in the cold war or as a weapon of freedom.

We ought to be more enthusiastic about this possibility that our weather satellites can be used not only to cover and supply a great deal of information for those underdeveloped nations in areas where the

weather coverage is scanty, but in addition to that as a weapon in the cold war. When you look at the rather sharp reaction of the Soviet Union against what we are doing in this field, it looks like they fear our progress, I would hope maybe you might "beef up" our interests and get a little more enthusiastic.

Mr. RUBEL. Mr. Chairman, I think there are perhaps three things we could distinguish in this regard.

As I said earlier, we are certainly in favor of international cooperation with respect to understanding the environment.

This doesn't per se, say anything about what the weather is then going to be tomorrow or what it is today, but learning more about the environment, what the upper atmosphere is about.

We don't care where we get that information. The more we learn about it the better it will be for us, even from just a purely military standpoint.

Secondly, with respect to the exploitation of weather data, for our own domestic purposes or for possibly domestic purposes abroad, predicting a typhoon off the coast of Japan, for example, might save people's lives or property.

Certainly, if we can contribute in any way as a Nation, the well-being of other peoples around the world and maintain our national posture, we would be happy to have a helping hand in that regard.

Third, is the utilization of a system, an operational system for military purposes and the relationship of that system to possible enemy operations or intervention.

Now here, I think we feel very strongly the following:

That we must have access to weather information, the best weather information, possible for the conduct of our military operations without the necessity of sharing that information with a potential enemy country; and secondly, our system ought to be highly invulnerable to acquisition or interference by potential enemy countries.

Being realistic, we'd like to—we'd like to extend the benefits of technological developments in the peaceful directions that you have indicated, but without doing so in a manner which would compromise our ability to make sure if everybody in the world weren't equally cooperative we would not as a result suffer a diminution in our capability.

Mr. HECHLER. All I am suggesting in a rather broad way, is that we are worried, about the Department of Defense budget and its size yet it's likely we will spend far less money in the future if we don't have to use some of these forces.

That was my only mild suggestion.

Mr. RUBEL. That is true.

Mr. HECHLER. Are there any other questions on meteorological satellites before we get on the communication satellites?

(No response.)

Mr. RUBEL. Mr. Chairman, I'd be glad to read the statement or be glad to proceed to questioning whatever you want.

Mr. HECHLER. Would you care to summarize your statement?

Mr. RUBEL. I'll be happy to do that.

The first portion of this statement relates to the objectives of the Department of Defense relative to communications satellites and what we are interested in.

It states that we work closely with other agencies of the Government including the IRAC, the Interdepartment Radio Advisory Committee, and the FCC, particularly on problems relating to the assignment, to the allocation of frequencies; and this is a very, very important question not only for the Department of Defense but for the whole Government of the United States in this field.

Then, we go on to describe the kinds of systems we are interested in, long haul fixed point-to-point trunks.

The long haul point-to-point links which would provide circuits to remote operational areas and, finally, mobile communications between fixed points and mobile stations or between mobile stations.

Then I point out there are different kinds of communications satellites, passive reflectors of various kinds, active repeaters in low- or medium-altitude orbits and active repeaters in synchronous orbits.

I singled out the active repeaters in low- or medium-altitude orbits from the other kind of repeaters because of the unique problems associated with even getting satellites into that particular orbit.

I then point out that there are different—these different classes of satellites offer different possibilities for meeting defense requirements and we are, in the Department of Defense, actively pursuing two of these.

West Ford—one is called needles, consisting of a band of small reflectors in a doughnut-shaped orbit around the Earth for eventually a backup communication capability and secondly, the Advent program.

Mr. HECHLER. You never found these needles?

Mr. RUBEL. I believe, Mr. Chairman, that although they found the little package that has the needles in them, they never came out, as you know.

Mr. WILCOVE. Mr. Rubel, when do they plan to send the second one up?

Mr. RUBEL. The exact flight date has not been determined.

Mrs. WEIS. You are continuing with that operation, despite your losing your first batch?

Mr. RUBEL. We expect to continue with the West Ford experiment but the precise details are still under consideration.

Mr. WILCOVE. You plan to send up the needles in the current fiscal year?

Mr. RUBEL. Yes, we do.

Then we talk about Advent, which is the Defense Department project for the creation of a satellite, a capability for a satellite in a synchronous equatorial orbit, and we describe as the objectives of the Advent project and some of its principal features.

We then describe the manner in which we have been working with other agencies, specially the NASA on Project Syncom which is a joint NASA-DOD program for a small satellite, a satellite weighing only about 55 pounds, also in a synchronous equatorial orbit, utilizing facilities on the ground furnished by the Army on the same frequency band and equipment essentially usable for the Advent system.

A very good example where two programs have been made to dovetail.

Then we described the manner in which we coordinate with the NASA on the AACB, just the Relay and the Telstar being supported by the NASA; but it is a privately sponsored program of the A.T. & T. Co.

Lastly, the discussion concerns the attitude of the Department of Defense concerning the proposed legislation for the establishment of a Corporation to exploit communication satellites for commercial purposes and essentially says that we are very anxious to cooperate with whatever agency is established.

The laws—the legislation that is proposed, really don't concern the Department of Defense directly, but only indirectly because only the FCC and NASA are primarily involved in the matters which relate to the way—to the procedures whereby a concern of this sort would be established and administered.

However, we do have a policy which has been issued.

In fact, we first issued this policy in the form of my testimony before your committee last year and we have, since then, issued this more widely and we have supplemented it with more specific technical details which we have made available to American industry on demand.

We have had many, many demands for this information and it has proved very useful for the people thinking about future communication satellite systems, to know what sort of things we have in mind in the Department of Defense, relative to the characteristics of communications satellites that might be of future use.

I have then put this in the record.

You will find the statement of our policy we put in the record here, is the same I testified to the fall of last year, but the additional technical information is now and was developed subsequent to my testimony last fall.

That, Mr. Chairman, concludes an outline of what the statement contains.

Mr. HECHLER. Without objection, your entire statement on communication satellites will be placed in the record.

Mr. RUBEL. That will be fine, Mr. Chairman.

(The information referred to is as follows:)

Let me turn now to a consideration of the national communication satellite program.

We feel that communications satellites can make a very significant contribution to improvement of the reliability, capacity, and geographical availability of communications to meet our critical national security needs. Further, we believe these systems have great promise for civil use. They can furnish new capabilities particularly in reaching remote regions of the world where communications provided by present systems are seriously deficient or even unavailable. The DOD works very closely with other agencies of the Government concerned with the important problems involved in the exploitation of space for communications purposes, particularly with NASA on the development of communication satellite systems and components and with the telecommunications office of the Office of Emergency Planning, the Interdepartment Radio Advisory Committee, and the Federal Communications Commission on general communications problems, particularly those related to frequency usage.

The Department of Defense is interested in three major types of communications to which satellite systems can make important contributions:

(*a*) Long-haul fixed point-to-point trunks providing numbers of circuits between major traffic nodes such as those located on the east coast of the United States, and those in Europe, North Africa, or in the Middle East and from points on the west coast to Hawaii, the Philippines, and Japan.

(*b*) Long-haul point-to-point links providing a few circuits to remote operational areas often with light traffic loads and a requirement for use of transportable equipment to establish new circuits on short notice.

(*c*) Mobile communications between fixed points and mobile stations or between mobile stations.

There are three general classes of devices in space which have potential for providing long-distance communications via satellites. These are, (1) passive reflectors of various kinds, (2) active repeaters in low or medium altitude orbits, and (3) active repeaters in synchronous orbits. I would like to discuss the DOD interest in these several types of devices.

The three classes of satellite systems offer different possibilities for meeting these defense requirements and the Department is actively pursuing investigations of two of them. First, Project West Ford is an example of a system using passive reflectors in space. The first flight test of the West Ford package on October 21, 1961, failed in that the tiny hairlike filaments (called dipoles), that are intended to reflect radio energy back to earth, failed to dispense to form a cloud or belt. Exhaustive investigation of all available evidence as to the causes of the failure indicate that it is extremely unlikely that the several fairly large fragments (into which the "dipole" package has broken) will ever disperse.

Preparations are underway for a second attempt to launch a West Ford dipole package later this year. Modifications to the experiment proposed for the next launch provide a significant measure of control and surveillance over the behavior of the package—in particular, the inclusion of a device for commanding the release of the dipoles from the ground after determining that a suitable orbit has been achieved, that is, one in which the lifetime of the dipoles in orbit is of limited duration.

The conduct of the West Ford experiment has been governed by the White House statement made available on August 11, 1961, and will continue to be so governed. That statement specifically recognizes the Space Science Board and its special committee on this subject as a vehicle by which continuing studies are to be undertaken. The Space Science Board has studied the report of the Lincoln Laboratory of the Massachusetts Institute of Technology relating to the analysis of the failure of the first test and plans for the proposed test and has forwarded copies of the Lincoln Laboratory report and the report of the Space Science Board Committee to the members of the West Ford Committee of the International Astronomical Union in accordance with the intent of the White House statement. The action of the Space Science Board along with the Lincoln Laboratory report were made available for release to the public on Sunday, March 11, 1962.

The proposed West Ford test will involve a pair of ground stations—one on the east coast of the United States and one on the west coast and the belt of dipoles in space. Each dipole is about one-third the thickness of a human hair and about three-quarters of an inch long. It is proposed to use about 250 million of these dipoles distributed along a thin, narrow, circular orbital ring or belt several thousand miles about the Earth.

The Department has for over 2 years been proceeding with Project Advent to develop a capability to put a vehicle into a synchronous orbit over any predetermined spot on the equator. With three such satellites in an equatorial plane and equally spaced around the Earth, it is possible to cover about 80 or 90 percent of the Earth with a communications system. The capacity of the Advent system can be very considerable. There will be somewhere between 10 to 40 megacycles of bandwidth available for communications and for the incorporation of antijamming and encryption features.

There are a number of problems associated with the development of the Advent system. One of the problems is getting it into position in the first place. This requires considerable complexity in launching; it requires continually steering the satellite once it is in position in order to keep it there; it is necessary to keep it pointing accurately at the Earth in order to make maximum use of the small amount of power available in the satellite and, of course, there is the problem of reliability.

The first satellite in the Advent program is now being fabricated and should be ready to fly in an intermediate altitude test orbit within the year. Although the object of Project Advent is the development of the components needed for a synchronous equatorial system uniquely tailored to our national security needs, most of the technology is directly applicable to development of nonmilitary systems. Further, much of the technology is applicable to medium altitude systems requiring stabilization and position keeping.

I should like to note again at this point that the development of communication satellite capabilities is still in an early phase and that considerably more development effort and experimental work must be undertaken in order to exploit the promise of space technology for operational use in communication satellite systems. This is properly a national effort utilizing national resources of many kinds and requiring the cooperative efforts of numerous agencies. The development efforts in this field are shared both by NASA and the Department of Defense. Our relations with NASA have been increasingly close to insure that the technical gains made by each are fully available for the benefit of our national effort. Our scientific advisory groups have had access to data made available both by NASA and by the Department of Defense and their technical thinking and assistance has been made equally available to both our agencies. In addition to frequent informal consultations, the Unmanned Spacecraft Panel of the AACB established the Communication Satellite Working Group consisting of representatives of the Army, Navy, Air Force, and NASA. This group has concerted planning and insured the free exchange of technical information and joint participation in numerous experiments.

Another example of this close cooperation between NASA and the Department of Defense is the Syncom project in which NASA is supporting the development of a very simple lightweight synchronous satellite which will provide a very few channels and should be available much sooner than the more sophisticated, more advanced Advent system. The Department of Defense is sharing in this project by designing and building three transportable ground stations for Syncom and modifying the Advent shipborne station to serve as the African Syncom station during the initial system tests. It is also planned to modify the Advent ground stations to perform tests and communicate via the Syncom satellite.

Although the Department has no active project for development of the third type of communication satellite system, that is the medium altitude active repeater, it is following the work of NASA on Project Relay and the Telstar project, now underway as a cooperative effort by NASA and the A.T. & T., with a great deal of interest.

The Department of Defense has participated in discussions at the space council and in working groups established by the secretariat of the council to consider various aspects of the development and promotion of a civil communications satellite system.

The Department of Defense and the National Aeronautics and Space Administration are together promoting the development of the space sciences and the engineering and the electronic systems techniques which can make commercial communications satellite systems economically and technically feasible.

Communications are vital to our military security. Accordingly, although the Department of Defense will undoubtedly establish a communications satellite system of its own to meet specialized requirements, it is anxious that its contribution to a civil system provide a system which will be of the greatest benefit to the Department.

In furtherance of this objective, on September 7 last year, the Department issued a policy entitled "Industry-Department of Defense Cooperation in Satellite-Based Telecommunications." This policy states that it is in the interest of the Department that industry be encouraged in the development and establishment of an operational communications satellite system as rapidly as feasible economically and technically. The Department offers its full assistance, particularly with respect to scientific information derived from military developments. A copy of this policy is herewith submitted for the committee's record.

In responding to a request for the views of the Department of Defense on pending legislation relating to various bills for the creation of an entity concerned with the establishment of a commercial communications satellite system, we have stated that:

"Any legislation which may be passed to promote development of a civil communications satellite system should provide adequate framework for expeditious establishment of a technically sound system. Communication via satellites should be considered in proper perspective as primarily a new means of providing for the long-distance relay of communications which originate and terminate within existing or future civil or military continental communication systems. To effectively aid our critical defense communicatons problems, any satellite systems must be technically and operationally integrated with these existing continental systems."

In commenting on the legislation prepared by the administration, H.R. 10115, before the Senate Aeronautical and Space Sciences Committee, we stated that:

"Of special importance to the Department of Defense in the legislation prepared by the administration is the recognition in section 102(d) that 'it is not the intent of Congress by this act to preclude the creation of additional communications satellite systems, if required to meet unique governmental needs or if otherwise required in the national interest.' This provision makes clear that the development and operation of a communications satellite system for national security needs, such as the Advent program, would in no way be affected by the establishment of the commercial system. It is also noted that under section 201(a)(6) the President would be directed to insure 'utilization and availability of the communications satellite system for general governmental purposes not requiring a special system.' This provision would insure that Government agencies would use the commercial system in accordance with normal practice, and that the power to assign priority of governmental traffic over commercial traffic as necessary for national security purposes would be reserved.

"It is noted that under the bill the Department of Defense would have no direct responsibility with respect to the proposed commercial system, and therefore the Department offers no further specific comments. However, the Department strongly supports the objective of the legislation to establish a civil communications satellite system as expeditiously as practicable."

INDUSTRY-DEPARTMENT OF DEFENSE COOPERATION IN SATELLITE-BASED TELECOMMUNICATIONS

It is in the interest of the DOD that industry be encouraged in the development and establishment of an operational communications satellite system as rapidly as economically and technically feasible. The DOD will assist in this endeavor to the extent practicable, in particular with scientific information derived from military developments and such other assistance as may subsequently be determined. In achieving this objective, it will be the policy of the Department of Defense:

1. To encourage and support to the maximum extent possible the efforts of private enterprise in the development of a space telecommunications system.

(*a*) By furnishing private enterprise technical specifications and prospective circuit requirements necessary to meet long-line military needs.

(*b*) By providing assistance, to the extent possible within security limitations, in the selection of locations for ground facilities.

(*c*) By providing assistance (when requested) to the FCC, NASA, and other Government agencies in the evaluation of various industry proposals for commercial satellite-based telecommunication systems.

(*d*) By making arrangements with NASA and FCC approved licensees, whereby under appropriate conditions, boosters and launching facilities may be made available by the Government.

2. In general to apply the same policy to satellite communications as to other long-line communications. In accordance herewith:

(*a*) The Military Department will use U.S. commercial facilities and provide exclusive military facilities only when required to meet those military needs that cannot be satisfied by commercial facilities.

(*b*) DOD circuitry will be terminated by U.S. controlled facilities as opposed to foreign facilities wherever practicable.

(*c*) The DOD will support the assignment of frequencies for commercially operated satellites in the same manner as for other common systems.

3. The Department of Defense is presently engaged in the development of the technological base upon which reliable, economical, and technically adequate communication satellite systems can be designed. No decision to establish a particular operational system has been made by the DOD. Such a decision will be made ta a suitable time dependent on the evolution of technology, the outcome of present development programs and decisions with respect to the nature and capabilities of a commercial system. Defense assistance to industry will be conducted through NASA unless particular circumstances dictate otherwise and specific arrangements are made with NASA to work directly with industry.

Any DOD operational system must be designed to provide long-haul trunks for the DCA satisfying the peculiar requirements of the military for reliability, security, ECM resistance, access to remote areas and use between mobile units.

4. Based upon these considerations and a projection of technology into the 1964–65 period, the DOD desires for technical characteristics of a commercially operated satellite system, in order to obtain the maximum benefit therefrom include, but are not necessarily limited to, the two general classes of service and three basic options set forth below:

(*a*) Service classes:

1. Toll quality voice circuits (4 kc) equivalent to the balanced four-wire toll circuits currently available.

2. Channels which will permit up to 40.8 kilobits digital binary stream as a maximum in any combination of steps consistent with military standards. The quality of the circuitry for digital use must provide for accuracy compatible with military telecommunication terminal equipments which is expected to be in the order of magnitude of 1 error in 10^6.

(*b*) Control options:

1. Channels capable of being equalized to accommodate facsimile and cryptographic equipment.

2. Channels capable of being combined to provide bandwidths of 48 kilocycles to accommodate special equipments which may require additional degrees of equalization and line control.

3. Under emergency conditions the system should be engineered to provide a capability for using all or part of the satellites' operable system bandwidth to meet military requirements for special purposes (e.g., application of spread spectrum techniques).

In more generality, commercial communication satellites should be real time relay or repeater systems capable of relaying planned voice, teletypewriter and data modes. The bandwidth and distortion, reliability and speed of transmission must be comparable to that presently obtained by transmission via wire, cable, microwave, tropo, etc. These satellites should provide a capability for channel derivation in voice band segments (4 kilocycles) which in turn are capable of being combined into broader bandwidths. Twelve voice channels combined into a 48-kilocycle bandwidth is acceptable.

No encryption equipment requirements are imposed for the commercial satellite, although transmission of encrypted traffic is a requirement of the system.

Channels derived from satellite systems are to be capable of automatic and manual switching through ground networks.

No anti-jam or ECM requirements are imposed for the satellites.

Satellite derived circuits between the United States and the geographic locations of presently deployed major components of the military forces are required. It would be most desirable that the commercial satellite communications system be capable of providing sufficient flexibility to provide for the wide support of military force deployment including certain forces under mobile conditions. The Department of Defense would find it particularly useful to be able to communicate via a commercial communications satellite from those portions of the world having nonexistent or primitive communications and will provide compatible military ground stations for such applications.

Mr. HECHLER. Any questions by the subcommittee before we proceed with the staff questions?

Mr. Hines?

Mr. HINES. The NASA Syncom and DOD Advent programs are confronted with the same orientation problem. That is, I am referring to the 22,300-mile orbit.

Will a single system and common hardware be used by both agencies to solve this problem?

Mr. RUBEL. The answer to that is "No."

If you care to have me do so, I will be happy to explain the reasons for the difference.

Mr. HINES. Yes, sir.

Mr. RUBEL. The Advent program has from the beginning contemplated a system as close as we could envision developing operational capabilities.

It called for a satellite weighing approximately 1,250 pounds.

One of the chief features of this satellite is that it will look down at the earth all the time.

Now this, of course, means it must have a stabilization system, because it's traveling around the earth every 24 hours and although it appears to stand still, of course, it's really rotating in space all the time.

This meant, then, the development of stabilization and control devices, the power supplies, the structure to accomplish that basic objective.

The chief problems associated with the development of a device of this sort are not only in the area of the communications portion, but also the development of the satellite capabilities.

How will you accomplish that stabilization?

How will you control it once you have it in orbit?

In fact, how will you even get it into orbit, in a fully effective way?

These are among the chief problems and relate more to space technology than they do to communications.

After we have been working on the Advent program for about 18 months we found that considerable progress had been made in the kind of technology that could be applied to the development of spacecraft, the kind of technology that could be applied to the communication equipment aboard spacecraft also.

And it seemed at that time to be a good idea—a good decision, to move forward and exploit that new technology without in any way disturbing the Advent program.

An agreement was accomplished in the fall of 1960 between NASA and the DOD which recognized the desirability of pursuing this new technology and the desirability of assigning that responsibility to the NASA since the DOD was already devoting so many of its energies, of its resources, to the Advent project.

The NASA studied this problem for a considerable period of time.

It wasn't until almost a year later, actually, that the decision was finally made to move forward with the Syncom.

But the decision was still taken in that same basic context.

Now, the Syncom satellite only weighs about 55 pounds, as distinguished from 1,250 pounds, so obviously will have much less capability from the communications standpoint than the Advent.

It is stabilized though in a very different way.

The Syncom is a rapidly rotating satellite and it is stabilized just like a gyroscopic toy. The familiar type of gyroscopic top is stabilized.

Doesn't have to have any gyros and control valves and the like aboard.

Once it's put in the right place, it stays there because it is spinning.

This has advantages and it has disadvantages, but it represents a different way of accomplishing the desired objective of putting a satellite into position or at least once it is in position, of maintaining it in position and accomplishing the desired function and it has many simplicities, too, relative to the Advent type of conception.

The possibility exists, for example, if this kind of technology works out, well it might turn out to be more economical to put several of these relatively smaller and simpler satellites in orbit to accomplish a given communication capacity and function than to use the larger type of satellite contemplated under the Advent program.

And because it seemed one could exploit this technology rather inexpensively and rather quickly, whereas, for many reasons it would take us much longer to actually get an Advent satellite built and in orbit; the decision was made by NASA to proceed with the acquisition of some Syncom satellites and to make the attempt to put them in orbit on a very, very rapid schedule.

Then the question arose, how will we tie these satellites in or this satellite program in, with all the other things that we are doing and the decision was made and I think this is a very important and fundamental one, that the frequency band that would be used for Syncom would be the same as the frequency bands on Advent.

Therefore, we are able to build a frequency band that will talk to Syncom, but will also talk to Advent with simple modifications and very inexpensive modifications.

There are two possibilities.

There are many possibilities, but there are two interesting possibilities to distinguish I think.

One is that Syncom will work right away and there won't be any problems associated with it.

If that should happen we will develop a very useful, albeit a very limited communication ability as soon as that experiment proves successful.

We open up a few telephone channels for example, between the United States and Western Europe.

In fact, between the United States and eastern Africa and this can be very useful from a military point of view which is one of the reasons why we in the military department are interested in Syncom.

But another possibility is that Syncom will not work properly, that we will find difficulties, that some of the problems which now seem relatively straightforward will prove not to be.

Well, inasmuch as this is a development program, one thinks that that is an excellent reason for proceeding with the program to solve those problems, to exploit the possibility of this kind of technology through the solution of such problems, to explore as only tests can enable you to do, what the possibilities and what the impediments in practice will turn out to be.

So, this is the thinking now, behind the Syncom program, and the interrelation of the NASA and the DOD effort in this particular area.

Mr. HINES. Thank you. That was very lucid.

I would assume, of course, that NASA's timetable for flight testing Syncom would precede that of Advent?

Mr. RUBEL. That is correct.

The first launch of Syncom is scheduled for January of 1963.

The first launch in an equatorial orbit of the Advent, in a synchronus equatorial orbit of the Advent, is still a problematical matter.

It depends upon the development of launch vehicles which haven't been developed and probably, I would say, is unlikely to occur before 1963.

Mr. HINES. You have answered, too, my upcoming questions.

Would Advent only handle classified traffic—classified communications?

Would it also have an in-the-clear capability?

Mr. RUBEL. Yes, it could have an in-the-clear capability.

We have not at this point resolved precisely the answer to that question.

How would you tie Advent in with a commercial capability if its capabilities exceed that required by the military department but there is no technical impediment to such utilization?

Mr. HINES. Is the Army managing the Advent program from DOD at the moment?

Mr. RUBEL. Yes, they are. They are managing it.

Mr. HINES. Geographically speaking, would the Advent program have ground stations coinciding with the Syncom or the commercial ground stations for transmission?

Mr. RUBEL. The answer to that is "Yes" it would, and there are two types of stations to distinguish in this regard, the fixed stations and the mobile stations.

The fixed stations, for Advent, are located at Fort Roberts and Fort Dix.

The mobile stations will be located in different places depending upon the particular application of interest.

But in the case of Syncom, at least one mobile station will have to be located somewhere in the neighborhood of the western coast of Africa, the northwestern coast of Africa, or possibly in the neighborhood of Ascension Island, unique to the manner in which we plan to put the Syncom satellite in orbit.

You must have a station over there for control purposes.

At least, in the initial phase of the program, that is.

During the phase in which Advent is being exploited it is contemplated also one would put remote stations, exploit stations, possibly shipborne stations in precisely those locations and others as well so there is a complete overlapping of the applicability of the Advent-type stations to the Syncom program.

Mr. HINES. I would imagine by doing—having geophysical identity here, it would pose much less difficulty in arranging international agreements, power requirements in isolated areas. These potential problems could be resolved very quickly.

Who are the prime contractors and subcontractors associated with Advent?

Mr. RUBEL. The General Electric Co. has the prime contract for what we call the final stage vehicle.

That is actually the spacecraft itself.

They are under contract to the Air Force.

The Air Force actually administers that contract for the Army.

The Bendix Corp. has the contract for the communication package that goes in the satellite itself.

The Bendix Corp. also has the contract for the mobile ground stations and for a great deal of the equipment which goes into the fixed ground stations for the Advent program.

In other words, the Syncom mobile stations and the fixed ground stations.

The Bendix Corp. also furnishes equipment for the shipboard installation that will be used both for Syncom and for Advent in which the Navy Department is responsible for supervising.

The Philco Co. has the contracts for the principal part of the TCC, the telemetry command control link to the satellite.

The other contractors—there are other contractors involved.

Those are the—well, the Aerospace Corp., for the Air Force, has a contract relative to the Advent for certain management services and technical services.

And STL had a contract with the Army, engineering and management services, too, but that contract either has or is about to expire.

Those, I believe, are the principal contractors on Advent.

I haven't mentioned the booster contractors, because they are not explicitly on Advent.

They would be making those boosters whether we had an Advent program or not.

Mr. HINES. Surely.

I detect a similarity or an identity with several of these contractors which are active in the NASA satellite program.

That is all I have.

Mr. WILCOVE. I have one question, Mr. Chairman.

Mr. Rubel, when do you anticipate that the Advent program will become operational?

Mr. RUBEL. I don't see how it can become operational before 1965, Mr. Wilcove, because it will be, I think limited by the availability of launch vehicles capable of putting the satellite into orbit.

Now, this is one of the most difficult parts of the total Advent job. It will be controlling as a factor.

Mr. WILCOVE. I believe NASA people testified that they didn't expect an operational system until 2 or 3 years beyond that date. So if you can get it up in 1965, that will be very encouraging.

Mr. RUBEL. I think we are going to have a system that will be very useful.

I don't see how you can define the term "operational."

I think in the case of the meteorological satellite it is going to be a little difficult to do.

I think you'll find there is going to be a lot of development work and at the same time we are going to get a day-to-day facility out of a communication program.

The word "system" as applied to a satellite system is a big word and one that's difficult to define with precision, so that undoubtedly, we are going to find 10 years from now we are still growing, what we call the system.

But I would expect a very substantial capability to evolve substantially before 1967.

Mr. WILCOVE. That is all.

Mr. HECHLER. Any members have any further questions?

If not, we want to thank you, Secretary Rubel for your very clear testimony.

Thank you, too, Mr. Foster for being with us this morning and the subcommittee stands adjourned.

(Whereupon, at 11:55 a.m., the hearing was adjourned.)

(The following was subsequently submitted for the record:)

ASSISTANT SECRETARY OF DEFENSE,
Washington, D.C., March 15, 1962.

Hon. KEN HECHLER,
Chairman, Subcommittee on Applications and Tracking and Data Acquisition, Committee on Science and Astronautics,
House of Representatives.

DEAR MR. CHAIRMAN: I should again like to state my pleasure at appearing before your committee on Wednesday, March 14, to discuss the Department of Defense interest in the national meteorological satellite program and the national communications satellite program. I am transmitting with this letter the additional information requested by your committee at that meeting.

Enclosed as attachments are: Statement of the DOD requirements for operational meteorological satellites, classified confidential (tab A); listing of the membership of the Joint Meteorological Satellite Advisory Committee (tab B); listing of the membership of the National Coordinating Committee for Aviation Meteorology (tab C); membership of the old Panel on Operational Meteorological Satellites (tab D); its replacement group, the Working Committee on Satellites of the National Coordinating Committee on Aviation Meteorology (tab E); plan for a national operational meteorological satellite system (tab F), also classified confidential; Department of Defense position with respect to recommendations contained in the plan for a national operational meteorological satellite system (tab G); membership of JMG/JCS (tab H).

The year of the involvement of the Army in the TIROS program was, as stated at the hearing, 1958. In April 1958, the director of the program in the Advanced Research Projects Agency wrote to the three military departments urging their participation in the program. The Army contributed the vehicle know-how that had developed out of the Juno and Jupiter projects as well as the television packages being developed by the Radio Corp. of America under the auspices of the Army Signal Corps.

We shall be happy to cooperate with the committee should further need for information develop.

Sincerely,

JOHN H. RUBEL.

TAB A

METEOROLOGICAL SATELLITE REQUIREMENTS (U)

I. DATA REQUIREMENTS

(*a*) Operational data to be provided by the initial operational program:

(1) Global cloud cover in pictorial form at a minimum daily frequency of once during daylight.

(2) Mean temperatures of radiating surfaces on a global basis at a minimum frequency of twice daily. (Desired objective for temperature is an accuracy within 1° C. and a resolution of 4 miles square.)

(*b*) Additional operational data to be provided by future operational programs when acquisition of these data are demonstrated to be feasible and a significant improvement over then existing methods of obtaining the same data:

(1) Global cloud cover in pictorial form at a minimum daily frequency of once during darkness.

(2) Winds throughout the operational environment of weapons systems.

(3) Height of cloud bases and tops.

(4) Areal extent and approximate intensity of precipitation.

(5) Vertical temperature, moistre, and density structure of the atmosphere.

(6) Index of refraction.

(7) Height of Tropopause and ionospheric layers.

(8) Surface pressure.

(9) Ground cover (e.g., snow, ice, vegetation, etc.).

(*c*) Environmental data for research and development purposes for possible inclusion in R. & D. satellites, but not to be provided by an operational program unless, and until, an operational application has been confirmed:

(1) Solar and terrestrial radiation;

(2) Atmospheric composition;

(3) Aurora and ion density;

(4) Magnetic and electrical fields;
(5) Meteoric activity;
(6) Atmospheric optical properties (e.g., scattering, polarization, etc.).

II. MINIMUM SYSTEM REQUIREMENTS

(*a*) Operational meteorological satellites should possess at least the following characteristics:
(1) Resolution and accuracy of location:
(*a*) Resolution of cloud picture data of 1 to 3 miles;
(*b*) Accuracy of location of all data of 50 miles or less, with accuracy of 10 miles or less desired as soon as practicable.
(2) Direct readout to selected military and Weather Bureau forecast centers and to operational commanders of cloud pictures covering an area about 1,000 miles square, at least four times per 24-hour period for each area of local interest.
(3) Receipt of global data at selected military and Weather Bureau forecasting centers in 3 hours or less after readout.
(4) Security of system:
(*a*) Means of preventing the enemy from acquiring command of the satellite;
(*b*) Means of minimizing acquisition of the data by the enemy with the ultimate objective of denying this data to the enemy;
(*c*) Means of minimizing the likelihood of the enemy jamming the satellite or any of its components.
(*b*) Development of meteorological satellite systems should be accomplished in such a manner as to assure the concurrent provision of both spaceborne equipment and the necessary earthborne equipment so that operational capability may be achieved at the earliest practicable date.

TAB B

JOINT METEOROLOGICAL SATELLITE ADVISORY COMMITTEE

Membership

Department of Defense:	
O.D.D.R. & E.:	
Col. Arthur E. Smith	Member.
Mr. Willis B. Foster	Alternate.
USAF:	
Lt. Col. Leslie W. Cowan	Member.
Lt. Col. Albert C. Trakowski, Jr	Do.
Col. George A. Guy	Alternate.
Lt. Col. James C. Sadler	Do.
Maj. James B. Jones	Observer.
USN:	
Comdr. Richard W. Sanborn	Member.
Comdr. W. A. Hopkins	Alternate.
Mr. Elbert F. Corwin	Do.
USA:	
Lt. Col. Donald E. Simon	Member.
Maj. Lothrop Mittenthal	Alternate.
Mrs. Frances L. Whedon	Do.
U.S. Weather Bureau:	
Mr. David S. Johnson	Member.
Mr. Arthur W. Johnson	Alternate.
National Aeronautics and Space Administration:	
Headquarters:	
Dr. Morris Tepper	Chairman.
Dr. William K. Widger, Jr	Secretary.
Dr. John F. Clark	Observer.
Dr. Robert Fellows	Do.
GSFC: Mr. William G. Stroud	Member.

TAB C

NATIONAL COORDINATING COMMITTEE FOR AVIATION METEOROLOGY

Membership

Commerce	Dr. F. W. Reichelderfer, Chairman.
Army	Lt. Col. M. M. Lawson, USA.
Navy	Capt. S. W. Betts, USN.
Air Force	Brig. Gen. N. L. Peterson, USAF.
Bureau of the Budget representative	Mr. W. Pfleger, Jr.
Civil Aeronautics Board representative	Mr. W. L. Halnon.
Federal Aviation Agency	Comdr. J. W. Hinkleman, USN.
National Aeronautics and Space Administration	Dr. Morris Tepper.
Treasury Department	Capt. E. V. Carlson, USCG.
U.S. Weather Bureau	Mr. M. R. Laro, Secretary.

TAB D

OLD PANEL ON OPERATIONAL METEOROLOGICAL SATELLITES

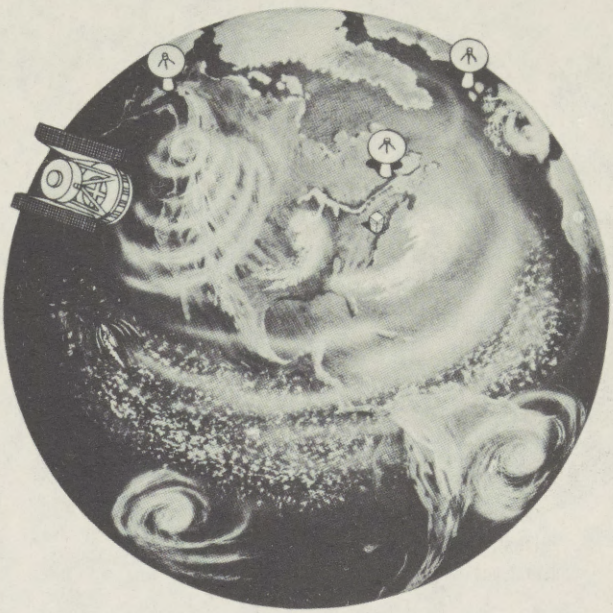
Mr. F. W. Burnett, U.S. Weather Bureau.
Mr. E. M. Cortright, NASA Headquarters, Chairman.
Mr. S. K. Greene, OACSI, Department of the Army.
Comdr. J. W. Hinkleman, Jr., Federal Aviation Agency.
Mr. David S. Johnson, U.S. Weather Bureau.
Col. C. E. Roache, USAF, Air Weather Service.
Comdr. R. W. Sanborn, USN, Office of the Naval Weather Service.
Mr. W. G. Stroud, NASA, Goddard Space Flight Center.
Dr. Morris Tepper, NASA Headquarters, Secretary.
Mr. Jack C. Thompson, U.S. Weather Bureau.

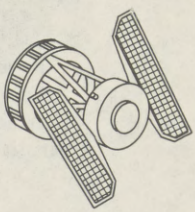
TAB E

THE WORKING COMMITTEE ON SATELLITES OF THE NACCAM

Mr. David S. Johnson, U.S. Weather Bureau, Chairman.
Mr. S. K. Greene, U.S. Army.
Comdr. R. W. Sanborn, U.S. Navy.
Lt. Col. C. E. Roache, U.S. Air Force.
Dr. Wm. K. Widger, Jr., NASA.
Member from FAA has not yet been appointed.

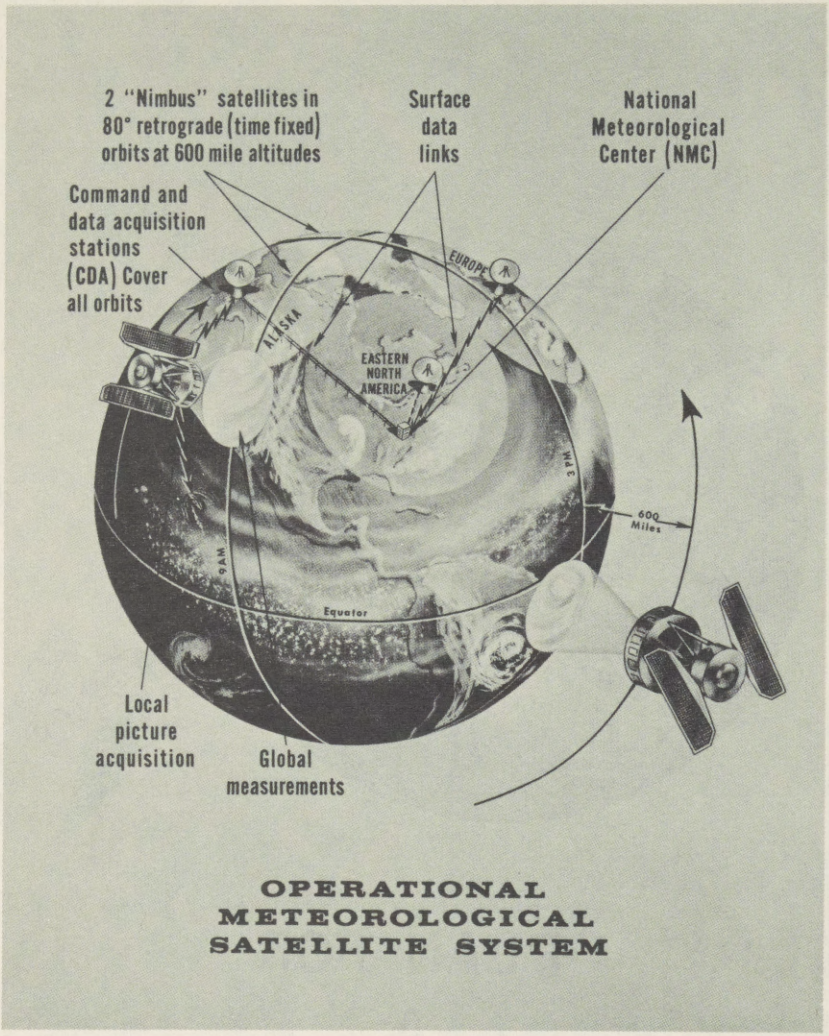
TAB F





PLAN FOR A NATIONAL OPERATIONAL METEOROLOGICAL SATELLITE SYSTEM

(2239)



OPERATIONAL METEOROLOGICAL SATELLITE SYSTEM

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

*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

(2241)

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.

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.

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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.

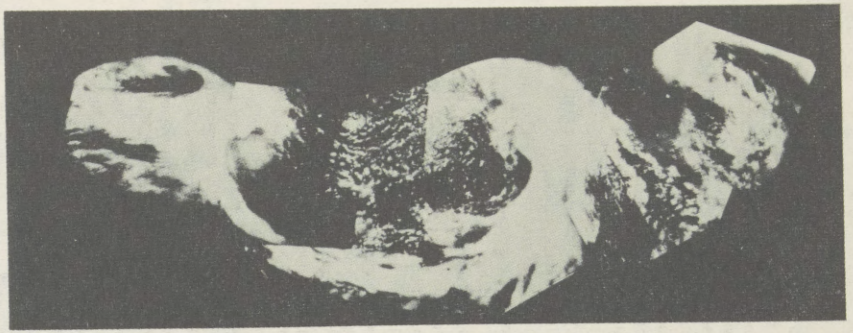
In submitting this plan, the Panel believes that the above criteria have been met.

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

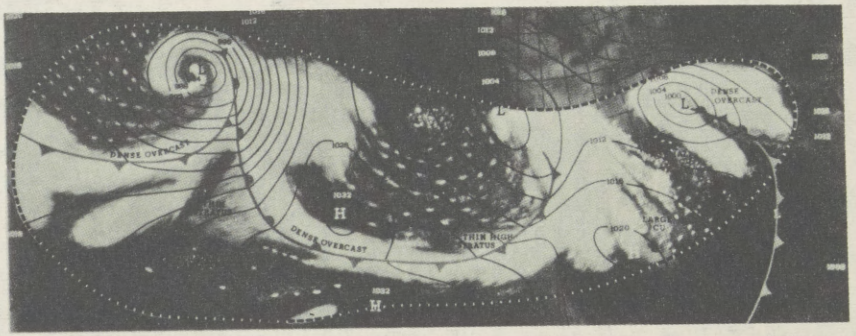
IT IS NO EXAGGERATION to state that nature uses clouds to draw its own weather map; satellites permit us to both see and use this map. The satellite will be a powerful tool, complementing existing systems by filling observational voids which exist even within dense data areas. Over immense oceanic expanses 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 back-up 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

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

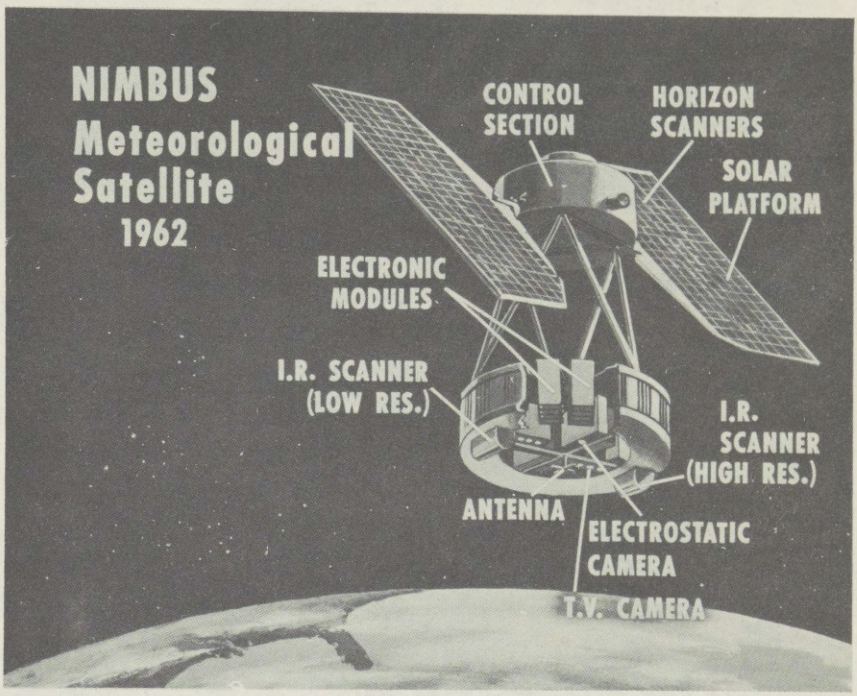
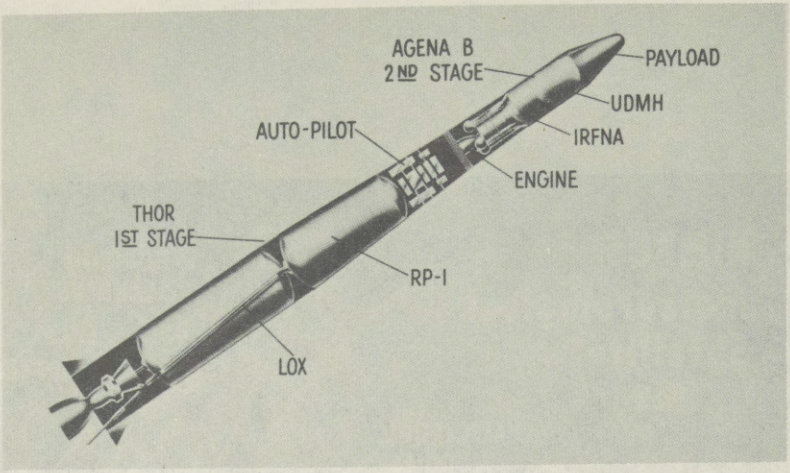
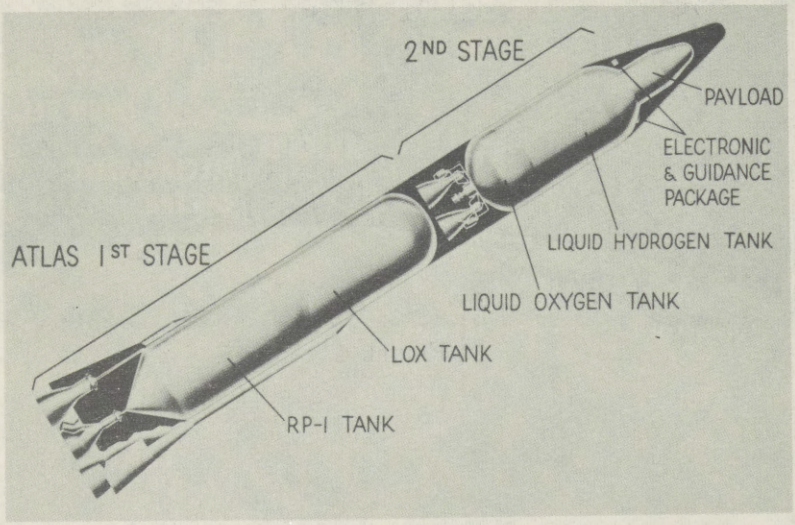

NIMBUS
Meteorological
Satellite
1962
CONTROL SECTION
HORIZON SCANNERS
SOLAR PLATFORM
ELECTRONIC MODULES
I.R. SCANNER (LOW RES.)
I.R. SCANNER (HIGH RES.)
ANTENNA
ELECTROSTATIC CAMERA
T.V. CAMERA

FIGURE 4

LAUNCH VEHICLES



THOR-AGENA B



CENTAUR

FIGURE 5

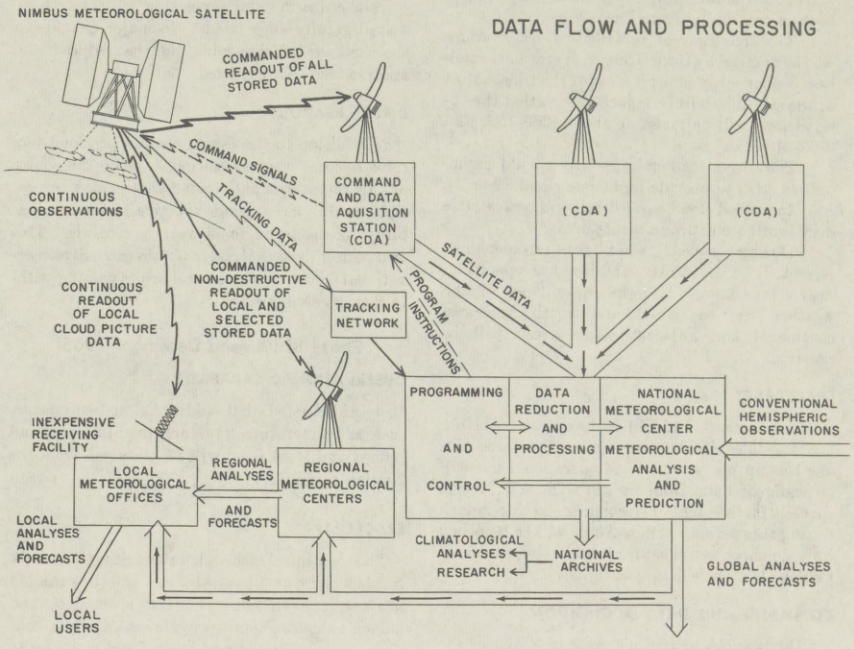

NIMBUS METEOROLOGICAL SATELLITE
DATA FLOW AND PROCESSING
COMMANDED READOUT OF ALL STORED DATA
COMMAND SIGNALS
TRACKING DATA
CONTINUOUS OBSERVATIONS
COMMAND AND DATA AQUISITION STATION (CDA)
(CDA)
(CDA)
SATELLITE DATA
PROGRAM INSTRUCTIONS
CONTINUOUS READOUT OF LOCAL CLOUD PICTURE DATA
COMMANDED NON-DESTRUCTIVE READOUT OF LOCAL AND SELECTED STORED DATA
TRACKING NETWORK
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
LOCAL USERS
CLIMATOLOGICAL ANALYSES
RESEARCH
NATIONAL ARCHIVES
GLOBAL ANALYSES AND FORECASTS
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.

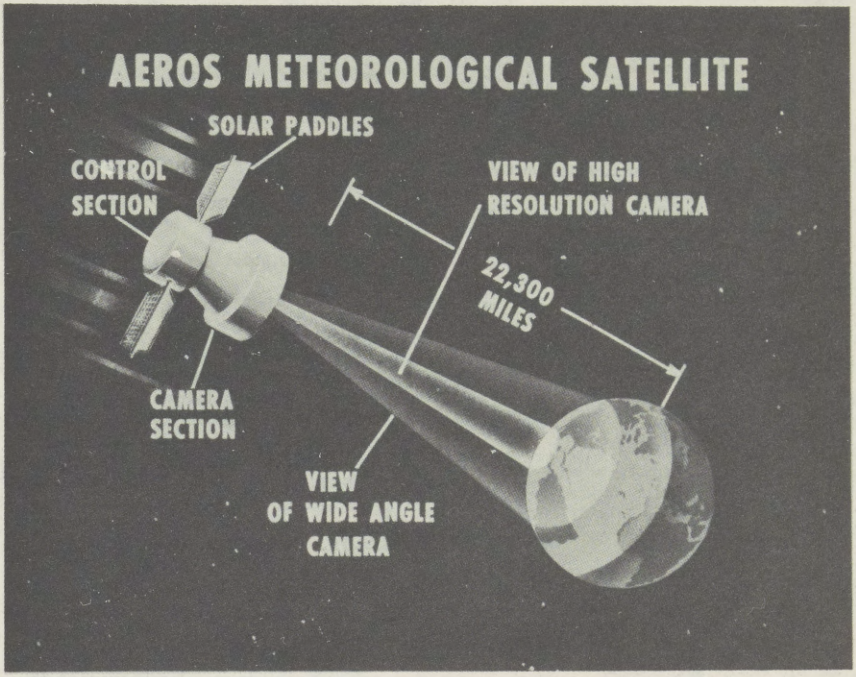

AEROS METEOROLOGICAL SATELLITE
SOLAR PADDLES
CONTROL SECTION
VIEW OF HIGH RESOLUTION CAMERA
22,300 MILES
CAMERA SECTION
VIEW OF WIDE ANGLE CAMERA

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.

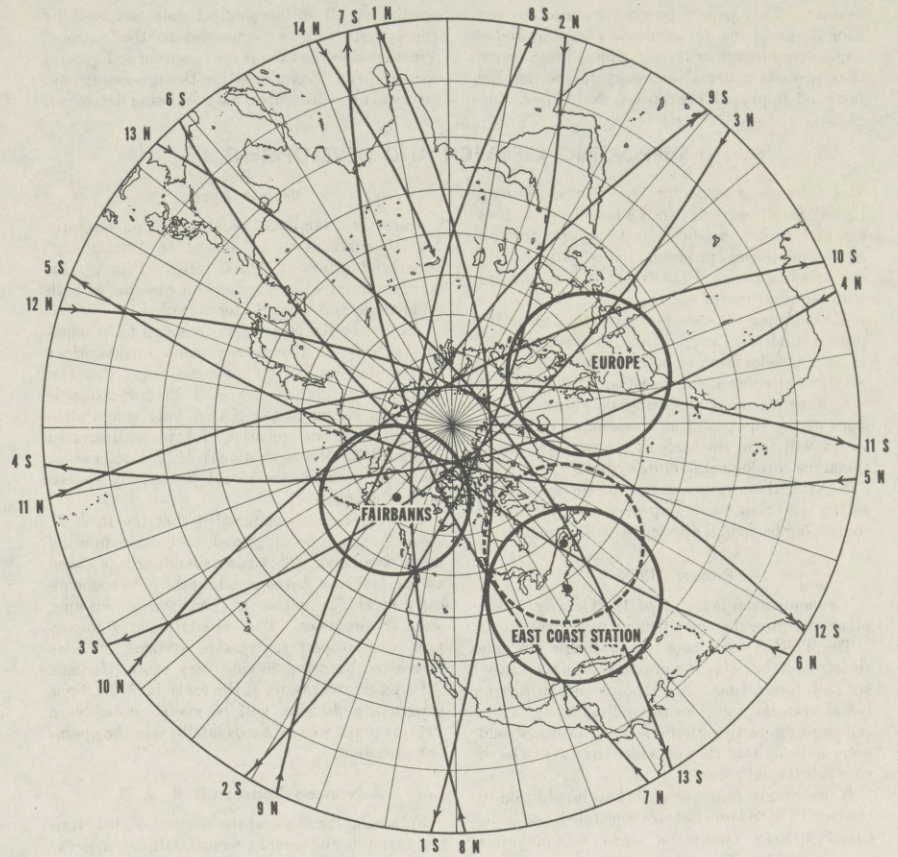
The Programing and Control group will be located in the NMC and share the computer facilities used for data processing. A computer equivalent to the IBM 7090 will supplement the NMC's present 7090. During Phase I, programing will be under NASA Space Control.

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

15

81158 O—62—pt. 5——18

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.

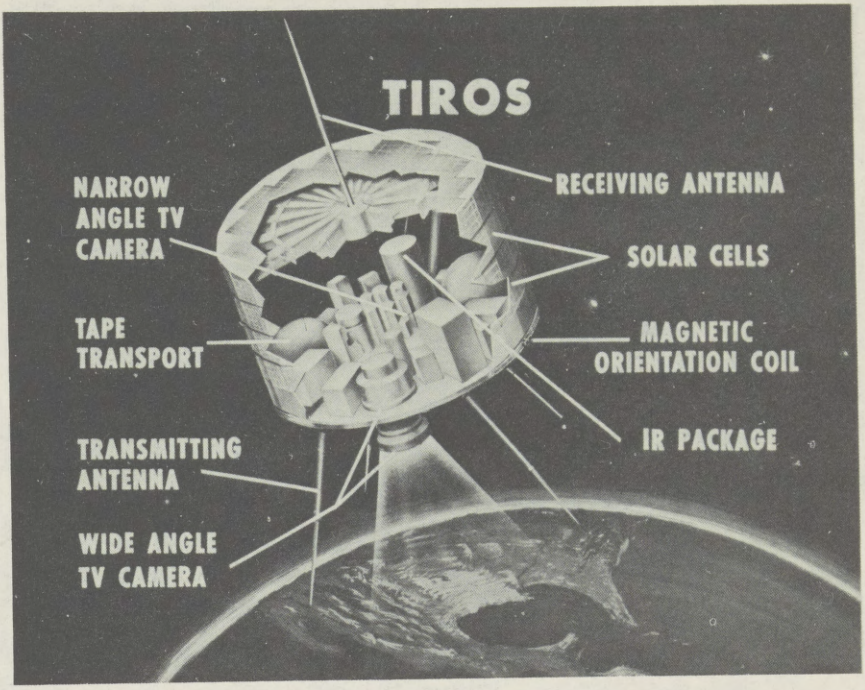

TIROS
NARROW ANGLE TV CAMERA
TAPE TRANSPORT
TRANSMITTING ANTENNA
WIDE ANGLE TV CAMERA
RECEIVING ANTENNA
SOLAR CELLS
MAGNETIC ORIENTATION COIL
IR PACKAGE

FIGURE 9

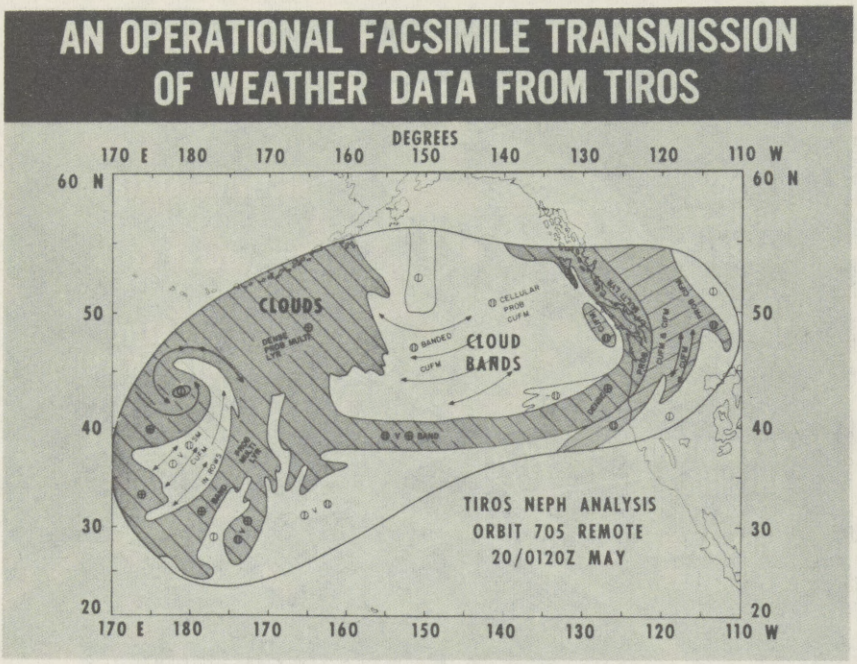

AN OPERATIONAL FACSIMILE TRANSMISSION
OF WEATHER DATA FROM TIROS
DEGREES
170 E
180
170
160
150
140
130
120
110 W
60 N
50
40
30
20
CLOUDS
CLOUD
BANDS
TIROS NEPH ANALYSIS
ORBIT 705 REMOTE
20/0120Z MAY

FIGURE 10

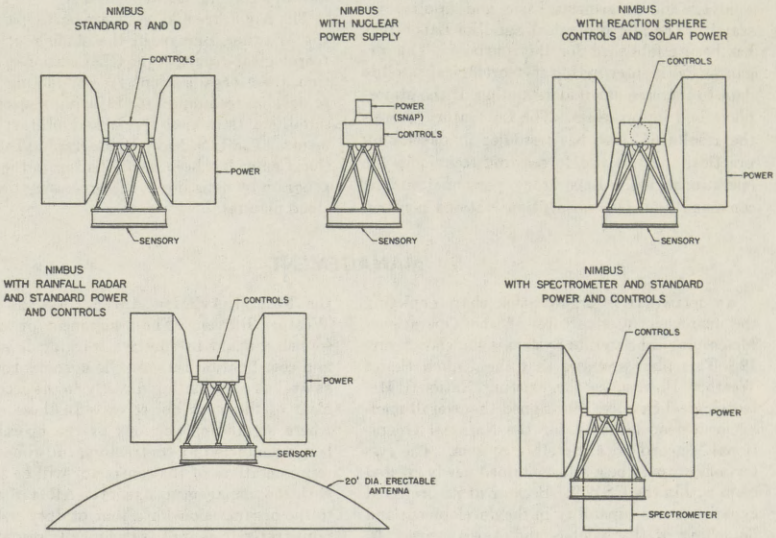


ILLUSTRATION OF NIMBUS FLEXIBILITY AND GROWTH POTENTIAL

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

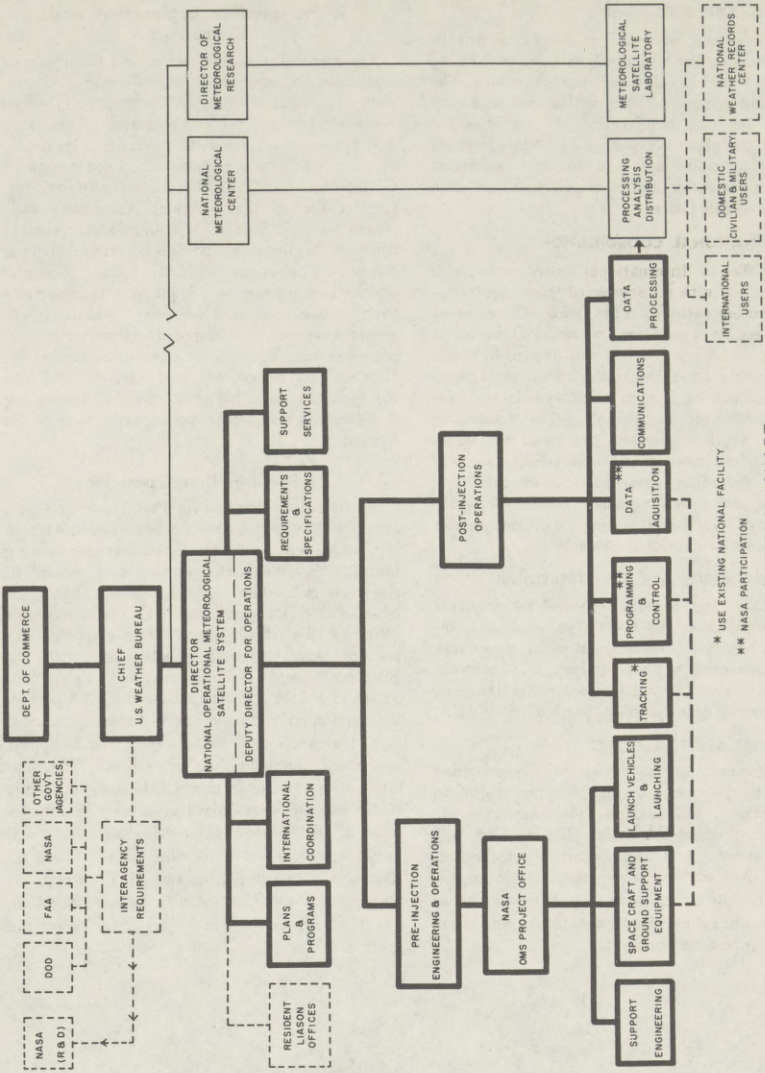
An illustrative organization chart depicting the management structure of the Operational Meteorological Satellite System is shown in figure 12. This plan proposes that the United States Weather Bureau, as the existing National Meteorological Service, be assigned the overall management responsibility 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

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

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JUN 12 1962
MANHATTAN, KANS.

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.

LIST OF PARTICIPANTS

POMS Membership

MR. F. W. BURNETT, U.S. Weather Bureau
MR. E. M. CORTRIGHT, NASA Headquarters, Chairman
MR. S. K. GREEN, OACSI, Department of the Army
CDR. J. W. HINKELMAN, Jr., Federal Aviation Agency
MR. DAVID S. JOHNSON, U.S. Weather Bureau
COLONEL C. E. ROACHE, USAF, Air Weather Service
CDR. R. W. SANBORN, USN, Office of the Naval Weather Service
MR. W. G. STROUD, NASA, Goddard Space Flight Center
DR. MORRIS TEPPER, NASA Headquarters, Secretary
MR. JACK C. THOMPSON, U.S. Weather Bureau

Other Participants

MR. ALBERT BROWN, Federal Aviation Agency
CAPTAIN W. R. FRANKLIN, USN, Office of the Naval Weather Service
LT. COLONEL JERRY C. GLOVER, USAF, Air Weather Service
MR. WILLIAM HAGGARD, U.S. Weather Bureau
MR. DAVID HOLMES, U.S. Weather Bureau
MAJOR JAMES B. JONES, USAF, Air Weather Service
LT. COLONEL M. M. LAWSON, Department of the Army
MR. ERNEST NEIL, NASA, Goddard Space Flight Center
MAJOR S. E. PEARSE, USAF, Air Weather Service
DR. WILLIAM K. WIDGER, JR., NASA Headquarters

TAB G

DEPARTMENT OF DEFENSE POSITION WITH REGARD TO SPECIFIC RECOMMENDATIONS CONTAINED IN A PLAN FOR A NATIONAL OPERATIONAL METEOROLOGICAL SATELLITE SYSTEM

Recommendation 1.—That the United States undertake to develop a national operational meteorological satellite system at the earliest possible date.

This is being done by the National Aeronautics and Space Administration in cooperation with the U.S. Weather Bureau, and the Department of Defense is cooperating in every way that it possibly can to help achieve an early operational capability.

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

The Department of Defense participated in the production of this document and does accept the document as the basis for implementation of an operational meteorological satellite system.

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

Funds were made available in early fiscal year 1962 to begin implementing the program, including those parts in which the Department of Defense participates.

Recommendation 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.

The Department of Defense concurs wholeheartedly in the assignment of management responsibility for the national operational meteorological satellite system to the U.S. Weather Bureau of the Department of Commerce.

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

The Department of Defense concurs.

Recommendation 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 NASA shall participate in such postlaunch 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 NASA and the U.S. Air Force without precluding operational use of satellite observations by other organizations.

The Department of Defense concurs and has continued to cooperate with NASA and the Department of Commerce in the establishment of command and data acquisition stations, as well as other activities connected with the operation.

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

The Department of Defense does as a user participate in the staffing of the various segments of the operational meteorological satellite system.

Recommendation 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.

The Department of Defense agrees that the system should evolve from research and development supported by and carried out by the National Aeronautics and Space Administration, and the DOD further agrees that the Aeros satellite should be supported for eventual incorporation in the operational system.

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

The TIROS program has provided a marked measure of operational capability and will continue to do so even through the first launching of the Nimbus satellite.

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

Consideration is being given to the eventual replacement of ground communications by satellite data relay.

Recommendation 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.

The Department of Defense concurs.

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

The Department of Defense concurs heartily in this recommendation and it is for this reason that the Department of Defense has urged the National Aeronautics and Space Administration to declassify subsystem A on the Nimbus satellite.

TAB H

MEMBERSHIP, JOINT METEOROLOGICAL GROUP OF JOINT CHIEFS OF STAFF

Cmdr. Robert L. Livingstone, Secretary.
Army: Col. M. M. Lawson.
Navy: Capt. S. W. Betts.
Air Force: Brig. Gen. N. L. Peterson.
Weather Bureau: Dr. F. W. Reichelderfer.

1963 NASA AUTHORIZATION

TUESDAY, APRIL 10, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON APPLICATIONS AND
TRACKING AND DATA ACQUISITION,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10:35 a.m., in room B–214, New House Office Building, Washington, D.C., Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. The subcommittee will come to order.

We are pleased to have with us this morning again, Mr. E. C. Buckley, Director, Office of Tracking and Data Acquisition; and Mr. Ralph E. Ulmer, Director of Facilities Coordination, Office of Programs; and Mr. David Williamson, Jr., Chief of Program Coordination, Office of Tracking and Data Acquisition.

This morning we would like to go into a little bit more detail in connection with the 1962 authorization bill. We have certain questions with relation to construction requests, site development, and construction costs.

Without objection, several memoranda, including one from Mr. Ulmer and Mr. Buckley and also from Mr. Theodore S. Toppin, will be placed in the record. Without objection, the March 13 memorandum will also be placed in the record at this point.

(The information is as follows:)

MARCH 13, 1962.

Mr. PAUL G. DEMBLING,
Director, Office of Legislative Affairs,
National Aeronautics and Space Administration,
Washington, D.C.

DEAR MR. DEMBLING: Enclosed you will find a staff memorandum which has been submitted to Mr. Hechler, Chairman of the Subcommittee on Applications and Tracking and Data Acquisition, for possible inclusion in the record of the subcommittee's hearings.

Mr. Hechler has requested that the memorandum be submitted to the appropriate authorities in NASA with a request for their views. These may be submitted in writing or in person.

Please advise me whether you will submit your views in writing or whether your people would prefer to appear at a hearing.

Sincerely,

RAYMOND WILCOVE,
Staff Consultant.

MARCH 8, 1962.

To: Hon. Ken Hechler, Chairman, Subcommittee on Applications and Tracking and Data Acquisition.

From: Raymond Wilcove and Richard P. Hines, Staff Consultants.

Subject: Comparison of costs for site developments at NASA facilities.

"Site development" at various NASA facilities for which funds are being requested for the 1963 fiscal year include these designations in the "Budget estimates" submitted to the committee by NASA: site preparation, paving of roads, grading, fencing, paving of parking areas, streets, etc.

The staff has noted a wide variance in the cost estimates for the tracking and data acquisition facilities. In addition, those for some facilities appear to be high in comparison with the cost estimates for site developments at other NASA facilities.

For example, the cost estimates for site developments at the Johannesburg and Woomera stations amount to 9 percent of the overall cost of the projects. This compares with a cost estimate of 1.7 percent for the Far East station, 1.4 percent for Goldstone, one-tenth of 1 percent at Cape Canaveral, and 4.7 percent at the Nova launch complex, to name a few.

Some site development costs are considerably higher than 9 percent, but special considerations appear to be involved in these instances. Thus, the cost estimate for "Utility installations" at the Atlantic Missile Range is 48 percent, but this covers such large and expensive categories as canals and bridges, as well as roads. Again, the cost estimate for the "Explosive safe assembly facility" at the Atlantic Missile Range is 22 percent, but this includes site preparation, roads and parking for four buildings. Still another facility where the cost estimate is 9 percent is the Apollo mission support facility at AMR, where six buildings are being erected.

Following is a staff comparison of the 1963 fiscal year cost estimates of site developments at a representative number of NASA facilities:

AMES

Project	Site development	Cost	Percent cost	Overall cost
Bioscience laboratory	Streets and parking	$37,200	4.0	$924,000
Helium tunnel	Grading, parking, and roads.	25,000	1.6	1,500,000
Space flight guidance research facility	Parking, roads, and utility connections.	90,000	(1)	9,790,000

ATLANTIC MISSILE RANGE

Modification to Saturn launch complex 34.	Site preparation	$50,000	1.3	$3,765,000
Modification to Saturn launch complex 37.	do			1,150,000
Launch complex-solid suborbital vehicles.	Site preparation, roads, parking.	85,000	4.9	1,717,000
Supporting facilities existing area (4 buildings).	Site preparation, grading and filling roads, parking.	244,000	8.1	3,000,000
Additional assembly facility	Site preparation, parking.	73,600	3.6	2,000,000
Explosive safe assembly facility (4 buildings).	Site preparation, roads, and parking.	98,500	22.0	450,000
Apollo mission support facility (6 buildings).	Site development	2,000,000	9.0	22,500,000
Titan II launch complex	do			2,400,000
Utility installations existing area	Roads	78,000	9.7	800,000
Advanced Saturn launch complex 39	Site preparation, roads	1,850,000	1.0	176,550,000
Advanced Saturn-Nova supporting facilities (6 buildings).	Site preparation, roads, parking.	964,000	2.4	39,121,000
Apollo static test facility	do	77,000	1.5	5,000,000
Nova launch complex	Site preparation, roads	3,800,000	4.7	79,500,000
Utility installations (new area)	Canals, bridges, roads, site preparation.	10,650,000	48.0	22,000,000

FLIGHT RESEARCH CENTER

Building additions	Paving	$16,000	1.2	$1,332,000
Visual flight simulator				475,000

GODDARD

Project	Site development	Cost	Percent cost	Overall cost
Applied sciences laboratory	Roads, parking	$100,000	3.1	$3,175,000
Attitude control test facility	Roads, parking, grading, clearing.	39,000	4.2	915,000
Development operations building	do	100,000	5.4	1,850,000
Launch phase simulator	Roads, clearing, grading	75,000	1.9	3,915,000
Spacecraft operation facility	Parking, roads	70,000	(1)	7,500,000
Tracking and telemetry laboratory	Roads, parking	100,000	3.1	3,175,000

JET PROPULSION LABORATORY

Telecommunications laboratory	Grading, paving, sidewalks, landscaping.	$30,000	1.0	$2,860,000

LANGLEY

Vehicle antenna test facility	Grading, paving	$30,000	1.7	$1,725,000

MARSHALL

Addition to computation division building.	Site development, parking.	$70,000	5.5	$1,255,000

GOLDSTONE

Advanced antenna system	Site grading, access roads.	$205,000	1.4	$14,250,000

JOHANNESBURG

Antenna facility	Site preparation, roads	$450,000	9	$5,000,000

WOOMERA

Antenna facility	Site preparation, roads	$450,000	9	$5,000,000

FAR EAST STATION

Data acquisition station	Site preparation, access road gradings, paving, fencing.	$110,000	1.7	$6,000,000

ROSMAN STATION

Data acquisition station	Site development			$3,500,000

MERCURY CONTROL CENTER

Modifications	Site preparation	$5,000	(2)	$5,000,000

WALLOPS STATION

Advanced data acquisition system	Site preparation, roads	$75,000	5	$1,500,000
Modification, expansion range control, safety and support systems, and equipment.	do	146,500	7.3	2,000,000

[1] Nine-tenths of 1 percent.
[2] One-tenth of 1 percent.

NASA's cost estimates for paving parking areas at tracking and data acquisition facilities also appear to be high at some facilities. As a method of comparison, paving costs of parking lots at the U.S. Capitol were obtained from the Office of the Architect of the Capitol.

Included in the NASA budget was an estimate of $60,000 to provide 150 parking spaces at the spacecraft operations facility, Goddard Space Flight Center, Greenbelt, Md. This is a cost of $400 per parking space.

But at the same Goddard Space Flight Station, the estimated cost for parking areas and roads for a tracking and telemetry laboratory was $100,000. No breakdown was furnished by NASA for the parking area alone, but since provision was being made for 350 people and since the cost of paving roads was also included, the expense probably would be considerably less than $285 for each parking space.

Still another NASA estimate was $50,000 for 150 cars at an addition to the Computation Division Building, Marshall Space Flight Center, Huntsville, Ala., or $333 per parking space.

As a comparison, the cost for paving congressional parking lots at the Capitol is presented herewith:

HOUSE PARKING LOTS

All parking lots, with the exception of No. 4, have 6 inches of compacted gravel for a base, and about three-fourths inch of asphalt for surface.

Lot No. 1 (back of Congressional Hotel): 112 spaces at $123 each, $13,776 overall cost; about 5 years old.

Lot No. 2 (behind New House Office Building): 265 spaces at $95, $25,148 overall cost; built in 1958.

Lot No. 3 (across from additional office building now under construction, where Kann's warehouse was formerly located): 271 spaces at $74, $19,980 overall cost; built in 1961. Cost includes lighting.

Lot No. 4 (across from additional office building now under construction. Last parking lot on street): 121 spaces at $122, $14,759 overall cost; built about 3 to 4 years ago. About 2 or more inches of surfacing.

SENATE PARKING LOTS

Same specifications as for House parking lots, excepting No. 4: 227 spaces at $212, $48,111 overall cost; quite a bit of grading involved; 229 spaces at $206, $47,178 overall cost; considerable grading involved.

Since the subcommittee did not have time at today's hearing to inquire at length into this subject, the data in the staff memorandum is being submitted to NASA for its comment prior to insertion in the record of the subcommittee's hearing.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, D.C., April 6, 1962.

Mr. RAYMOND WILCOVE,
Staff Consultant, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. WILCOVE: Reference is made to your letter of March 13, 1962, enclosing a copy of a staff memorandum dated March 8, 1962, concerning certain costs for site developments at NASA facilities.

We are herewith submitting our views in writing in the attached memorandum dated April 4, 1962, from Mr. R. E. Ulmer, Director of Facilities Coordination, Headquarters, NASA, to this Office.

Sincerely yours,

PAUL G. DEMBLING,
Director, Office of Legislative Affairs.

MEMORANDUM

APRIL 4, 1962.

To: Director of Legislative Affairs.
From: Director of Facilities Coordination.
Subject: Site development costs for NASA facilities.

In response to Mr. Brown's oral request of this date, the following comments are submitted relative to Mr. Wilcove's memorandum of March 13, 1962, regarding site development costs for certain NASA facilities in the fiscal year 1963 budget.

The staff of the House Committee on Science and Astronautics has correctly noted the variance in several of the cost estimates for site development. A brief review of the manner in which NASA facility estimates are prepared for inclusion in the budget submissions is believed desirable prior to a discussion of the necessity for the cost variations.

Following the practice established by the Congress for the NASA's predecessor agency, the National Advisory Committee of Astronautics, NASA authorization and appropriation requests are considered concurrently by the Congress. This procedure, which permits a substantial saving of time in the construction of NASA facilities, does involve acceptance of the principle that budget estimates for the facilities are, in fact, estimates based on the cost of similar facilities previously constructed, on the most reasonable extrapolation or projection of past experience, or on the use of a nominal estimate in those cases where similar facilities have not previously been constructed. The budget estimates in most cases are not based on completed designs or on detailed engineering studies by architect-engineers. This principle is particularly applicable to the site development portions of the estimates in those cases where specific site selections must await the authorization of the facilities by the Congress.

With the enactment of the fiscal year 1962 authorization bill, the Congress approved the establishment of a new account within the "Construction of facilities" appropriation entitled "Advanced facility planning and design." This account permits the advanced design of facilities for which authorization and funding may be requested in future years. By the use of this account it is anticipated that future year budgets for many facilities will be based on more detailed estimates supported by architect-engineer studies while still retaining the basic principle of concurrent congressional consideration of the authorization and appropriation bills.

Reference is made in the staff report to the wide variation in the cost estimates for site development based on percentages of the total cost of the projects. Irrespective of the preliminary nature of many of the estimates, wide variations in site development costs when expressed in such percentages are perfectly normal and should be expected. The difficulty arises from the use of the total facility cost in the derivation of the percentage figures and the attempt to compare site development costs on the basis of the percentage figures. For example:

The staff paper indicates the site development costs for the Goddard Center's spacecraft operations facility to be only nine-tenths of 1 percent of the total project cost while site development costs for the Development Operations Building exceed 5 percent of the total project cost. The apparent low figure for the spacecraft operations facility results from the fact that $5 million (or 67 percent) of the total estimated cost of the facility is for equipment which bears no relationship to the site development requirements. In the case of the Development Operations Building there is no equipment involved in the cost estimate since the function of the project is to provide a building to house equipment already available. If the equipment costs are removed from the total cost of the Spacecraft Operations Building project, the site development costs become 2.8 percent of the estimated total project cost or 3.6 percent of the estimated building cost.

Similar variations in percentage may be derived depending on the base used for the comparison. For example, note the following percentage variations for the Goddard Center facilities mentioned in Mr. Wilcove's memorandum:

Project	Total project cost	Site development costs expressed as a percentage of—		
		Total project cost	Total project cost less equipment	Building cost only
Applied sciences laboratory	$3,175,000	3.1	3.5	4.0
Attitude control test facility	915,000	4.2	7.3	12.2
Development operations building	1,850,000	5.4	5.4	6.8
Launch phase simulator	3,915,000	1.9	6.1	8.3
Spacecraft operations facility	7,500,000	.9	2.8	3.6
Tracking and telemetry laboratory	3,175,000	3.1	3.5	4.0

Care should be taken even in attempting to draw conclusions from a comparison of the site development costs expressed as a percentage of the building cost (last column) because this comparison involves the factor of the specific building cost which normally bears no relationship to the site development costs. In the above table, for example, site development costs for the Development Operations Building are shown as 6.8 percent of the building cost while those for the spacecraft operations facility are only 3.6 percent. A more detailed examination of the projects reveals, however, that the building cost for the Development Operations Building averages approximately $21 per square foot while that for the spacecraft operations facility averages $28 per square foot. The difference in the construction estimates in no way affects the site development costs for either project. Were the technical requirements of the facilities such that the building costs for the two facilities were reversed, the site development percentage for the Development Operations Building would then become 5.1 percent and that for the spacecraft operations facility would become 4.8 percent.

As another example, note the wide range of the site development percentage for the launch phase simulator going from 1.9 percent when related to the total project cost to 8.3 percent when related to the building cost only.

It is believed the above analysis indicates the manner in which apparent differences in site development costs expressed as percentages of project costs may be misleading if used as a basis for examining the validity of the estimates. The estimates for site development costs involved in facility construction at existing centers and stations are prepared by the construction engineering staffs at those locations and are based on the most recent experience in executing previously authorized construction projects. Estimates for site development costs for projects proposed for construction at sites yet to be selected are, of course, somewhat less firm and are, of necessity, nominal estimates. The actual site development costs may vary substantially from the estimates, either upward or downward, depending upon the foreign country or State selected, the topography or condition of the specific building site selected, and the situation with respect to local construction costs at the time and actual construction contracts are let. Even at established centers and stations, the latter item can result in wide variations in actual costs compared to the estimates.

The specific inquiry directed to the estimate for the parking spaces at the Goddard Center's spacecraft operations facility was answered in the hearing before the Subcommittee on Applications and Tracking and Data Acquisition on March 8, 1962, wherein it was established that the budget backup book was in error in indicating that only 150 parking spaces would be provided. The correct figure is 300 spaces, the additional 150 spaces being required to provide additional parking facilities for personnel of the adjacent Central Flight Control and Range Operations Laboratory.

The apparent high cost of the parking spaces for the Marshall Center's Computation Division Building results from the fact that the cost estimate includes $9,500 for the relocation of an existing steam line, $500 for the removal of an existing fence, and $7,000 for special evacuation and backfill because of 15 to 20 foot variations in elevation within the proposed parking area. With proper consideration for these special requirements, the proposed cost estimate compares favorably with recent costs for similar installations.

I will be pleased to supply any additional information on the facility estimates that may be desired by the committee.

RALPH E. ULMER,
Director of Facilities Coordination.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington D.C., April 6, 1962.

Mr. RAYMOND WILCOVE,
Staff Consultant, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. WILCOVE: Attached memorandums dated April 4 and April 6, 1962, have been prepared in response to the questions posed during our phone conversations on April 2 and April 5, 1962.

The following individuals will be standing by at NASA headquarters on Monday, April 9, 1962, and will be available on short notice should the chairman

or the members of the Subcommittee on Applications and Tracking and Data Acquisition require their services:

Mr. Edmond C. Buckley, Director, Office of Tracking and Data Acquisition (tracking and data acquisition facilities).

Mr. Ralph E. Ulmer, Director of Facilities Coordination, Office of Programs (site costs).

Mr. William E. Lilly, Director, Program Review and Resources Management, Office of Manned Space Flight (Mercury Control Center addition).

Sincerely yours,

JOHN S. BROWN,
Assistant Director, Office of Legislative Affairs.

APRIL 4, 1962.

Memorandum for the Office of Legislative Affairs.
From: Office of Manned Space Flight.
Subject: Addition to Mercury Control Center (1,600 square feet, at $50, or $80,000).

The following reasons were given for the high cost per square foot:

(*a*) Require special noise absorbing material to keep the sound level low.

(*b*) Require a double floor; that is, a raised false floor similar to the type installed in a computer center is required for installation of the instrumentation cables, also to have flexibility in the movement of equipment.

(*c*) Abnormal construction conditions such as:

(1) During flights all personnel must be cleared of the area, except operational people in the Center.

(2) All communications must remain energized during construction.

(*d*) Special construction methods, due to close tolerances for precise setting of electronic equipment.

(*e*) Nonconducting materials must be used to prevent electrical interference to equipment.

THEODORE S. TOPPEN, *Facilities.*

APRIL 6, 1962.

Memorandum for Director of Legislative Affairs.
Subject: Fiscal year 1963 Office of Tracking and Data Acquisition Facilities.
Reference: Telecon—Mr. Brown and Mr. Buckley of April 4, 1962.

1. FAR EAST DATA ACQUISITION FACILITY

(*a*) This large-aperture antenna facility is required to fulfill the mission requirements of the EGO (Eccentric Geophysical Observatory) and OAO (Orbiting Astronomical Observatory) scientific satellites. These projects alone represent an existing investment of more than $25 million. Lack of this facility is estimated to endanger seriously the successful accomplishment of these flight missions. For example, the stabilized OAO spacecraft must be read out and commanded once per orbit if the satellite is not to become inoperative very early in its life.

(*b*) The specific location of the facility cannot be chosen definitely until the entire project is authorized. The present site survey effort is, therefore, in no way a site selection effort. Site selection implies a real commitment by NASA to a foreign agency or government; such commitment cannot be made without legislative authorization.

(*c*) Construction leadtime of such a facility makes the operating costs, carried in the "Research, development, and operation" appropriation, fall into fiscal year 1964 rather than fiscal year 1963.

2. DEEP SPACE NETWORK FACILITIES

(*a*) Two facilities, identical to the existing ones at Woomera, Australia and Johannesburg, South Africa, must be built in fiscal year 1963 to afford proper coverage of the lunar and planetary flight program. Both new facilities will be located at approximately the same longitudes as the existing stations but not necessarily at the same latitudes.

(*b*) Any foreign site requires full agreement by the host nation prior to installation. The official negotiations leading to site selection and installation cannot begin prior to legislative authorization. In turn, detailed cost estimates

cannot reflect the differences inherent in the individual sites until such sites have, in fact, been selected. The fiscal year 1963 estimates therefore are based upon a typical deep space station with the full knowledge that the final costs for each of the two will differ because of terrain, survey requirements, soil conditions, labor costs and shipment distances. The NASA feels certain, however, that two operational facilities can be built within the total requested funding of $10 million.

EDMOND C. BUCKLEY,
Director, Office of Tracking and Data Acquisition.

COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON APPLICATIONS AND TRACKING AND DATA ACQUISITION,
April 9, 1962.

To: Members, Subcommittee on Applications and Tracking and Data Acquisition,
From: Raymond Wilcove and Richard P. Hines, staff consultants.
Subject: NASA estimates for "Site development and utility installations."

NASA witnesses are scheduled to testify Tuesday, April 10, concerning funds for the development of sites at NASA facilities.

NASA regards the installation of utilities as part of the cost of preparing a site and lumps it together in its budget books with the cost of paving roads, parking areas, fencing, and so forth.

In order to provide the subcommittee with a clearer understanding of what is involved, the staff has divided the category of "Site Development and Utility Installations" into two parts, as follows:

A includes the cost of parking areas, paving of roads, sidewalks, fencing, and so forth.

B includes the cost of utility installations, such as water and steam lines, sewers, electric power and communications, and so forth.

The NASA estimates for the various categories are as follows:

Total estimate for "Site development and utility installations," $4,555,000.
Estimate for A, $1,656,000.
Estimate for B, $2,898,000.

(NOTE.—The totals do not include the comparable estimates for the Far East station.)

Goddard:
(1) Spacecraft operations facility:
A, $70,000.
B, $330,000.
(2) Tracking and Telemetry Laboratory:
A, $100,000.
B, $175,000.

Jet Propulsion Laboratory:
(1) Data operations and command facility:
A, $25,000.
B, $100,000.
(2) Telecommunications Laboratory:
A, $30,000.
B, $105,000.

Langley Research Center: (1) Vehicle antenna test facility:
A, $30,000.
B, $190,000.

Marshall Space Flight Center:
(1) Addition to computation division building:
A, $70,000.
B, $40,000.
(2) Expansion of instrumentation systems in west area: A and B, no funding requested.

Mississippi test facility: (1) Data acquisition reduction center (CF12–C1): A and B, no funding requested.

Goldstone station: (1) Advanced antenna system:
A, $205,000.
B, $695,000.

Johannesburg station: (1) Antenna facility:
A, $450,000.
B, $520,000.
Woomera station: (1) Antenna facility:
A, $450,000.
B, $520,000.
Far East station: (1) Data acquisition facility:
A, $110,000.
B, $292,000.
Rosman station: (1) Data acquisition facility:
A, no funding requested.
B. $160,000.
Cape Canaveral: (1) Modification to Mercury Control Center:
A, $5,000.
B, no funding requested.
Wallops station:
(1) Advanced data acquisition system:
A, $75,000.
B, $25,000.
(2) Modification and expansion of range control, safety, and support systems and equipment:
A, $146,500.
B, $38,500.

Mr. Ulmer, in your memorandum of April 4, entitled "Site Development Cost for NASA Facilities," a four-page memorandum, on the first page, in the last paragraph, you point out that the 1962 authorization bill permits funds for the advanced design of facilities for which authorization and funding may be requested in future years. The general question that the subcommittee is interested in is why this authority wasn't utilized in order to provide the Congress with more detailed estimates supported by architect and engineering studies for fiscal year 1963.

Your memorandum further indicates:

The budget estimates in most cases are not based on completed designs or detailed designs by architects.

Mr. Ulmer. The statement in my memorandum is correct. The difficulty in using this design account for the advanced design of facilities in the 1963 budget came about because of the timing of the 1962 appropriation. I believe our appropriation did not become law until about the middle of August of last year. At that time estimates for most of the 1963 facilities had been prepared and we were getting ready to go to the Bureau of the Budget to discuss the final figures that would be submitted by the President.

Last year also was the first year that we had the advanced facility planning and design account. This should be pointed out. I think you will see by an examination of the manner in which we have since used the account that it is going to pay off in the future.

We now have under advanced design some facilities that will appear in next year's budget. We expect the designs will be far enough along to give firm estimates for the next budget. We did apply the 1962 advanced design account to a number of facilities in the 1963 budget but, for the most part, this was done after the budget estimates had been prepared. Some are in this tracking area. One was the large tracking dish at Goldstone. Some of the other facilities, as a matter of policy, we will not put under advanced design until site locations are determined.

Mr. HECHLER. Regardless of whether you use these specific funds, aren't there any available personnel within NASA or personnel in other Government agencies that you could call on to provide a firmer base for your estimates?

Mr. ULMER. We feel our estimates have a rather good base, in that they were prepared by design engineering groups at our centers who have had long experience in this type of business. I do recognize in some areas we do not have what you might call firm estimates. However, they are based on experience in constructing similar facilities in the past. They are made by competent engineering people.

In the facilities business I think we have to recognize that there is a long way between the estimate and the construction of the facility. I am wrestling at the office right now with a problem involving a relatively simple office-type facility to be built at the Jet Propulsion Laboratory. There is nothing particularly difficult about this building. The architects and engineers who designed it are competent and they assured us that the building could be built within the money. This is around a $3-million job.

We received an unusually large number of bids. I think there were aproximately 10 bidders with a bid spread of less than 6 percent. Yet the low bid is some $200,000 above our estimate. I am not saying that anybody is at fault here. This is just a situation you get into in this kind of business. You make the best effort you can based on your experience. Sometimes you are going to get estimates that come in high and sometimes they come in low.

Mr. HECHLER. On that point of past experience, you bring this matter up in the third paragraph of your memorandum of April 4 in the second sentence, which mentions that estimates are based on cost of similar facilities or on the use of a nominal estimate in those cases where similar facilities were not previously constructed.

What is a "nominal" estimate? How do you arrive at a nominal estimate?

Mr. ULMER. I must confess to an improper use of the word "nominal." After Mr. Wilcove's call, I looked up the word "nominal." I understand it means "very small compared to expectations." This was not the sense in which I meant the word to be used. What I meant to say was that we generally take an average of comparable experience where we have no firm basis for the estimate. If you know where a facility is going, if you are sure of the location, and the cubic feet of concrete you are going to need for roads and sidewalks and this type of thing, the estimates are quite firm.

If you don't know the location, you take the average of several facilities you have built in the past. I should have used the word "average" instead of "nominal."

Mr. HECHLER. There are many questions concerning this I would like to ask. I know members of the subcommittee would like to pursue this. Are there any other members of the subcommittee who want to follow this up?

Mr. ROUSH. On which facilities did you use this so-called nominal estimate or average adjustment? Would it just be the Far East facility?

Mr. ULMER. I would say generally for the site development costs on projects for which sites have not been selected.

Mr. ROUSH. How many of those do you have?

Mr. ULMER. I would estimate 10 or 12 within the overall budget.

Mr. HECHLER. Do you care to name those at this point?

Mr. WILCOVE. Are they all within our subcommittee's jurisdiction?

Mr. ULMER. No, they are not. Most of them appear under the budget heading "Various Locations." This would be the Far East station, facilities for the F–1 engine program, facilities for the M–1 engine program, manned space flight control centers, space radiation effects laboratory, and the Nova stage manufacturing facilities are the major items.

Mr. HECHLER. What about Johannesburg?

Mr. ULMER. The site has not been selected for that facility either.

Mr. WILCOVE. Let's see if we can't clarify the situation at Johannesburg and Woomera. In your budget estimates book for the fiscal year 1963, on page CF14–CD1, you have it listed as "Antenna facility—Johannesburg Station" and "Antenna facility—Woomera Station." As a matter of fact, you may locate your new stations thousands of miles from those locations. Is that correct?

Mr. ULMER. That is correct. The budget book wording was the best estimate at the time the budget was put together.

I would like for Mr. Buckley to speak on that.

Mr. BUCKLEY. I will discuss the two facilities, one at a time, starting with the Woomera facility in Australia. As you go into a country such as Australia it is necessary to negotiate where the site should be. The economics of the problems must be examined, but there is also the question of getting scientific assistance. Perhaps the other country has some choice about where they would have a cooperating agency. All of these factors applied in the original choice of the Woomera site. We thought we were very fortunate in going on the Woomera firing range. At that time the workload at the Woomera range was not very great. Since then, the workload has picked up considerably on that firing range.

I think it very probable that the Government of Australia would like to negotiate with us as to where we will put the site. It will still be in Australia.

Mr. HECHLER. It could be several hundred miles away?

Mr. BUCKLEY. Yes, sir.

Mrs. WEIS. You will keep the one you have?

Mr. BUCKLEY. One of these dishes will supplement the other. We are not going to get rid of the one we have.

Mr. WILCOVE. With regard to the one listed as "Antenna facility—Johannesburg Station"—what about that?

Mr. BUCKLEY. At this point I would like to go off the record, if I may.

Mr. HECHLER. We can't go off the record in open session. We will discuss this later in executive session.

Is it possible with any greater degree of precision to indicate the basis for the estimates at Johannesburg and Woomera? The members of the subcommittee were disturbed by the fact they were lumped together and not separated with any precision and justification given for the difference.

Mr. BUCKLEY. The figures given are approximately 10 percent higher than the cost of the stations that now exist at those sites which

are about the same. There are two reasons, I believe, for allowing the 10-percent increase.

In one case we used some surplus DOD equipment. In both stations we used surplus DOD equipment to assist us in putting in the stations a little more cheaply than they would have cost otherwise. The second thing is that in both stations we were able to make use of economic benefits already there. In the case of Australia, the support that was already existing on the range, certain roads, allowed the cost to be a little bit lower than otherwise would.

In South Africa the construction procedures that they used resulted in the cost being lower than we originally expected. The figure was $4½ million. A similar station is estimated at $5 million in this year's budget.

Mrs. WEIS. If you had to move to a new location, wouldn't it increase the cost?

Mr. BUCKLEY. I think it would. That is why we increased the price 10 percent.

Mrs. WEIS. How advanced are you with your negotiations with the Australian Government?

Mr. BUCKLEY. We have discussed the matter of our desire to come and meet with the Australians; that is as far as we have gone.

Mr. HECHLER. What would happen if we cut this item by 50 percent?

Mr. BUCKLEY. We couldn't put the station in, and the effect would be passed back, of course, to the deep space program where we would be deferring spacecraft. I will go a little further and say that the purpose of the launching of probes to the Moon and planets is to get information, and my program, then, is responsive to the requirements that come from the scientific programs in the manned space flight program.

Mr. HECHLER. Perhaps my question should have had the two words "this year" included in it. The purpose of my question was to find out whether you needed the authorization if you didn't have the site.

Mr. BUCKLEY. In 1964 we will not only have spacecraft going to the Moon, but we will have two going to Venus and two to Mars. These additional facilities will allow us to watch all of them. The requirements are that you must watch them continuously if you are to obtain the desired information. You cannot watch them without adequate facilities.

Mrs. WEIS. Can you get the new dish in operation by 1964 if you have not talked to the Australian Government about a possible site?

Mr. BUCKLEY. Yes, we can. I would like to make one comment, and that is in both Australia and South Africa the governments of both countries designated a cooperating agency to work with us, a scientific agency in both countries who assisted in the choice of the site, assisted in the planning and the construction, and they are now operating the equipment. This is a cooperative program with both countries. Based on our experience from putting up the original dishes, I believe we can put the other two in by 1964.

Mr. HINES. In view of the fact that there is a leadtime problem associated with developing components and equipment, and in view of the fact that you have not selected the site, would the elimination of the support systems funding affect your program?

Mr. BUCKLEY. There are two answers. I would like to have Mr. Williamson answer the second part of this thing relative to the use of the funds. I would like to say that we have to have an authorized project if we are to go to a country and ask permission to build there. In general, such a request very quickly gets to the highest levels in the government. You can see if a country were to come for a tracking station here—by law, this would become a matter of congressional decision if another country came in this country and asked for a tracking station. As we go to another country we have to go in with a rather definite plan, because it becomes quite embarrassing if we go as far as a cabinet member or prime minister and then we find we have to back out. It is essential we have the authorization as a complete package. This would hold us off from any negotiations at all on a site selection, and we would come back another year. You couldn't proceed on the basis of where the site would be.

Mr. HECHLER. Does the State Department advise that this is necessary?

Mr. BUCKLEY. The State Department strongly prefers that we come in with a plan that is complete and that we know what we are going to do. In fact, we can only make the most preliminary contact without it.

Mr. ULMER. I would like to add that we feel very strongly in the agency about the desirability of full funding all construction projects wherever possible. The policies that we follow in this respect are essentially a carryover of the congressional policies established for the National Advisory Committee for Aeronautics, where for many years all of our projects were fully funded. We feel this is an excellent method of funding for the construction of facilities.

The designer knows the authorized and approved cost of the project. He knows what he has to cut his cloth to fit. I think the record we have established in the construction of our facilities bears out the wisdom of this approach.

Now, the design of some facilities such as launch complexes is dependent on the design of the vehicle to be launched and for these facilities it is sometimes necessary to use incremental funding. We like to consider these as exceptions to the general rule. There is certainly no argument that theoretically you could apply the incremental funding approach to all of the projects. We think this would be bad. We would like to keep them as exceptions.

Mr. HECHLER. Even though this be a space program, there are many aspects of it that we have to keep our feet on the ground. In connection with construction of site selections, these are things where we do have prior experience that we can utilize. We should also utilize to the greatest extent possible those architects and engineers who can provide us more realistic estimates.

Mrs. WEIS. Could I ask you what would happen if this is authorized and the money is not given to you in the appropriation bill? Do you have the power to negotiate with the Government if you have the authorization?

Mr. ULMER. This would become a matter of priority within the agency. If the authorization were passed and the funding were cut, and if there were no specific item cut in the appropriation bill, it would be a matter for the Administrator to determine how he would

distribute the available appropriation among the authorized projects. Perhaps later in the year, using the transfer authority that exists in the authorization bill, additional authorized projects could be funded by reprograming or by the transfer of research and development funds.

Mrs. WEIS. Let's assume they gave an across-the-board cut.

Mr. ULMER. That has been the practice in the past.

Mrs. WEIS. Your agency has expanded so far in the past few years. I think it is a matter of concern to all of us on the committee. There are going to be some long looks taken when we present this bill to the House.

Mr. HECHLER. Following up your question and my previous question about a 50-percent cut, you would still have authorization.

Mr. WAGGONNER. It would seem unreasonable that there would be a 50-percent cut. No subcommittee is going to put itself in the position of saying this phase of your program is going to be cut out. You can't say just wipe this out of your program, because these other things are all integral parts. Without one part you don't have the whole.

Mr. HECHLER. Mrs. Weis made a very good point. If you had the authorization without the appropriation you would still have the authority to negotiate if you had a lesser amount of your authorization for your Johannesburg and Woomera.

Mr. WAGGONNER. That goes back to the point that was raised yesterday when Mr. Davis said the use of the word "concurrent" was confusing. The Congressman wanted to know if this was actually being done.

Mr. DAVIS. I had reference to the first sentence in the third paragraph.

Mr. ULMER. The word "concurrent" means that in the same session of Congress the authorization is being considered at the same time the appropriation is being considered. For example, we appear before the Independent Offices Subcommittee of the House Committee on Appropriations next week to defend this budget. We are now appearing before your committee for the authorization. Within a week or so we will be appearing before the Senate on the authorization. This is a very desirable approach, because by the time the authorization and the appropriation bills are finished we know exactly what our program will be and what we will have to live within. Our experience has indicated, particularly in the facilities area, that this is very desirable approach.

Mr. WAGGONNER. What led to my misunderstanding was your use of the words "the Congress." Really, you are referring to the committee.

Mr. ULMER. I am referring to the various committees of the Congress.

Mr. HECHLER. Getting back to my observation about a 50-percent cut, I was wondering if you had any reaction to it.

Mr. BUCKLEY. If there was a cut of 50 percent this would result in only one station going in completely. This would result in our planning one station completely, and using the funds designated for it—I don't think we would go into this thing at all without the funds for the complete station. I think the answer is that we would put in one of the two stations completely.

Mr. HECHLER. This is one of the difficulties, where you lump the two together and present it to a committee and say take or leave both of them.

Mr. BUCKLEY. I think we are following sound practice on this, of getting congressional authority and coordinating with all elements of Government. I think it is sound practice we are using.

Mr. WAGGONNER. Reference was made to the State Department. Has the State Department actually issued any instructions as to your limitations in negotiating these sites? Have they given you a guide rule or is the guide rule under which you are presently operating your own?

Mr. BUCKLEY. As we consider any site, we immediately contact the State Department and look for a preliminary report on the political situation. We also get a report on the scientific situation. In one case a country had considerable disagreement between the scientific elements and this had to be taken into account as we proceeded. The State Department gave us the background on this.

Mr. WAGGONNER. What has been done up until today with regard to Woomera and other Australian site locations? What contacts have been made and what tentative agreements have been reached?

Mr. BUCKLEY. I would like to answer that later, if I may.

Mr. WAGGONNER. In building these sites—tracking sites, as well as other facilities, because the situation is the same—what percentage of the work is actually done by the contractors with whom you negotiate these contracts and what percentage is subbed out?

Mr. WILLIAMSON. I think perhaps I can help a little here. We are looking at this particular pair of facilities. Under the "Facilities Construction" portion, the first item is the antenna and mount. That will probably be one contract done by one contractor, all by himself. The installation and erection, depending on what procedures we follow, could well be done by that same contractor, his own people; again no subs are involved, except maybe some subs in the way of steel procurement.

Then in the equipment instrumentation and support system, the hydraulics and the feeds and recording equipment, some of the components are off the shelf. You can buy six of that and three of the other. These would not be considered subcontracts, I think, in the way you are asking the question. You might have maybe 15 percent subcontracted effort at the most, assuming this would go to a contractor to build the electronics. He would probably do 85 percent of the work himself.

Mr. WAGGONNER. Here is what I am getting at. We know that every time we bring an additional subcontractor into these negotiated cost-plus contracts we are increasing the overall cost of any particular program. We talk about broadening the base of the concerns which have the capability of doing this work for the Government, no matter what the phase of work might be or what area the work to be contracted might be in. Are we reaching the point where we are broadening the base for the subs and not for the general contractors—a point where contractors are really never touching anything? Are they subbing out everything? Is the Government being billed for an extra 10 or 15 percent every time another sub comes in?

I have an idea that on these two particular stations there are some general contractors who will never go near the sites except for maybe a supervisor. Subs are going to do a lot of this work and they are going to reap a vast benefit from cost-plus contracts.

Mr. WILLIAMSON. I can speak for these facilities. I think Mr. Ulmer can speak to the general question you are raising. In this case the contractor, the general contractor, if you will, is NASA itself. We act as our own general contractor in this sense. The work would break down as follows on an oversea site: the foundation would be done on the site by elements of the host country to the design criteria we would establish; the construction of the antenna itself, the major piece of equipment, is very likely to be by a contractor here in the States and shipped to the site, and he will send his own people to erect it or else, depending on the country——

Mr. WAGGONNER. On a cost-plus basis?

Mr. WILLIAMSON. Fixed price. In this case I know we can get fixed-price antennas because we already have built similar ones. There is competence in the country and you can draw up specifications for these antennas and get them essentially duplicated——

Mr. WAGGONNER. How much of that information, knowing all these things, has been incorporated in your actual estimate?

Mr. WILLIAMSON. On these items where we know that much, like the antenna, that is in there.

Mr. WAGGONNER. What you are actually saying is this: the unknown factor has to do with the topography and that sort of thing and where the final site might be. You know what the equipment installation cost is going to be and there isn't any horseback guess there. The only thing really unknown is actual site development and procurement cost?

Mr. WILLIAMSON. Yes. It depends on how you are required by your agreement to operate. A foreign country may say, "Fine, we will cooperate with you, but let us build the buildings to your criteria." You can't estimate in detail what an oversea cost will be.

Mr. WAGGONNER. What are the relative estimates? I am talking about equipment and material. I am not talking about the actual site and the building development. Comparatively speaking, how does the cost of this project compare with the projects we already have in operation?

Mr. WILLIAMSON. In the areas where we are quite certain of our grounds, I would say it is within 5 percent. It is 5 percent lower than what we have actually paid.

Mr. WAGGONER. Five percent lower?

Mr. WILLIAMSON. Yes.

Mr. WAGGONNER. Your experience has helped you?

Mr. WILLIAMSON. We are getting to that position now with these particular antennas, with the experience at Goldstone, which is the center station of the net, and at the two outlying stations.

Mr. WAGGONNER. We have paid for our mistakes and we are now able to take advantage of them.

Mr. WILLIAMSON. The great saving that we are developing is that we are standardizing these stations. The one at Goldstone was built essentially, as you say, as a research and development facility. The second antenna at Goldstone is the standard against which we are

measuring the others. The other two, the Woomera and Johannesburg stations, are as close duplicates as possible.

Mr. WAGGONNER. With desired modifications?

Mr. WILLIAMSON. With any modification you can foresee. The antenna cost itself is not very high in comparison to the electronics cost. We are coming down very definitely because of our ability to standardize, since we know what our job is in the area of tracking.

Mr. WAGGONNER. Does NASA or the State Department have a rule of thumb by which you are guided in negotiating these contracts for these sites as to time, a minimum amount of time, for example, for which this site would be available, or its it on an indefinite time or yearly basis, or what?

Mr. WILLIAMSON. It depends on the program we are supporting. In this case we are asking for either indefinite agreement or long-term leases.

Mr. WAGGONNER. With options?

Mr. WILLIAMSON. Well, I think I would have to ask Mr. Buckley.

Mr. BUCKLEY. I don't recall any options.

Mr. WAGGONNER. It seems to me options would be highly desirable. We wouldn't want to be in a place where we had these tremendous investments, with satellites depending on the tracking stations there, suddenly take away because a host country didn't get enough foreign aid and decided they wouldn't go along with us.

Mr. BUCKLEY. Realistically, I think that you would end up going through the same process whether you had the option or not, that they would strongly desire you to go through additional discussion with them periodically every so often. Actually, we have one agreement, for instance, that was dated to run for the tenure of the President of that particular country. In a change of government we will have to go back.

Mr. WAGGONNER. What happens to agreements in countries that are so subject to a rapid turnover?

Mr. BUCKLEY. We are trying to select countries that don't have a rapid turnover, if we can. I am afraid that the agreement would have to be reconsidered, if there was a major turnover.

Mr. WAGGONNER. I assume there are only three antennas, of the type that you have at Goldstone, scheduled for future construction. That is at Johannesburg, Woomera, and Goldstone. Is that correct? Your system of tracking for deep space will consist of only three large dish antennas. Is that correct?

Mr. WILLIAMSON. What we are asking for is two more at these three different longitudes.

Mr. WAGGONNER. You have one?

Mr. WILLIAMSON. We have two at Goldstone.

Mr. WAGGONNER. You want two more and that will give you three?

Mr. WILLIAMSON. We have two at Goldstone and one at Woomera and one at Johannesburg.

Mr. WAGGONNER. They are about 120 degrees apart around the globe?

Mr. WILLIAMSON. We would like to have two at each longitude around the globe.

Mr. WAGGONNER. That, then, would enable you to keep in constant touch with spacecraft?

Mr. WILLIAMSON. Yes.

Mr. WAGGONNER. If you just had two, then your spacecraft would be out of sight.

Mr. BUCKLEY. It would raise the issue as to whether they would limit their firing to one that you could watch with one set of dishes. For instance, if you are firing a spacecraft toward the moon you have to pay close attention to it as it approaches and maybe after it stays on it. You are not going to turn away and watch something else and lose what valuable information you went after in the first place. I think you would end up limiting your program to the things you could watch.

Mr. WAGGONNER. That is all.

Mr. HECHLER. I was simply confused by one figure, the percentage that Mr. Williamson used. Does this square with what you mentioned before about 10-percent increase?

Mr. BUCKLEY. I was referring to the overall cost of the station, and we allow 10 percent because in both of those two deep-space stations we would not be quite where we are now.

Mr. Williamson was speaking to the particular electronics and so forth, the items we know very well. He thinks the proper figure on this, here, as being 5 percent less than it was before.

Mr. DAVIS. May I suggest that subcommittee counsel go down the list of questions that they prepared and make sure that all of them have been answered. Some are pretty good questions. Some have already been answered.

Mr. WILCOVE. With regard to the sites that have not yet been selected, I would like to stress this one thing. I think in the future it would be helpful if NASA would state in so many words that you just have not selected a site. You have done this for the Far East station. Unfortunately, on Johannesburg and Woomera the impression I got was that the new antennas would be located somewhere adjacent to the existing facilities.

In the future, I think it would be very helpful if you would say the sites have not yet been selected, and if possible, give the general area where they will be located ultimately. As I understand it, as far as your Johannesburg station item is concerned, the new facility could be located in Africa or some part of Europe. That would also suit your purposes, would it not?

Mr. BUCKLEY. The station could be in South Africa. In other words, it could be north and south along that longitude line. You can't go too far from the Equator. So we actually have written the State Department a letter that asks about possible locations.

Mr. ULMER. I think Mr. Wilcove's point is well taken. By all means, wherever possible, we should indicate a firm site, and where a firm site does not exist that fact should be clearly spelled out in the backup book.

I would like to make one point here, though, that the book you see before you, in effect, is a picture of the current planning as of a certain date. The people who prepare this book, and I am basically responsible here go around to people like Mr. Buckley and say: "What do you mean, you have not made up your mind where this site is going." Sometimes we push him too far, and at that time, to the best of his thinking, he has tentatively picked a site, and we use it in our writeup.

Perhaps in this case we went too far. Normally we like to come to you with all of our sites picked.

We can prepare better estimates if we know the sites.

I think Mr. Wilcove's observation is well taken. The site location on this particular project should have been made less firm than it was in the writeup.

Mr. WILCOVE. With regard to the construction of the numerous buildings called for in the estimates will the money actually be required in the 1963 fiscal year?

I will phrase the question another way. Insofar as the money for the actual construction of the buildings is concerned, would it delay your program if you came back, say next January, and asked for funds in your 1964 program to put up the buildings?

Mr. ULMER. Mr. Wilcove, I believe I indicated before that in some of these areas it would not delay our program. What you are speaking about, however, is the philosophy of budgeting. I think the procedure we are following basically is sound, that is to full-fund the facilities in the fiscal year for which authorization and appropriation are requested. Many of these facilities could be incrementally funded but I do not think this would be the most economical way of building the facilities.

Take again the example of the facility at the Jet Propulsion Laboratory I mentioned before. Here a bid comes in $200,000 above the estimate. It was a well-bid job. We are going to have to live within the money we have for that facility. We are going to have to cut the cloth. We may have to take out some things we think are desirable. The point is we are living within the funds appropriated. Here is the great merit in the full-funding approach.

Mr. WILCOVE. Assuming Congress authorizes the funds, will all these funds be obligated during the 1963 fiscal year?

Mr. ULMER. No. That is the reason the appropriation is a no-year appropriation. I believe a fair estimate is that of this total appropriation of $818 million, about $60 or $70 million will carry over.

Mr. WILCOVE. With respect to the buildings, what percentage of the funds will be obligated?

Mr. ULMER. I think that all of the funds for the buildings under your jurisdiction will be obligated in 1963.

Mr. HECHLER. You used a word a few minutes ago with respect to an answer to a question by Mr. Wilcove. You said if some of the construction was not put through this year there would be delay and in others there would not be delay. Is that correct?

Mr. ULMER. I believe that is correct.

Mr. HECHLER. I am wondering if you can give us a priority here, as far as the effect of the action of the subcommittee.

Mr. ULMER. This is difficult to do, unless you are talking about specific programs. I want to get back to the philosophy of budgeting that we were discussing. Granted, some of these contracts are not going to be let in the fiscal year 1963, but a great deal of work has to be done before the contract is let, and a good designer wants to know what his budget is going to be. If you build your own house you want to know what the loan company is going to approve before you sign the construction contract. We can do a much better and more economical job in this way.

As you know, many years ago the Congress used a procedure called contract authorization. This approach was somewhat similar to what Mr. Wilcove is talking about. I think most agencies have come back to the principle that the most economical way to build facilities where you can reasonably determine what you want is the full funding method.

Mr. HECHLER. As an old political science and administration professor I admire your argument. But getting to specifics, can't you give us any perspective on where the most critical building requests are and which represent in your mind the most important items in your request for building construction?

Mr. ULMER. I am afraid I am not a prepared witness on that subject at this time. I did not come prepared to discuss the relative priority of the various facilities. As a general matter, the most critical facilities are the program related facilities, and in that area the most critical ones are the ones that pace the program, where the leadtime on the construction of the facility is a critical element in the overall program. In this area, of course, you would find the large launch complexes for the Advanced Saturn and the Nova vehicles, and Mr. Buckley's tracking facilities, which must be there to acquire the information.

Then you get to certain buildings which may be designated with a lower priority. But if these buildings are not provided in a timely manner, we find ourselves in a situation where at the Jet Propulsion Laboratory, for example, we have to rent about 150 trailers to accommodate the staff. We think our entire facilities budget is top priority. We have included only items we believe are necessary to the program.

Mr. WAGGONNER. I would think a facility budget is priority for full funding because the leadtime there is not what it is in launching vehicles. The leadtime for a launch vehicle is considerably longer than for these facility items. If the leadtime for every phase or every component of this overall project was the same, then you would not need budgeting past any fiscal year. The leadtime varies. You have to have full funding or guarantee of it to be able to coordinate and predict within any accurate range the time interval of a successful completion of a project.

Mr. HECHLER. We are only seeking information.

Mr. WAGGONNER. This leadtime is the key to this thing.

Mr. WILCOVE. There is one thing we would like to have clear. You did say that the funds for the construction of the buildings that are in this program will be actually obligated or committed in the 1963 fiscal year?

Mr. ULMER. You are speaking about the buildings in the tracking station projects?

Mr. WILCOVE. That is correct.

Mr. ULMER. That is correct.

Mr. WILCOVE. I think what the subcommittee is interested in determining is whether funds actually authorized and appropriated would not be committed in 1963 fiscal year. But according to you, that isn't so.

Does your organization have its own staff architects and engineers? Do you have a staff of your own?

Mr. ULMER. We do at each center.

Mr. WILCOVE. Is it a fairly large one?

Mr. ULMER. It varies between centers. Let me give you an example. At the Langley, Ames, and Lewis centers our own staffs select the architects and engineers to design the facilities and we also do our own construction supervision. At some of our newer centers we have solicited the help of the Corps of Engineers who are doing these jobs for us. So at the newer centers the staffs in this type of work might proportionately be smaller than they are at some of our older centers.

Mr. WILCOVE. You also use outside designers, do you not?

Mr. ULMER. Oh, yes. We feel this is a very fine way of getting work done quickly and economically.

Mr. WILCOVE. Is it NASA policy to continue this, or do you propose eventually to build up your staff?

Mr. ULMER. We propose to continue the existing practice of contracting for outside design services wherever this is feasible.

Mr. WILCOVE. Do the Army Engineers make a general survey when you avail yourself of their help, for example of topography, the geoogical structure, water, and so forth, or do they examine the site from the point of view of the structure to be built and the mission of the site?

Mr. ULMER. Yes, if we request them to do so. The best example I can give you of this is the work they did in connection with the sites for the Houston center and for the Mississippi test facility. They made a very careful examination of the sites, the topography, the soil conditions, and so forth. All of this information of course is necessary to the proper use of the site and the design of the building foundations.

Mr. WILCOVE. As between the work done by your own architects and engineers and the Army Engineers, what would be the percentage breakdown, generally speaking?

Mr. ULMER. I would have to give a very rough guess. Perhaps 25 percent we are doing ourselves, and the balance the Corps of Engineers is doing for us. It depends on the locations at which the facilities will be built.

Mr. WILCOVE. In the overall work, what percentage is done by outside engineers and designers?

Mr. ULMER. I would say perhaps 80 to 85 to 90 percent. I would like to point out that our own people must, however, be intimately involved in establishing criteria. I am considering the function of establishing criteria as distinct from architect-engineer services.

Mr. WILCOVE. What would be the purpose to continue to employ in future years such a proportion of outside engineers?

Mr. ULMER. Building programs, as you know, can vary rapidly from year to year. We feel it would be uneconomical to handle in-house all of the architect-engineer services for a $40 million program at one center and then next year have to discharge the staff if the program was only $2 million. Our experience has been that generally this type of service can best be provided by contracts with outside competent people.

Mr. WAGGONNER. I think they are on sound ground there.

I would have to side with them 100 percent on that issue.

Mr. ROUDEBUSH. Isn't it also true that Army Engineers employ outside contractors?

Mr. ULMER. They follow the same principle themselves.

Mr. HINES. Mr. Ulmer, there are several items under our jurisdiction which you have lumped together and have funded collectively. Isn't it necessary to have more specific estimates for each item?

Mr. ULMER. Yes, it is. Budgeting is a very difficult task in the Government because of the time situation. The basic estimates that you have before you were prepared by dozens of people at all of our centers. It is a very difficult thing to edit the projects and get details in each cost breakdown that are somewhat comparable. I think we have done a rather remarkable job in having as much uniformity as we have presented in the books before you, considering the wide range in the types of facilities we are proposing to build. I do agree with you that there could be more uniformity in this area of site development.

Mr. HINES. I would also suggest that for future purposes, in view of the fact that our committee is examining the budget in extensive detail, it would be very helpful if we could discern precisely just where the allocations are applied.

Mr. HECHLER. When we are planning for parking orbits we have to take a lot of estimates on faith. When we are planning for parking facilities, these are items that should have fully justified estimates.

Any further questions by members of the subcommittee?

Any further questions by members of the staff?

(No response.)

Mr. HECHLER. If not, we will go into executive session at this point.

(Whereupon, at 11:30 a.m., the subcommittee proceeded into executive session.)

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