AIR WEATHER SERVICE
AND
METEOROLOGICAL SATELLITES

1950–1960

AWS HISTORICAL STUDY NO. 5

MILITARY AIRLIFT COMMAND
UNITED STATES AIR FORCE
SCOTT AIR FORCE BASE, ILLINOIS

74-31056

A I R   W E A T H E R   S E R V I C E

AND

M E T E O R O L O G I C A L   S A T E L L I T E S

1950 - 1960

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and
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Edited By

Mr. John F. Fuller

Air Weather Service Historical Study No. 5

December 1973

Air Weather Service
Military Airlift Command
United States Air Force
Scott Air Force Base
Illinois

The heights by great men reached and kept
    Were not attained by sudden flight,
But they, while their companions slept,
    Were toiling upward in the night.

Longfellow, The Ladder of Saint Augustine

FOREWORD

With the removal of the rigid security trappings from DAPP--Data Acquisition and Processing Program--products a year ago, public attention was refocused on the Air Force's and Air Weather Service's--AWS--efforts and accomplishments in the field of meteorological satellites. Light entered where darkness had prevailed--at least publicly. Only a handful within the Air Force and the Defense Department, carefully screened on a strict need-to-know basis, were privy to DAPP's details theretofore. Even within AWS most were unaware of its existence and significance. In unveiling some of the DAPP pictures before a Pentagon press conference in March of this year, Under Secretary of the Air Force John L. McLucas said that DAPP would "furnish the best data possible to decision makers anywhere in the world whose operations are affected by weather," and in a subsequent issue of the Air Force Magazine he described DAPP as "a meteorological tool of great usefulness and importance."* DAPP's public debut sired a rebirth of identity with meteorological satellites within the AWS "family" at large.

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*"USAF Admits Weather Satellite Mission," Aviation Week & Space Technology, Vol. 98, No. 11, 12Mar73, p. 18; "A New Look From USAF's Weather Satellites," Air Force Magazine, Vol. 56, No. 6, Jun73, p. 67.

This study is both timely and appropriate, therefore, because it traces the genesis of AWS' identity with, and involvement in, meteorological satellites through 1960--the year meteorology moved out into space with the launch of the first two TIROS satellites. Designed as a general reference and orientation tool rather than a technical text, the study is primarily a compilation of the events and activities--especially those pertinent to AWS--related to those two satellites.

A rough draft of the study, entitled "Meteorology In Space," was originally completed by the authors in 1961.* It had been coordinated with both the Scientific Services Directorate and Operations, and approved by the AWS command section for publication as the fifth in a series of AWS historical studies**--General Peterson writing that it was a "very good" document that "should be useful to all AWS organizations."+ While some of the appendices had been final typed for multilithing, a shortage of secretarial

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*At that time Mr. Dickens was the AWS historian and MSgt Ravenstein an assistant. As of today, Mr. Dickens is the Military Airlift Command historian and Charles Ravenstein is employed as a civilian by the Historical Research Branch, Albert F. Simpson Historical Research Center, Air University, Maxwell AFB, Alabama.

**The other four studies, in order, were: The Air Weather Service Reorganization, Fiscal Year 1952; Inspections and Surveys, Fiscal Year 1952; Measuring the Wind: The AN/GMD-1A; and "Weather Reconnaissance - Its Role In the Modern AWS," an unpublished, 147-page draft, completed in the mid-Sixties, which traces the history of AWS weather reconnaissance through mid-1959.

+Peterson's comments were penciled to DD Form 95, Memo Routing Slip, Dickens to Col Walter C. Phillips, chief of staff, AWS, 10Mar61.

help and the press of other duties prevented the authors from seeing the love of their labor published. For the ensuing dozen years it collected dust in the AWS historical archives.

I believe that with DAPP's emergence from the catacombs of security, General Peterson's words ring as true today as they did then. This study is DAPP's legacy, its heritage. It is DAPP's deepest roots. Further, I visualize it as merely the first curtain on a trilogy. The second would relate DAPP's classified history, blanketing the decade from 1961 through 1972. Of course the concluding study would depart from DAPP's declassification and the subsequent unveiling of its pictures.

I sounded my thoughts with Colonel Castor Mendez-Vigo, Jr.,* and, after reading the rough draft, he concurred in General Peterson's earlier assessment: published, the study had utility. With his and Mr. Dickens' encouragement, I decided to see it through.

The draft required extensive editing--primarily a reorganization for the sake of continuity and readibility. To preserve the study's character and flavor, however, no source material was introduced that was not available to the authors in 1961, with the notable exception of the 1962 Senate subcommittee staff report on meteorological satellites and Mr. Klass' book. In addition I changed the footnoting mechanics. Perhaps the most significant alteration, however, was the introduction of pictures and charts to illustrate graphically the textual themes.

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*The assistant DCS for Systems, Headquarters AWS.

I screened hundreds of them in the AWS historical photo archives before settling on the thirty-one included.

My edited draft was then reviewed by selected key individuals, including Colonel Mendez-Vigo again and some of the text's personages--Colonel Blankenship, Mr. Pearse, and Mr. Woffinden. Mr. Dickens reviewed it too. I want to acknowledge my debt to those who willingly invested their time on the study. Wherever possible their constructive comments and suggestions were incorporated. It was then approved by the AWS command section for publication and dissemination.

John F. Fuller (Editor)
AWS Historian
Scott AFB, Illinois
10 December 1973

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Early Plans

Interest in high-altitude cloud photography was stimulated as early as World War II by the Japanese successes in sending balloons across the North Pacific to North America in 1944. It was obvious to meteorologists that high-altitude, free-floating, manned and unmanned balloons might prove convenient vehicles for very-high-altitude photographic cloud reconnaissance. While the idea was not new, the development of techniques for the radio transmission of visual materials broadened the area of opportunity in the opinions of some meteorologists. Air Weather Service--AWS--meteorologists of the United States Air Force--USAF--experimented with model depictions of cloud cover over militarily strategic areas as early as 1944 to encourage such developments.[1]

Although a few scattered articles on the use of rockets to acquire cloud photographs appeared in various meteorological publications prior to 1950,[2] it was not until

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[1] U.S., Congress, Senate, Committee on Aeronautical and Space Sciences, by the Library of Congress, Staff Report, Meteorological Satellites, 87th Cong., 2d Sess., 29Mar62, p. 27. Hereafter cited as Senate: Meteorological Satellites.

[2] See for example Maj Delmar L. Crowson, Geophysical Svcs Br, Eng Div, Dir of R&D, DCS Materiel, Hq USAF, "Cloud Observations from Rockets," Bulletin of the American Meteorological Society, Vol. 30, No. 1, Jan49, pp. 17-22. Maj Crowson's was one of the first published references to the meteorological use of cloud pictures from space.

April 1951 that anything appeared in regard to meteorological satellites. At that time, Drs. William W. Kellogg and Stanley N. Greenfield of the RAND Corporation authored a classified report on the subject, published as RAND publication R-218.[3] Actually, RAND documents provided clear evidence that weather observation from satellite vehicles had been proposed by Dr. Kellogg prior to 1950. Later, other individuals, including Dr. Greenfield, were hired by RAND and subsequently contributed to the first published studies.[4]

Dr. Kellogg headed a committee of the Advanced Research Projects Agency--ARPA--which formally proposed the use of satellites to picture the earth's weather. ARPA began the study in the summer of 1958 and the project was turned over to the National Aeronautics and Space Administration--NASA--in April 1959.[5]

Subsequent to the Greenfield-Kellogg paper, an increasing number of scientists began to study, research, and develop equipment for meteorological satellites.[6] RAND publication R-218 was revised slightly to an unclassified format and in August 1960 was reissued as RAND publication

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[3] RAND--Research and Development--Corporation, established by the Air Force in 1946, was the first U. S. agency to design a satellite. See ltr, Dr. Robert D. Fletcher, HQ AWS, to Prof Jule Charney, Dept. of Met., MIT, 7Jun60.

[4] Ltr, J. Doyne Sartor, RAND Corp., to Fletcher, 1Jun60.

[5] Ltr, Fletcher to Charney, 7Jun60.

[6] *Ibid*.

R-365, "Inquiry into the Feasibility of Weather Reconnaissance from a Satellite Vehicle."[7] It was, basically, an examination of weather conditions by a television camera placed in an unmanned satellite vehicle.[8]

The RAND Corporation, as well as other independent workers both in the United States and abroad, continued to suggest that certain atmospheric physical properties could be measured more effectively from outside the earth's envelope of air than from the surface. Although most of these scientists were able to prove that even crude photocell scanners could transmit cloud-cover data of great potential value, the satellite-borne television cameras were considered by many as an impractical dream.[9]

The optimistic belief that meteorological satellites would be more effective in some respects than earth-measured weather conditions was by no means unanimous. Some scientists held that modern meteorological analysis was based almost entirely upon dynamic and kinematic concepts, e.g., upon the fields of temperature, pressure, and motion. Therefore, satellite observations, which would measure those quantities rather poorly, would be of limited value to practical forecasting.

Such a conservative viewpoint was dominant in the thinking of the general meteorological community when ARPA --at that time, in charge of the meteorological satellite aspects of the national space program--awarded to the Radio

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[7] Ltr, Dr. William W. Kellogg, Head, Planetary Sciences, RAND Corp, to Fletcher, 27Feb60.

[8] Ltr, Sartor, to Fletcher, 3May60.

[9] Information furnished by Capt Daniel H. Lufkin, HQ AWS (AWSSS--Directorate of Scientific Services), in article

Corporation of America--RCA--the contract for the construction of a vehicle to be known as the Television and Infrared Observation Satellite--TIROS.

With the design of TIROS completely committed to meteorology, but with the actual uses to which the observations would be put still in some doubt, ARPA, on 29 September 1958, issued ARPA Order No. 26-59, assigning certain portions of the meteorological satellite program to the Air Force Cambridge Research Center--AFCRC.

In particular, AFCRC's Geophysical Research Directorate--GRD--was asked to begin a formal project to study methods by which the televised cloud pictures from TIROS could be used in routine forecasting activity. The GRD formed a small Meteorological Satellite Branch under the direction of Dr. William Widger,[10] who had already been studying the possibilities of satellite meteorology for more than a year. The point of view from which GRD, as well as other small groups in the Army Signal Corps and within RAND, approached the problem of satellite data was illustrated in Dr. Widger's early survey:

> Present-day forecasting techniques and the data to be expected from a satellite are not compatible. The primary factors a forecaster uses in his business are the four-dimensional fields of motion, pressure, and temperature. While it is hoped the satellite will

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[9] (Cont'd) "The Background of Present Meteorological Satellite," n.d. (circa 1960).

[10] Dr. Widger was appointed as the number two man in NASA's meteorological satellite program in September 1960. There he worked under Dr. Morris Tepper--described by The New York Times (23Nov70) as the "Brain Behind Tiros," and an ex officer who served with AWS in the Pacific in World War II.

be able to gather some data of these types through the use of radiometers, at best they will be far inferior in both quality and quantity to our present domestic observations.

It is expected the primary observations made by a satellite will be of clouds, which are presently treated as secondary factors in forecasting. This leads to two possible avenues of attack: to tailor the satellite data to the forecaster or to tailor the forecaster to the data. The former seems the surer path. It means the primary aim is not to devise true forecasting techniques based on satellite data; instead, it involves means of translating satellite data into the kinds of information that are important to present-day techniques.[11]

Just after GRD began its work, Headquarters USAF's Directorate of Research and Development suggested that AWS assign a full-time liaison officer to the agency. The offer was declined. AWS officials felt that the 4th Weather Group's staff weather officer could provide sufficient liaison; that Major James Sadler, an AWS officer then in the process of being reassigned to the GRD, would be able to represent the viewpoint of the practical forecaster in the GRD research effort. However, the invitation did generate a sharpened interest in the problems and promises of meteorological satellites within AWS. Beginning in October 1958, AWS became closely involved with monitoring the progress of the satellite program.[12]

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[11] Lufkin, "The Background of Present Meteorological Satellite."

[12] AWSSS' Research Rqmts Br had been unofficially monitoring satellite research and received project status under direction of Maj Jerry C. Glover in Oct 1958.

the wobble changed as the satellite dipped slightly into the outer fringe of the atmosphere at each perigee. The degree of change varied, depending on whether the perigee was on the dark or the light side of the earth. As a result, much of the data received from the Vanguard II package had not been rectified by late 1960, although there was some hope that the data records could eventually be unscrambled and interpreted.[16]

The 91½-pound Explorer VII was carried aloft and placed into orbit--with an apogee of 672 and a perigee of 346 statute miles, as of 1 March 1960[17]--from the tip of a four-stage Army Juno II rocket. By far the most sophisticated United States satellite to that date, it was crammed with instruments that would identify and count heavy particles of cosmic rays (knowledge crucial to manned space flight), study the transfer of heat from tropical to polar regions and from the earth back into space (basic to weather forecasting), and carry out other experiments. The pill-box shaped satellite was spun to stabilize it and had two transmitters--one powered by a chemical battery and the other solar powered.[18]

Meteorologists, of course, were principally interested in the heat-balance experiment of Explorer VII, and several things were learned from Dr. Suomi's experiment. The heat loss at equatorial latitudes was shown to average

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[16] Ibid.

[17] "Current Orbiting Satellite Situation Report," AWSSS Review, Vol. 2, No. 1, 2Mar60.

[18] "Hat Trick," Time, 26Oct59.

about twenty-five percent more than at polar latitudes. Non-periodic variations almost as large as these, and of a few days' duration, were noted over the United States. Dr. Suomi related the latter to broad synoptic conditions. However, since the data analysis was still in its early stages, AWS expected that much more useful information from this experiment would eventually be gained. Certain obstacles and problems had to be overcome. For example, the instrumentation aboard Explorer VII broadcast continuous measurements with no provision for storage and rapid "dumping" on command from a ground receiving station. Also, the sparcity of ground stations limited the reception to less than one-fourth of the observed information.

To alleviate the latter problem, AWS agreed to help NASA and the United States Weather Bureau by operating an Explorer VII ground-receiving station at Lajes Field in the Azores. The 9th Weather Group's Detachment 3 at Lajes was charged with the responsibility. The necessary equipment was installed late in December 1959.[19]

Potentially significant new data about trapped and cosmic radiation near the earth were also reported by Explorer VII--the last of the IGY satellites. The limited heat-balance measurements substantiated the usefulness of satellites for meteorological observation purposes. Despite comparatively primitive earth heat-balance measurements, the early results indicated that the more sophisticated meteorological satellites already under development by NASA could probably recognize storm areas

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[19] See Vol. I, "Narrative," pp. 549-50, of "History of Air Weather Service," 1Jul-31Dec59.

even on the dark side of the earth. According to Dr. Suomi it was possible to see a direct correlation between earth-measured weather conditions and the heat-balance recordings from space, in spite of the relatively coarse-grain data available from the Explorer VII package. However, Dr. Suomi announced that considerably more experience and better data would be needed before it would be possible to predict future weather conditions on earth, based solely on satellite radiation data.[20]

Dr. Suomi advised AWS on 6 June 1960, that the heat-budget data from Explorer VII were being processed by an IBM--International Business Machines--704 computer. Preliminary results, from hand-processing, were then available and were to be forwarded to AWS. Dr. Suomi said that he had found the radiation patterns to be closely related to the broad synoptic weather patterns and the TIROS I cloud patterns which were available by that time. Captain James R. Blankenship, of AWS' Scientific Services Directorate, monitored Dr. Suomi's work closely.[21]

Detachment 3 at Lajes Field continued its support of Explorer VII on a routine basis. This work was described in the AWS command newspaper in May 1960 as follows:

> Weathermen of Detachment 3, 9th Weather Group, at Lajes Field, Azores, have recently begun operating a receiving station to record important observations from the National Aeronautics and Space Administration's Explorer VII satellite. Thus, TIROS is not the only weather satellite on which AWS men are active.

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[20] Philip J. Klass, "Explorer VII Reports Sporadic Radiation," Aviation Week, 11Jan60, pp. 29-30.

[21] AWSSS Staff Briefing Item, 8Jun60.

Early Experiments

By 1956, plans had been formulated for the use of earth satellites to collect data of meteorological significance during the International Geophysical Year--IGY--then approaching. As a member of the Technical Panel of Meteorology for the United States National Committee for the IGY, Dr. Robert D. Fletcher, AWS' Director of Scientific Services, participated in the planning for the IGY meteorological satellite program. The panel functioned from January 1955 until the late 1950's.[13]

By the close of 1957, experimental payloads were ready to be boosted into orbit around the earth. And, by the close of 1959, two meteorological packages were actually in orbit. The first was the Stroud cloud-cover experiment, launched by Vanguard II on 17 February 1959. The second was the Suomi[14] heat-budget package, one of eight experiments conducted aboard Explorer VII, launched from Cape Canaveral, Florida, on 13 October 1959.[15]

The Stroud cloud-cover experiment instrumentation--using a simple photo-electric cell--worked, but the satellite unfortunately was injected into orbit with a wobble. Had it been anticipated, a simple wobble could have been overcome by a more sophisticated system of geometrical rectification of the observations. To make matters worse,

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[13] MATS Form 44, "Quikcom," Fletcher to AWSDI (Hist Div, Directorate of Info), "Draft Chapter for AWS History," 30Aug70.

[14] Prepared by and named after Dr. Verner E. Suomi, Prof of Meteorology, U. of Wisconsin.

[15] "Satellite Meteorology," AWSSS Review, Vol. 2, No. 1, 2Mar60.

Five times a day, as Explorer VII passes over the Azores at an altitude of from 345 to 673 miles, an automatic time switch turns on a tape recorder to record tone signals transmitted from space. These signals represent observations of heat radiation entering and leaving the earth's atmosphere.

Each morning the men of the detachment's rawinsonde and sferics sections check the equipment's master clock, place a fresh reel of magnetic tape in the recorder and put a verbal "label" on the tape by means of a microphone. Once a week recorded tapes and logs are mailed to Washington. Here, the observations are decoded by scientists of the U. S. Weather Bureau and the University of Wisconsin. Another weekly chore at Lajes is programming the time switch from satellite passage predictions computed by NASA.

Because Explorer VII has no recorder on board for storing data, it transmits its observations continuously. If scientists are to understand the world-wide nature of the earth's heat balance, observations from many parts of the globe must be made every day so that many bits of data may be fitted together, jigsaw-puzzle-fashion, into a coherent pattern.

Dr. Verner Suomi . . . expects the satellite's heat radiation observations to aid in improving science's understanding of the basic forces which drive the circulations of the atmosphere.

Explorer VII will remain in orbit for years to come, but its transmitters will be turned off by remote control this October to free radio channels for use by newer and more sophisticated space observatories.[22]

In addition to the specialized data gained from the Vanguard II and Explorer VII satellites, other important meteorological information was gained from observation of other satellites' orbital changes. For example, changes in apogee height from circuit to circuit revealed the air's drag effect. In this way, the mean temperature and density

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[22] AWS Observer, Vol. 7, No. 5, May60.

at heights above 200 miles was found to be considerably higher than previously estimated by meteorologists. The change in orbital elements from one pass to the next was not a regular one, but showed small fluctuations which apparently paralleled the variations in intensity of very short-wave solar radiations measured by radio-telescopes on the ground. Attempts to put into orbit a very large, light-weight satellite that would be more sensitive to density variations had not proved successful by early 1960,[23] but was finally achieved on 12 August 1960, when Echo I was successfully launched. It was expected to provide considerable useful "drag effect" data for the meteorological community.

The densities inferred from the satellites did not show the apparent latitudinal variation which appeared in the IGY rocketsonde data. Scientists determined that the inconsistency was probably due to the "sampling" effect of the rocket data, which were made at different latitudes in different years and thus included a secular trend associated with sunspot cycles.

All things considered, satellites had furnished a great amount of useful meteorological information by early 1960, although in most cases the instrumentation was not designed for that specific purpose. Data on atmospheric composition, ion density, type and intensity of radiations, and even geomagnetic anomalies, could all help to answer the basic long-range research question: how were variations in the heat source of the atmospheric engine translated

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[23] AWSSS Review, Vol. 2, No. 1, 2Mar60.

into changes in the tropospheric weather patterns? That problem, it appeared, would engage the efforts of researchers for many years to come.

The major event awaited by meteorologists of AWS and many other agencies in early 1960 was the appearance of a satellite designed specifically to measure parameters of direct and immediate meteorological significance. In a manner of speaking, it was "just around the corner" as the year opened.[24] The launch of the first in a series of NASA meteorological satellites was imminent. The potential utility of a photographic satellite cloud-observation system had been substantiated by a GRD analysis of cloud photos taken from an Atlas Intercontinental Ballistic Missile--ICBM--nose cone over the Atlantic, which had produced "a remarkable definition of the large-scale tropospheric flow pattern."[25]

While the first meteorological satellite was to have a television capability, later models in the NASA series would include infrared sensors to measure surface and cloud-top temperatures and the water-vapor content for various layers. Inclusion of radar for observing precipitation patterns of the earth was also under study.[26]

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[24] See Vol. I, "Narrative," of "History of Air Weather Service," 1Jul-31Dec59, pp. 529-31.

[25] AWSSS Review, Vol. 2, No. 1, 2Mar60.

[26] NASA requested bids for the development of radar meteorological satellite observation platforms. Weather Bureau plans for an operational weather radar network over the eastern portion of the U. S. were also being realized early in 1960 and it was obvious that any launching of an experimental meteorological satellite observation platform of the radar type should be carefully planned so that the

Within the Air Weather Service, the Scientific Services directorate felt that AWS weathermen had already learned "a little" from satellites up to early 1960, and were expected to learn "a great deal more" in the near future. Although meteorological satellites were not to be looked upon as the forecaster's panacea, as some news accounts implied, they were expected to plug many observational and theoretical gaps.[27]

The First Meteorological Satellite

In response to a request by Headquarters USAF,[28] AWS' initial requirements for information from meteorological satellites were set forth formally in February 1959. Basically, AWS' operational concept was that the satellites would provide much basic meteorological and geophysical information of common value to both civil and military users. Continuous day and night observation of the amount and distribution of clouds over the earth's surface was needed to enlarge and refine AWS' cloud climatology background; to recognize peculiar cloud configurations possibly associated with jet stream location and intensity; to observe and track tropical storms from birth; and to improve the capability to determine the extent of cloud systems associated with major extra-tropical storms. Some

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[26](Cont'd) orbit into which it would be launched would take full advantage of the surface network in being. See "Program of the Eighth Weather Radar Conference, April 11-14, 1960, San Francisco, California" in Bulletin of the American Meteorological Society, Vol. 41, No. 3, Mar60.

[27]AWSSS Review, Vol. 2, No. 1, 2Mar60.

[28]Msg, HQ USAF (AFDRQ-S/C), 56578, 13Feb59.

of the basic geophysical data AWS indicated a need for included solar-terrestrial radiation balance, aurora and ion density, meteoric activity, magnetic and electrical fields, and atmospheric constituents such as liquid water, ozone, and carbon dioxide content.[29]

From a purely military standpoint, AWS believed that continuous meteorological satellite coverage would enhance cloud climatology in areas of special interest such as Eurasia and the polar regions. It would improve the capability to observe and forecast cloud cover in the data-sparse, air-refueling areas utilized by the Strategic and Tactical Air Commands (SAC and TAC), and it would improve AWS support to the missile ranges. In addition, AWS hoped to improve its support of the Emergency War Plan--EWP--by using the coverage to make its extended-period, three-to-five day forecasts as accurate as its twenty-four hour forecasts.

Some special EWP requirements were also outlined by AWS. In the event of hostilities, it recognized that weather data would be denied from many areas. A series of meteorological satellites would fill the synoptic gap. They would have to have a capability to take high-resolution photographs; a combined photographic, infrared, and radar capability to produce observations of cloud coverage and type, surface and cloud-top temperatures, and precipitation and storm areas; a capability to completely cover specific areas of military interest at six hour intervals and provide

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[29] Ltr, Maj Gen Harold H. Bassett, comdr, AWS, to DCS/Development, HQ USAF, "Requirements for Information from Meteorological Satellites," 24Feb59.

for the reduction and dissemination of the data to selected weather centrals and command-and-control sites within one hour; and, if the above were feasible, have the capability to transmit a limited number of specific parameters directly to the same facilities.[30]

In September 1959 AWS also accepted a Weather Bureau invitation to place a full-time liaison officer with the Bureau's Meteorological Satellite Section at Suitland, Maryland.[31] Major James B. Jones was the officer eventually selected.[32] Under instructions to assist in the development of procedures for incorporating satellite data into operational weather programs, Major Jones' efforts became increasingly important as the level of activity heightened in anticipation of the scheduled launching of the first purely-meteorological satellite, TIROS I, in late 1959.

AWS' early activities were confined largely to attendance at TIROS technical-direction meetings. Those meetings, which brought together representatives from agencies involved in the design and construction of the payload, and from agencies which were prospective users of the satellite data, enabled AWS personnel to become familiar with most of the details of the TIROS program before mid-1959. It was during that early period of AWS participation that NASA was created from the former NACA--National Advisory

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[30] Ibid.

[31] Ltr, Dr. Francis W. Reichelderfer, chief, USWB, to comdr, AWS, 26Aug59, and ltr, Maj Gen Bassett to Dr. Reichelderfer, "Liaison Officer to Meteorological Satellite Section," 8Sep59.

[32] Maj Jones became a one-man operating location under HQ AWS, supervised by AWSSS' Tech Svcs Br.

Committee For Aeronautics. As part of its area of responsibility embracing non-military satellite operations, NASA was, on 13 April 1959, put in charge of the entire meteorological satellite effort, absorbing from ARPA and ARPA-affiliated military agencies, many of the people then active in TIROS development. The Weather Bureau, which by then had formed a small study group concerned with satellites, was named as NASA's operating agency for meteorological matters. Funds transferred from NASA were used to expand the Bureau's nucleus group into the Meteorological Satellite Section. From its inception, the new section worked with GRD's Meteorological Satellite Branch on problems connected with the operational use of TIROS observations.

As the scheduled launch date of TIROS I approached, and was subsequently slipped to early 1960, it became apparent to all of the agencies involved that the best use of TIROS facilities and data would be gained by pooling people and communications at the ground readout stations. Accordingly, the Weather Bureau, AWS, GRD, the Army Signal Corps, and the Naval Weather Service agreed informally to operate jointly the readout stations at Camp Evans, New Jersey, and Kaena Point, Hawaii. The manpower contribution was to be divided as follows:[33]

READOUT STATIONS	USWB	GRD	AWS	USN	SIGNAL CORPS
Camp Evans	2	4	1	1	1
Kaena Point	1	2	1	1	0

GRD's representatives at Camp Evans would include Allied Research Associates contract personnel; the Signal Corps man

[33] Lufkin, "The Background of Present Meteorological Satellite."

would work part time.

By mid-1959, AWS had made arrangements to relay televised pictures of cloud formations from the satellite to its forecasters on the east coast and in Hawaii.[34] This was later enlarged to include facsimile pictures for European-based forecast facilities.

As events proceeded, more plans were made public. For example, the August 1959 issue of the American Meteorological Society's Weatherwise carried an article entitled, "On Observing the Atmosphere from Satellites--I. Cloud Observations," by the Weather Bureau's Dr. Sigmund Fritz. It described the cloud and radiation data expected from the initial TIROS vehicle. In January 1960, the Bulletin of the American Meteorological Society contained another significant article entitled, "Plans for Dissemination of Satellite Meteorological Data from Project Tiros," which detailed how cloud and radiation data would be made available to interested individuals and agencies. It was emphasized that the plans were subject to change, dependent upon the success of the experiment, data retrieval, and processing problems.

The principal activity of the Defense Department portion of the TIROS team was the engineering of "real-time" operational use of the satellite's observations. In effect, it meant that the satellite would become part of the active weather service from the very beginning, and would not be just another research instrument.[35]

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[34] Ltr, Maj Gen Bassett to Lt Gen William H. Tunner, MATS comdr, 31Jul59.

[35] "How Goes It" briefing, presented to HQ AWS staff agencies by AWSSS directorate, December 1959.

Air Weather Service officials took a hard look at the programmed instrumentation of the satellite and of anticipated observations to be derived, concluding that although TIROS would show cloud patterns indicating a tropical disturbance, for instance, other methods would still be required to determine the intensity of such disturbances and the meteorological structure. In other words, the satellite was not expected to replace weather reconnaissance or other observation means. If AWS was to forecast storm development and movement, TIROS would be of some value in determining upper-level winds, but it would not provide all of the parameters necessary for accurate prognoses.[36]

Nevertheless, for an over-all cloud picture, TIROS was expected to be the best means yet devised. The television cameras would provide actual pictures of clouds over a strip about 800 miles wide and some 6,000 miles in length. Although clouds alone were not all that was important in defining weather patterns, they would provide clues to the middle-scale behavior of the atmosphere. AWS was thus enthusiastic about the project.

Over regions where conventional weather stations were reasonably plentiful, such as the continental United States, TIROS observations--when combined with those made at the surface or by rawinsonde--would permit a more detailed understanding of the structure and mechanism of meteorological phenomena. Over oceans and other "silent" areas, cloud pictures would initially be useful for locating fronts

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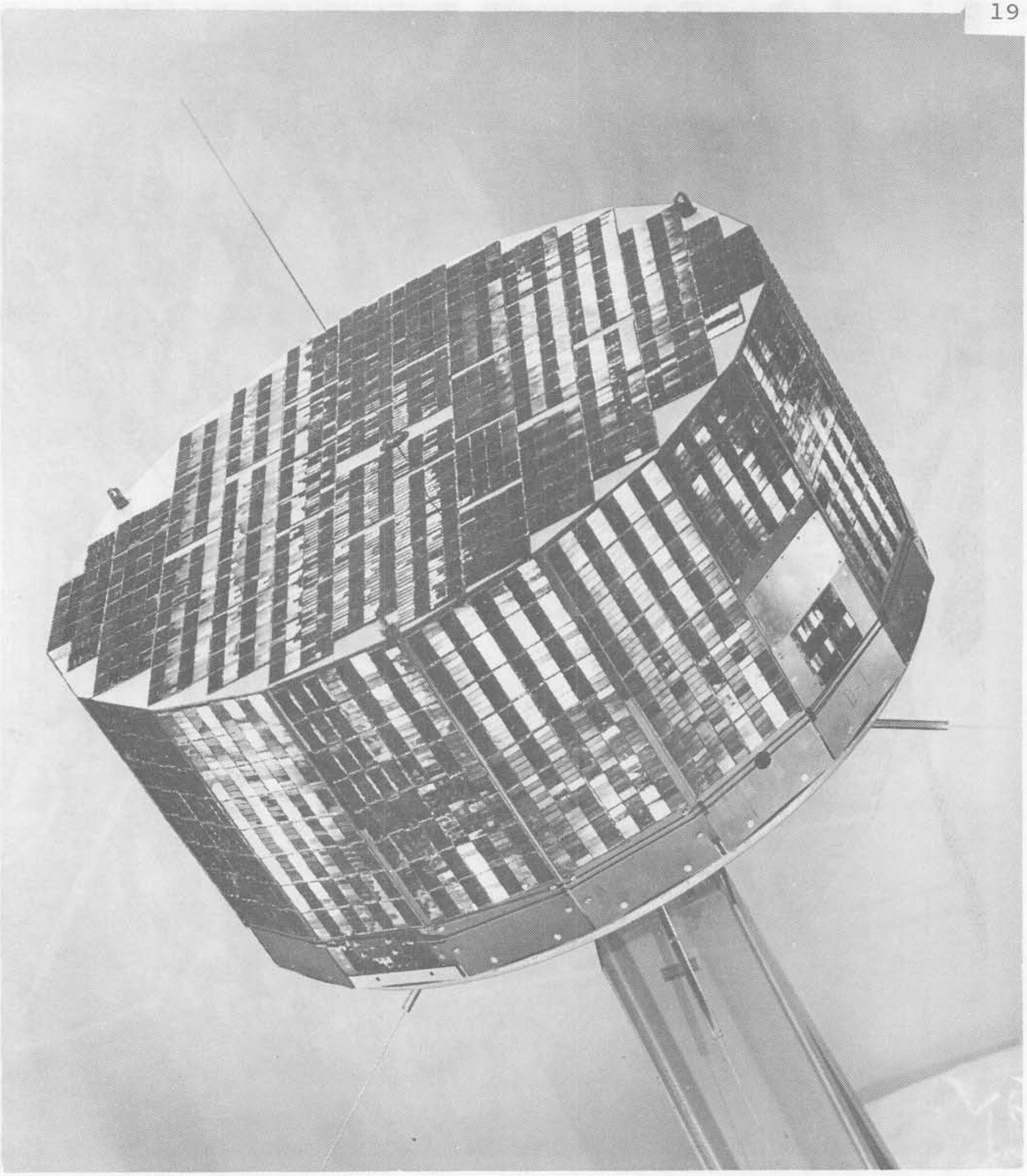
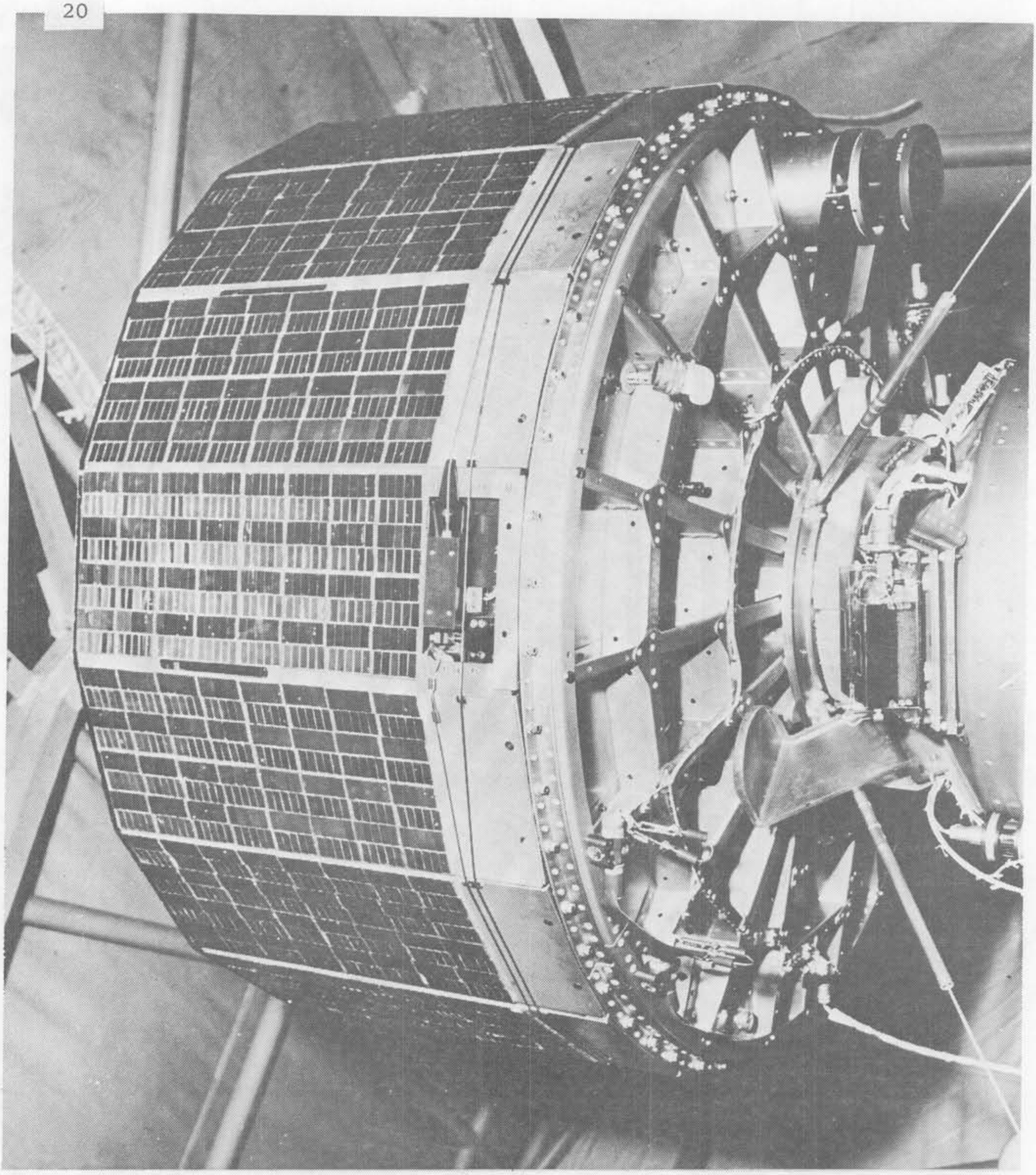
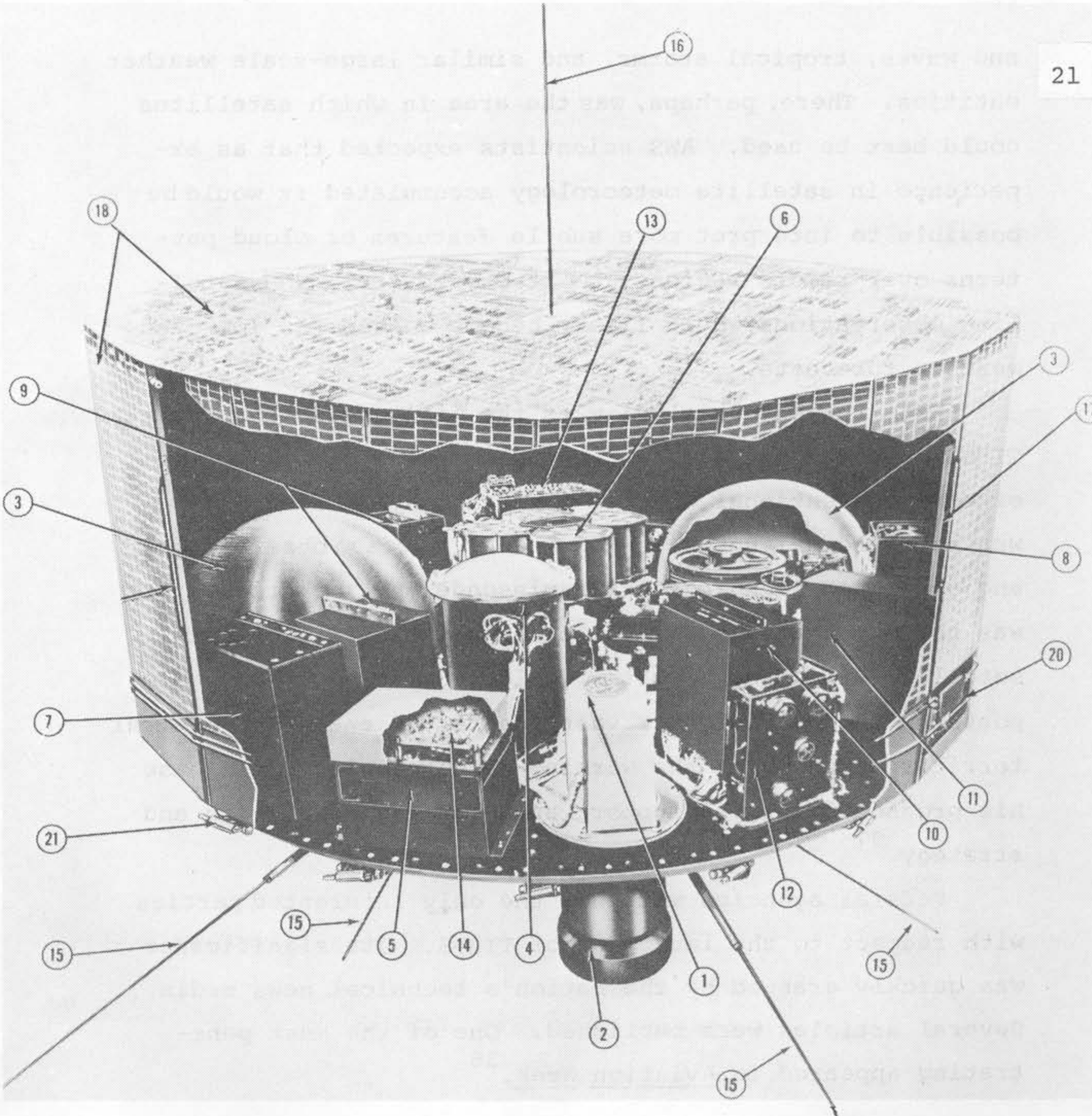
[36] "COMATS" briefing, presented to HQ MATS staff agencies by chief of staff, AWS, on 19Nov59.



TIROS I--a 270-pound experimental weather satellite designed and built for NASA by RCA's Astro-Electronics Division. (NASA Photo)



TIROS I. (NASA Photo)



A cutaway view of TIROS I indicating the principal components: (1) one of two ½-inch Vidicon cameras; (2) wide-angle camera lens; (3) television tape recorders; (4) electronic "clock" for controlling sequence of operations; (5) television transmitter; (6) storage batteries; (7) camera electronics; (8) tape recorder electronics; (9) control circuits; (10) auxiliary controls; (11) power converter for tape motor; (12) voltage regulator; (13) battery charging regulator; (14) auxiliary synchronizing generator for TV; (15) transmitting antenna; (16) receiving antenna; (17) solar sensor to measure position of satellite with respect to sun; (18) solar cells; (19) precession damper to eliminate "wobble" after satellite is orbited; (20) de-spin "yo-yo" mechanism; and (21) spin-up rockets. (NASA Photo) and waves, tropical storms, and similar large-scale weather entities. There, perhaps, was the area in which satellites could best be used. AWS scientists expected that as experience in satellite meteorology accumulated it would be possible to interpret more subtle features of cloud patterns over remote regions. If it proved true, then satellite observations would likely become a base for improved weather forecasts.

From the parochial view of the military meteorologist, TIROS observations seemed to supplement the global network of more conventional weather observing systems such as weather reconnaissance, weather radar, surface observations, and upper air soundings via rawinsonde and rocketsonde. It was obvious that the satellite, or better still, several satellites in spaced orbits, would provide "eyewitness" reports on the weather over vast reaches of enemy and neutral territory upon which the working meteorologist could base his prognoses for the support and planning of tactics and strategy.[37]

Federal agencies were not the only interested parties with respect to the launching of TIROS. Its significance was quickly grasped by the nation's technical news media. Several articles were published. One of the most penetrating appeared in Aviation Week.[38]

AWS Support

Within Air Weather Service, planning for the TIROS I

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[37] "How Goes It" briefing, AWSSS, Dec59.

[38] "Tiros I Will Scan Cloud Cover, Earth Temperature," 14Mar60, pp. 26-28.

launch moved at an accelerated pace early in 1960. Major Jones continued his study of cloud photographs taken from various rockets and missiles in preparation for operational use of satellite observations.[39] AWS field units gathered preliminary information on various aspects of the project for study and evaluation, including sample analyses of cloud observations from rocket and missile photos.

The job of interpreting and disseminating the TIROS observations was the responsibility of seven-man teams at both readout points, under general leadership of the Weather Bureau. Although studies to develop interpretation and dissemination methods had been in progress for more than a year, it was a difficult chore because meteorologists had such limited experience. It had been confined mostly to the analyses of photos made from V-2 and Aerobee rockets until the successful recovery of Atlas and Thor nose cones during the summer of 1959.[40]

Other specific support to be rendered the TIROS project by AWS field units concerned both ground and airborne weather radar. Dr. Myron Ligda of the Stanford Research Institute completed a test with the 55th Weather Reconnaissance Squadron[41] early in 1960, which indicated that radar scope photos taken during weather missions were valuable to

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[39] For his outstanding service during the TIROS I operation, Maj Jones was awarded the Air Force Commendation Medal on 9Aug60.

[40] "Military, Civilian Agencies Preparing New Weather Satellite for Shoot," Observer, Vol. 7, No. 2, Feb60, p. 5.

[41] Based at McClellan AFB, California.

his study of the relationships between TIROS photographs and radar observations. Accordingly, AWS planned to issue enough 0-15 cameras to permit the routine photography of radar scopes on all over-water, weather reconnaissance missions.[42] In addition, Dr. Ligda's study called for the use of ten AWS AN/CPS-9 weather radars overseas to provide extensions of the Air Defense Command network which he depended upon stateside.

The Army Signal Corps' Research and Development Laboratory at Fort Monmouth, New Jersey, in addition to participating in the immediate operational-use program at the Camp Evans readout site, planned to compare TIROS pictures with weather radar scope photographs from a network of stations along the eastern seaboard. That study, initiated by a Mr. Bastian, planned for the installation of automatic cameras on AWS AN/CPS-9s at eight east coast bases from Massachusetts to Florida.[43] The cameras operated automatically, requiring only a correction to the scope video circuit and about 200 watts of 115-volt, AC power. AWS' role was confined to changing film spools weekly.

Because both of the studies were, in a sense, duplicative, AWS asked Mr. Bastian and Dr. Ligda to coordinate their efforts to ensure that no unnecessary data-gathering was required of AWS units.

Shortly before the TIROS I launch, NASA's ground rules for dissemination of satellite data were tightened. No distribution of cloud analyses based on the satellite's

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[42] AWSSS Staff Conference Notes, 23Mar60.

[43] _Ibid_.

photographs was authorized to any agency outside of AWS channels. That included Weather Bureau stations. Since the Weather Bureau shared communications facilities with AWS at Kaena Point, Hawaii, AWS officials immediately recognized that there would be difficulties in distributing TIROS observations to Hickam and Kunia. NASA's position in the matter apparently stemmed from a desire to protect the entire meteorological satellite program from unfavorable publicity in the event that a bad advisory was attributed to TIROS data. NASA also believed that since TIROS was an experiment, its meteorological agency, the Weather Bureau, should have a chance to evaluate all data before any release was made for applications beyond NASA's control. The policy presented no cause for concern insofar as AWS' general requirements were concerned. AWS officials were, however, hopeful that most restrictions would be relaxed once TIROS was functioning properly.[44]

<u>Success!</u>

At 0640 hours Eastern Standard Time, on 1 April 1960, NASA launched TIROS I from Cape Canaveral, Florida. The launch time was selected to permit the satellite to take pictures over the Northern Hemisphere during the first two to three weeks of its life. TIROS I was injected into an orbit at an inclination of about 48 degrees and at an altitude of approximately 450 statute miles, with an excursion--coverage--between 48° North and 48° South latitudes--or approximately from La Paz, Bolivia, to

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[44] *Ibid.*

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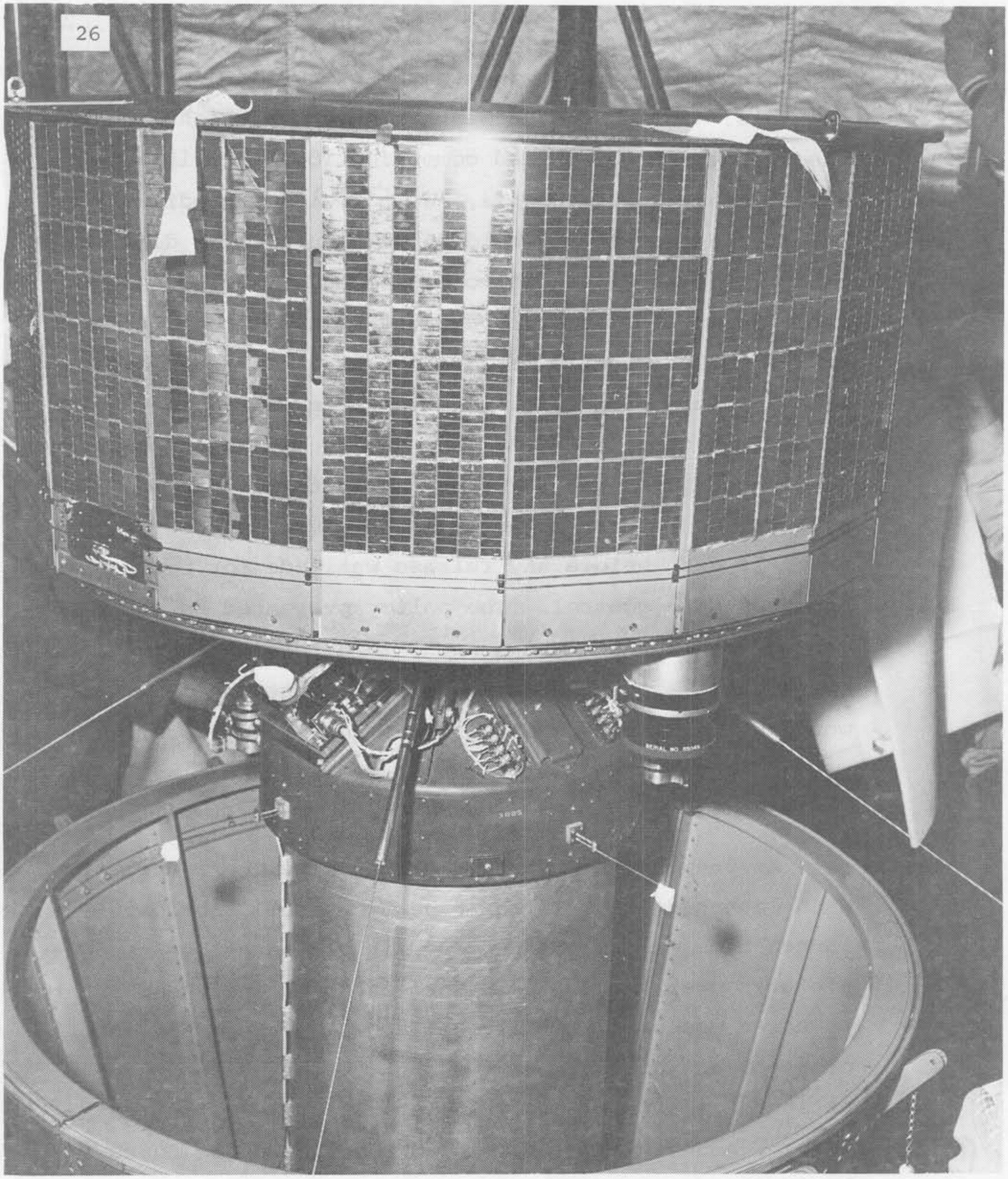
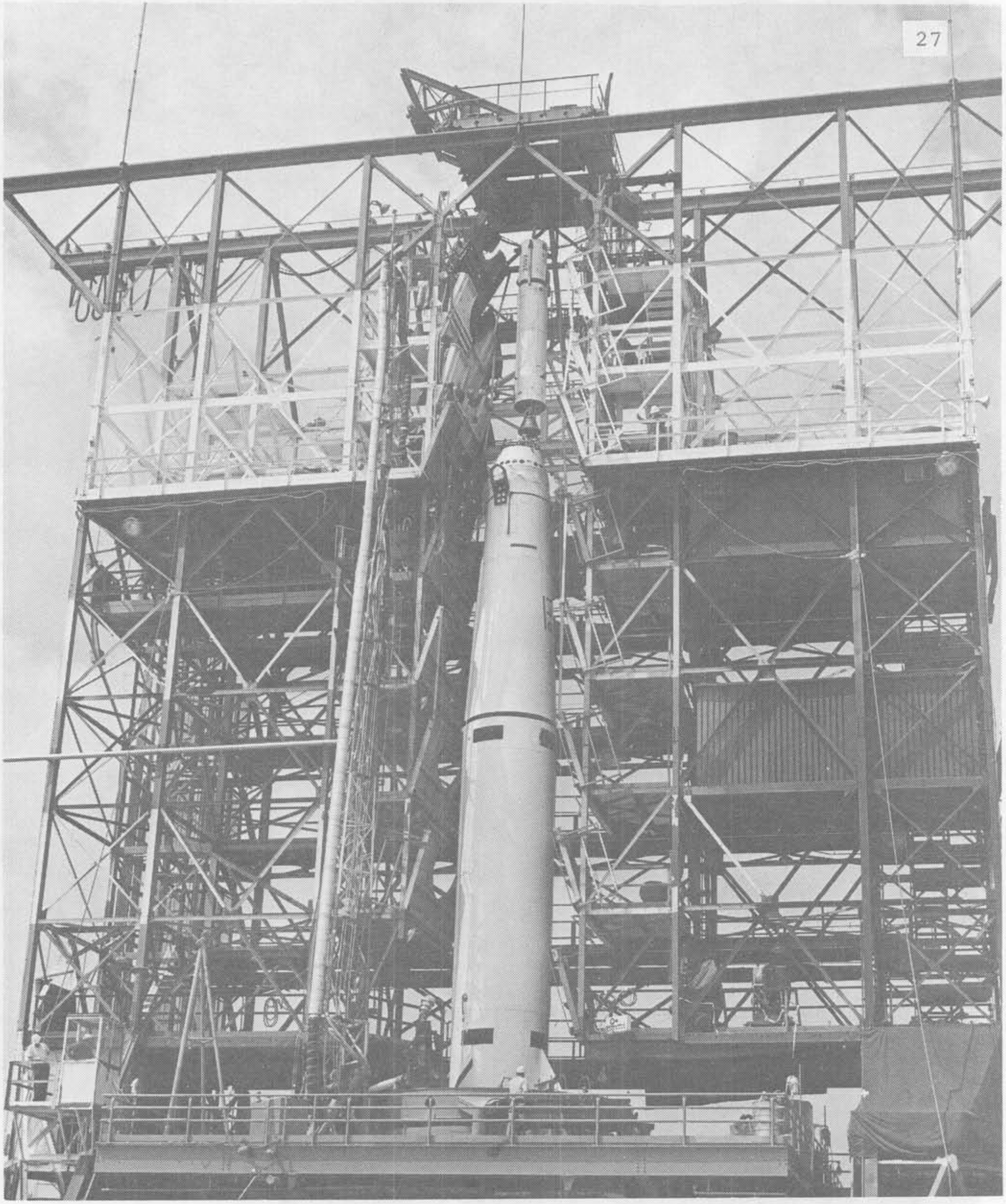
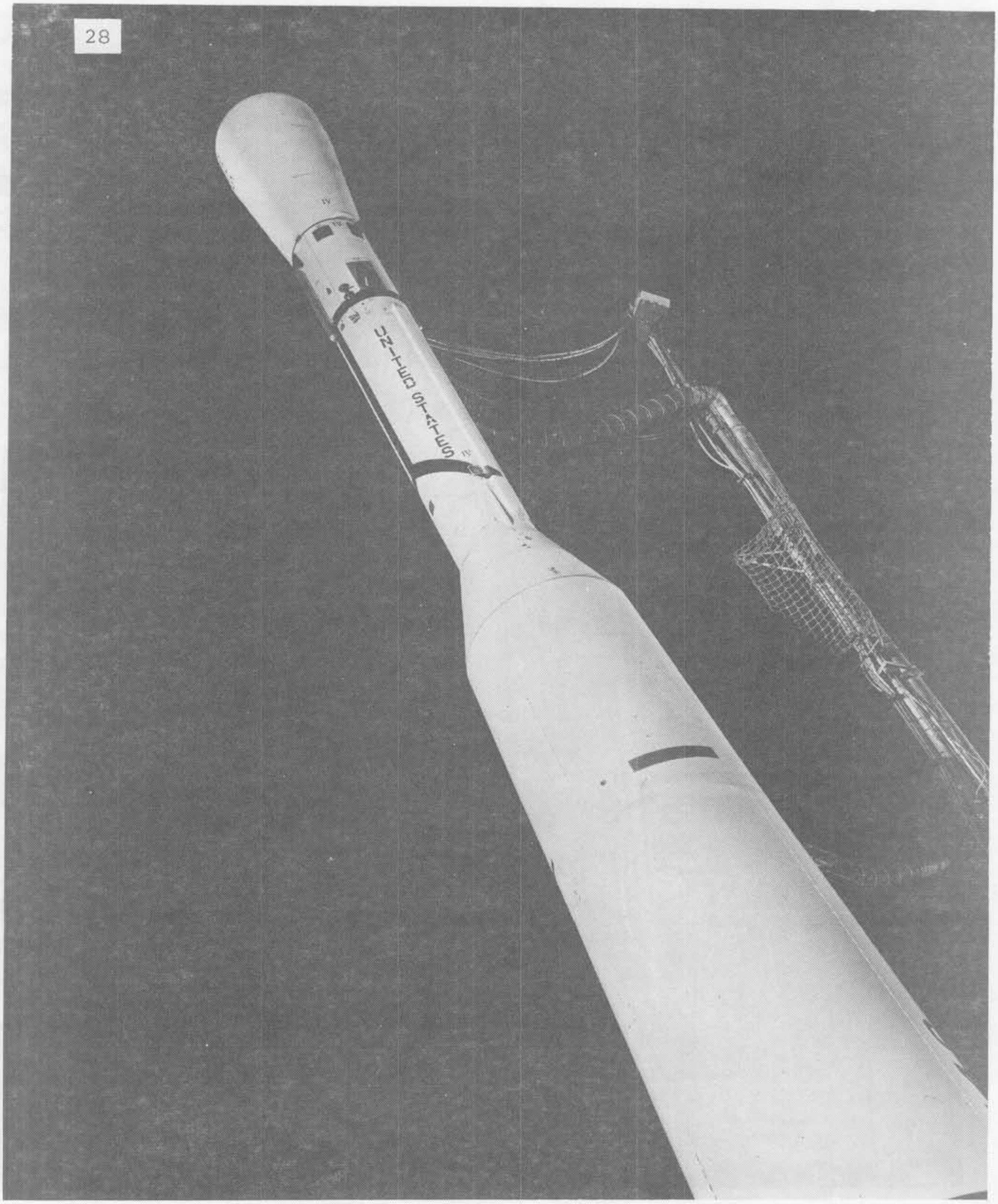


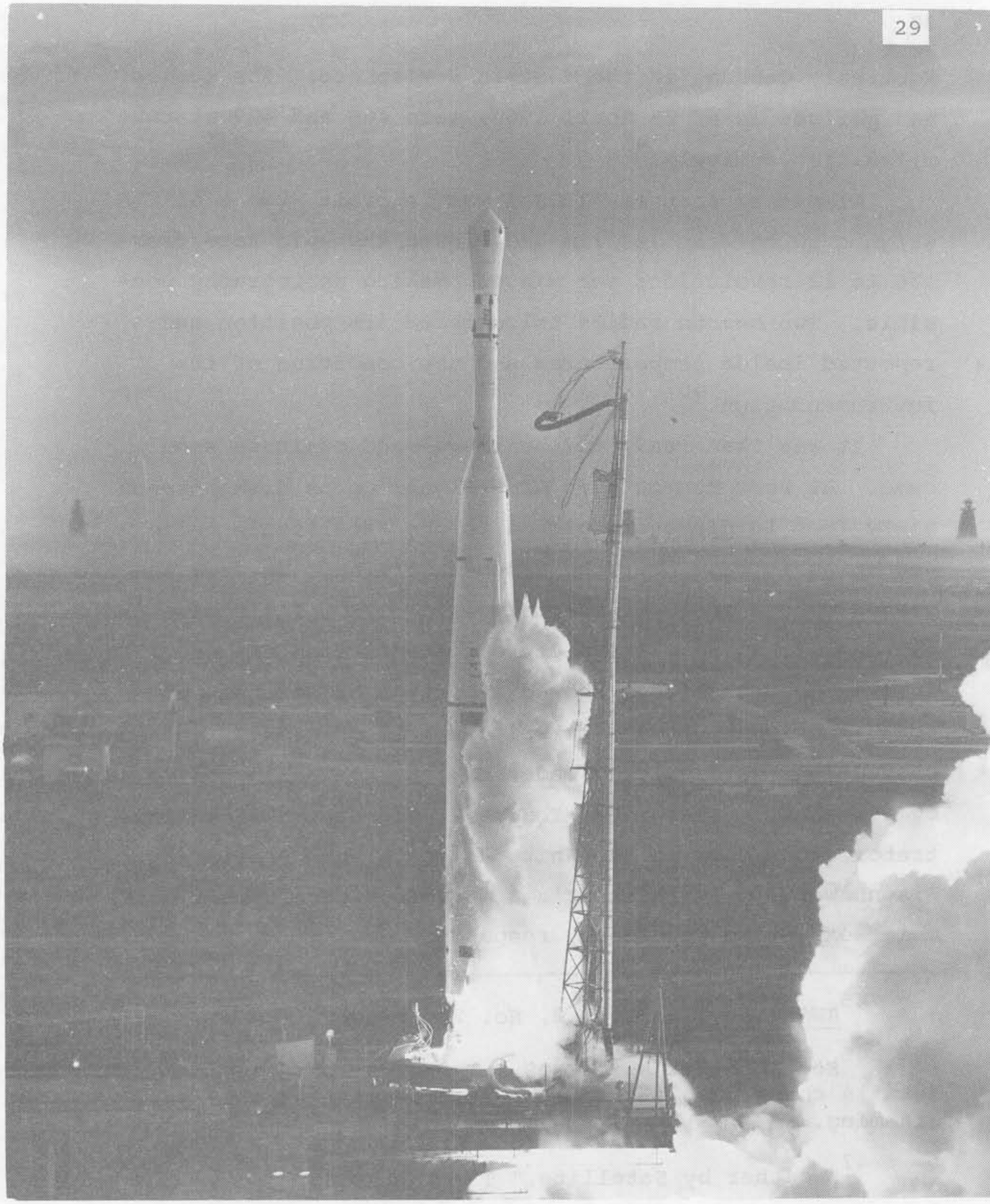
The TIROS I meteorological satellite and the live, third-stage of the Thor-Able boost vehicle. (NASA Photo)



Erection of TIROS I atop the Thor-Able boost vehicle at Cape Canaveral, Florida. (NASA Photo)



TIROS I ready for launch. (NASA Photo)



The launch of TIROS I from Cape Canaveral, Florida, on 1 April 1960. (NASA Photo)

Montreal, Canada, in the Western Hemisphere. Its apogee and perigee as of 26 April 1960, were 468 and 429 statute miles, respectively.[45]

Almost as soon as TIROS I was in orbit, two small weights swung from its rim and slowed the spin rate from 136 to 12 revolutions per minute, making photography possible. Two beacon radios telemetered its position and reported inside temperatures and the condition of its instrumentation.[46]

It was then ready for business--and business soon came. At Fort Monmouth an Army Signal Corps dish antenna, sixty feet in diameter, picked up the satellite's radio beacon as it came over the earth's horizon. Up from the ground went a coded signal triggering TIROS I's transmitting mechanism. The picture returned from the satellite's television transmitter showed a portion of northeastern North America spotted with white swirls of clouds. Reproductions were quickly made and sent to Washington, D. C., by wirephoto. There, Dr. Thomas K. Glennan, NASA Administrator, took them to the White House to show President Eisenhower.[47] "I think it's a marvelous development," the chief executive reportedly responded.[48]

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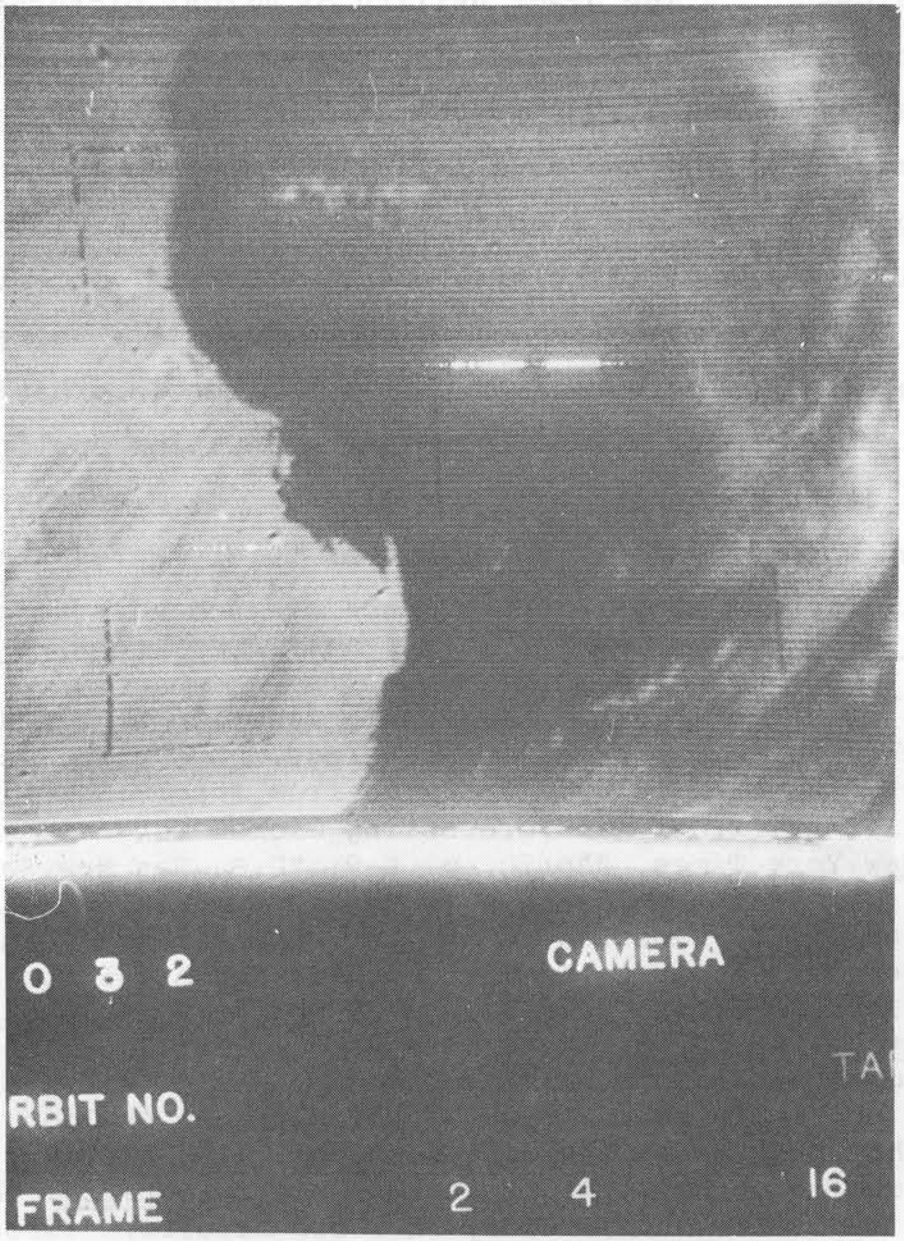
[45] AWSSS Review, Vol. 2, No. 2, 10May60.

[46] See Appendix A, "TIROS I Technical Data," for the details concerning its launch, instrumentation, and programming.

[47] "Weather by Satellite," Time, 11Apr60.

[48] "New Weather Satellite in Nearly Perfect Orbit for More Photographs; President Calls First Cloud Pictures From 270-Pound Tiros Marvelous," St. Louis Post-Dispatch, 2Apr60, p. 1.



One of TIROS-I's earliest photographs, received at Kaena Point, Hawaii, on 4 April 1960, during its thirty-first orbit, clearly defined the western coast of French West Africa from approximately Cape Blanco to St. Louis. (NASA Photo)

As anticipated, the President's reaction was one echoed by the press. Headlines in newspapers coast-to-coast cited the importance of TIROS I and related its usefulness.[49] "The exact utility of Tiros' pictures in weather mapping and forecasting was hard to assess immediately after the launch," the credible Aviation Week magazine reported ten days later, "but meteorologists are pleased with the results and the proof the photographs provide of the validity of weather satellite concepts."[50]

While the magazine acknowledged TIROS I's value for meteorological purposes, it also noted the international problems it posed by demonstrating principles applicable to military reconnaissance satellites. Despite the fact it had been repeatedly described as purely a research satellite, and despite the absence of much adverse comment

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[49] See Appendix B, "News Media Reaction to TIROS I Launch," for examples of the coverage. See also: John W. Finney, "Weather Televised; Image from Space; New Tiros Satellite Will Help in Forecasting Global Conditions," The New York Times, 3Apr60, p. E-9; "U.S. Has New Satellite; It Carries TV Cameras To Photograph Weather; 270-Lb. Payload Is Expected To Aid in Prediction of Tornados; Device, Called Tiros, Is Carried Aloft by Air Force Thor-Able Rocket--Orbit 400 Miles Up Is Sought," St. Louis Post-Dispatch, 1Apr60, p. 1; "Countdown Hold Periled Tiros Firing; Another Four Minutes and Shot Would Have Been Put Off," Baltimore Sun, 2Apr60, p. 1: Courtney Sheldon, "Weather Unit Accents Practical Hopes; TIROS I Hints at New Satellite Era," The Christian Science Monitor, 4Apr60, p. 6; David Lawrence, "Today in World Affairs: 'Tiros I' Is Called a Lesson to Critics of U.S. Program," New York Herald Tribune, 6Apr60; and Frank Carey, "Future Satellites to Probe Many Weather Mysteries," St. Louis Globe-Democrat, 4Apr60, p. 1.

[50] Craig Lewis, "NASA Tiros I Demonstrates Potential Satellite Reconnaissance Utility," 11Apr60, pp. 28-30.

from the communist countries, the fact that TIROS I was photographing areas of Mongolia, China, the Middle East, and southern and eastern Russia gave both the State Department and the Central Intelligence Agency cause for concern.[51] Fully aware of the international implications also, NASA took pains to stress that the satellite's television cameras could only detect large terrain features and lacked the capability of detailed surface reconnaissance. The narrow-angle camera had a design resolution of about 0.2 miles. Therefore, NASA asserted, an object that size appeared merely as a "blip" on one of the 500 lines in a picture and was impossible to identify.[52] As an additional safeguard, NASA carefully screened all photographs before their release to insure that no feature of a sensitive nature was developed.

Notwithstanding the relatively minor political and

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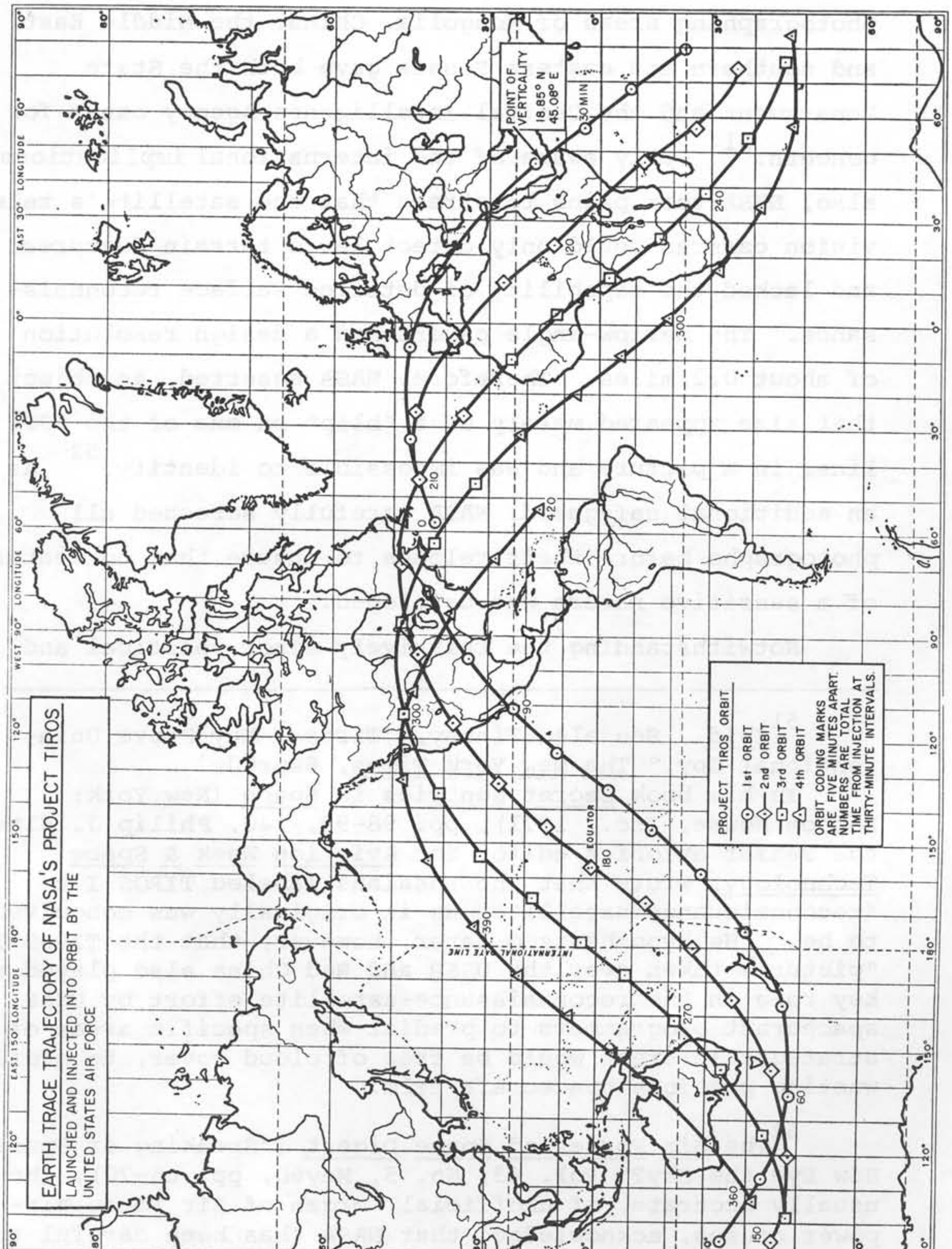
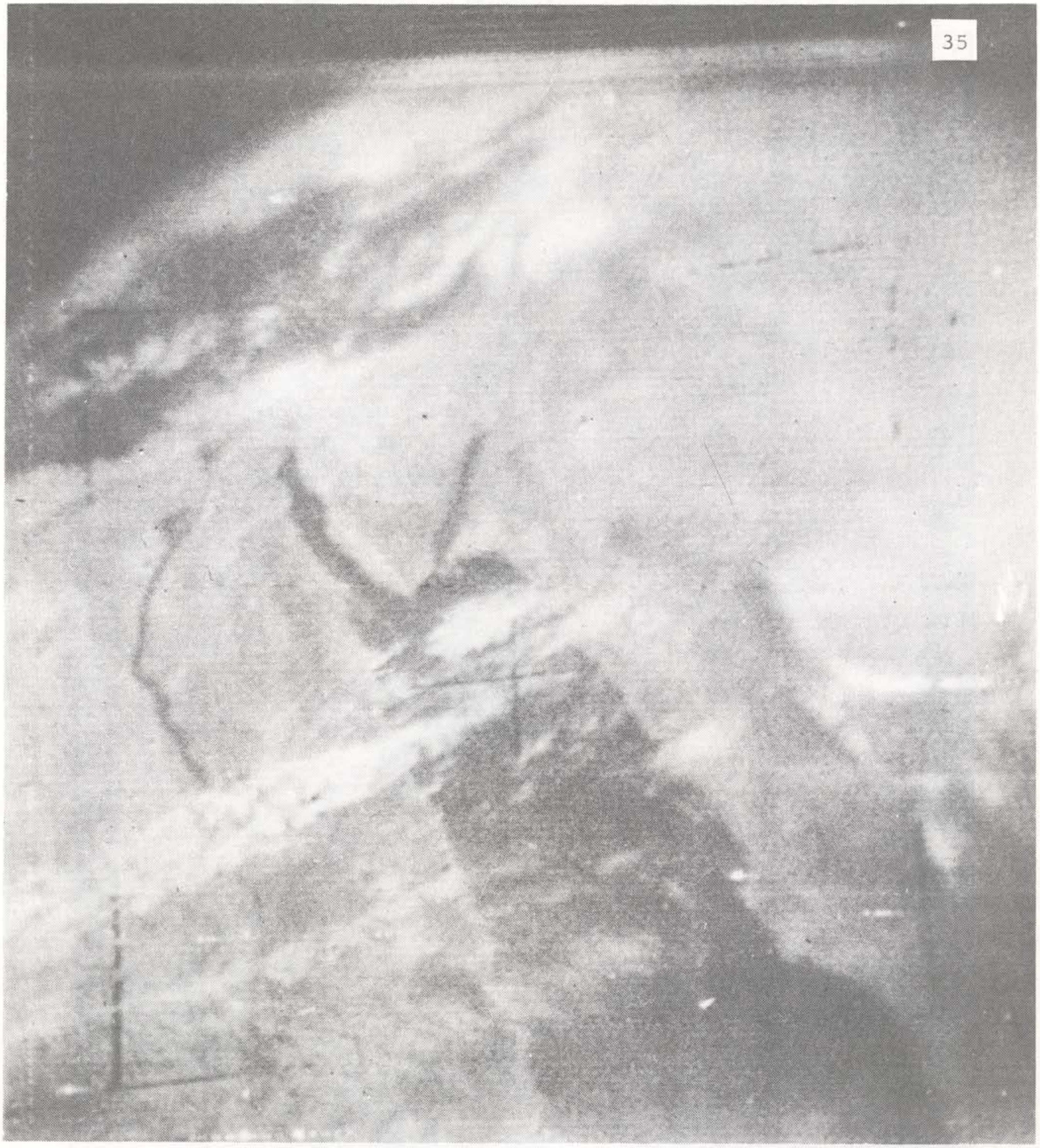
[51] Ibid. See also Finney, "Tiros I May Prove Unintentional Spy," The New York Times, 6Apr60.

In his book Secret Sentries in Space (New York: Random House, Inc., 1971), pp. 98-99, 140, Philip J. Klass, the senior avionics editor for Aviation Week & Space Technology, wrote that the Russians labeled TIROS I a "reconnaissance satellite--as it originally was conceived to be." He hypothesized later, however, that the TIROS I "pictures taken over the USSR and Red China also played a key role in the reconnaissance-satellite effort by USAF spacecraft programmers to predict when specific areas of strategic interest would be free of cloud cover, to avoid wasting precious spacecraft film."

[52] The Air Force and Space Digest ("Speaking of Space: How Eye the Sky?" Vol. 43, No. 5, May60, pp. 66-70), the usually accurate, if unofficial, organ of Air Force airpower causes, acknowledged that NASA "has been careful to insist that no real ground detail is discernible in the photographs" and that it "was doubtless true now." However,



TIROS I's orbital path. (NASA Chart)



A TIROS I photograph, taken on 4 April 1960, showing clearly the Red Sea, the Gulfs of Suez and Aqaba surrounding the Sinai Peninsula, the Nile River, and the eastern tip of the Mediterranean Sea. "Just like Rand McNally," the National Broadcasting Company's television newscaster David Brinkley remarked upon seeing it.* (NASA Photo)

*"Speaking of Space: How Eye the Sky?" Air Force and Space Digest, Vol. 43, No. 5, May60, p. 66.

TIROS I photograph of the Caspian Sea taken during orbit 657 on 16 May 1960. The shore line runs vertically through the picture's center and a cloud mass dominates its lower portion. (NASA Photo) technical problems, it was immediately evident to the agencies concerned that TIROS I was a complete success.[53] To the skeptics who had claimed that satellites were a little more than spectacular stunts, its photographs provided a spectacularly practical answer. During its first ten days, TIROS I transmitted some 2,000 photographs of the earth and its cloud cover in a convincing demonstration that satellites could indeed be used to survey weather conditions and surface features from space. At the very least, TIROS I ushered in a new era in meteorology.

Air Weather Service meteorologists were most enthusiastic about its products. Although TIROS I photographs were limited to what could be scanned along the satellite's pre-determined orbit, it was obvious to AWS officials that enough was observable to be of operational value.[54]

Transmitting the Data

Early in June it was revealed that a circuit between TIROS I's high-resolution camera and the recorder that stored its information had failed a day after launch. However NASA noted that on 11 May the circuit had cleared and

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[52] (Cont'd) in the course of making a pitch for the Air Force being designated the single manager for the military space mission, and thereby printing the unprintable in official Air Force circles, it averred that "today's Tiros is cousin to tomorrow's Samos [Satellite and Missile Observation System], the Air Force's projected reconnaissance satellite."

[53] Evert Clark, "Tiros Exceeds Weather Bureau Hopes," Aviation Week, 2May60, p. 30.

[54] AWS News Release No. 60-9, "USAF Weathermen Start Test on TIROS Satellite Data," n.d. (circa Apr60).

TIROS was thereafter able to store and relay high-resolution pictures. RCA speculated that an internal temperature change was responsible for the failure and later operation of the circuit.[55]

Transmission of nephanalysis TIROS data on communications circuit 1R9--Strategic Facsimile Network--commenced during the first week of operation. A bottleneck in data handling developed but was alleviated by AWS through the assignment of one airman from the headquarters and three airmen from 4th Weather Group detachments to the east coast readout station.[56]

Cloud-pattern charts transmitted over facsimile circuits 1R9--to stateside stations--and 21x19--to High Wycombe Weather Central in England--were produced by a team of meteorologists at Camp Evans, New Jersey, under the direction of the Weather Bureau's Meteorological Satellite Section. AWS members there were headed by Major Jones--AWS' liaison officer to the satellite section. A similar team at Kaena Point, Hawaii--on which AWS was represented by the 1st Weather Wing's Major William H. Staten--analyzed that readout station's pictures for local use. Since the aspect angle for each picture had to be computed by manual methods, the Camp Evans' team was hard-pressed during the first few days of activity. But with the help of the four AWS observers under Major Jones, the information was disseminated much quicker.[57] Additionally, MANAM--communica-

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[55] "TIROS Spin Rate," Aviation Week, 7Jun60, p. 30.

[56] AWSSS Staff Conference Notes, 6Apr60.

[57] The four observers were A/2C Stanley Fell, A/2C Donald Fry, and A/3C Stephen Hirjak, from the 4th Weather

tions schedule change--action was requested by AWS for two open periods on facsimile circuit 21x19--at 1800 and 0255 hours--and for all open periods on circuit 1R9 for the unscheduled transmission of satellite nephanalyses. In effect, such action merely "legalized" what was then transpiring.[58]

From the TIROS readout stations, bulletins describing cloud observations were sent to the selected forecasting agencies and facsimile analyses were transmitted on the communications circuits. Because these analyses had to wait for free periods on the facsimile circuits, the information was often six-to-eight hours old by the time it reached field units.[59] Often it was older. Although communications difficulties resulted in the charts being delayed for an average of nearly ten hours between observation and receipt of the data in the field, a survey of AWS stations revealed that many field forecasters still judged the data's potential operational utility as "very promising."[60]

The lateness of the data prevented many stations from making operational use of the information, but several detachments commented that the cloud-pattern analyses could

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[57](Cont'd) Group's Detachments 3, 6, and 12, respectively, and A/2C Gary Grabau from HQ AWS' Directorate of Scientific Services. See Capt Lufkin, "TIROS I, World's Photographer," Observer, Vol. 7, No. 5, May60, p. 5.

[58]AWSSS Staff Meeting Items, 13Apr60.

[59]"TIROS I, Pioneer Weather Satellite, Proving Successful," Observer, Vol. 7, No. 4, Apr60, p. 1.

[60]Lufkin, "The Background of Present Meteorological Satellite."

have taken the place of locally-prepared charts if they had been received earlier. For example, the 5th Weather Group's Detachment 5 at Homestead AFB, Florida, noted that the 5-April TIROS analysis over the eastern United States showed remarkable correlation with their own analysis over the areas for which ground observations were available.[61] Over the Atlantic, where the Homestead chart had only three observations, the TIROS chart had just as much detail as over any other region.[62]

Not long after the satellite was launched, AWS personnel were informally advised that from about the middle of April until about the third week of May, the point from which TIROS looked vertically at the earth's surface would be located in the Southern Hemisphere. Those pictures of the Northern Hemisphere which could be seen at all would be so distorted by perspective that no reliable analyses could be made from them. Thus, those stations which were receiving charts of TIROS observations were warned to expect fewer during the "dark period" before about May 24. Other plans were also outlined:

> When TIROS reappears on the Northern Hemisphere scene, the meteorological teams at the readout stations hope to have overcome the delays in picture processing and communications. The goal is to have TIROS data in the hands of field forecasters within about two and a half hours.
>
> Working to such a schedule, TIROS data will reach the field at about the same time as the major synoptic

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[61] The TIROS chart also confirmed the efficiency of the Homestead station's charts, drawn independently of TIROS data.

[62] "TIROS I, Pioneer Weather Satellite, Proving Successful," Observer, Vol. 7, No. 4, Apr60, p. 1.

charts, bringing a wealth of fresh information on the state of the atmosphere over very large regions. (Exactly what uses, aside from the obvious ones of pilot briefing and oceanic analysis, TIROS data will serve, no one yet knows.) The TIROS teams invite AWS men everywhere to inspect their charts and bulletins carefully, to try to integrate the information into their usual forecasting methods, and to report their ideas and opinions to the AWS team member. Send questions, comments, and suggestions to Maj James Jones.[63]

The expected change in attitude of TIROS I transpired late in April, and the readout stations at Camp Evans and Kaena Point went to a standby status for a period. The lack of landmarks and exact attitude data made observations unprofitable, so manning at the readout stations was kept to a minimum. However, a few observations continued to be transmitted as a check on the instrument package's condition and to provide further data to refine the computer program for position and attitude forecasts.[64]

In mid-May, when TIROS began to see the Northern Hemisphere again, the readout teams went back to full operation. Captain Searle D. Swisher of Detachment 3, 1st Weather Wing, replaced Major Staten as the AWS representative at the Kaena Point readout station. More AWS meteorologists began participating in the program, and the teams sought ways to speed data transmission, the principal bottleneck. Although the goal of two-and-one-half hours from satellite to forecaster was optimistic, a gradual speeding up of data dissemination and increasing emphasis

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[63] Ibid.

[64] AWSSS Staff Conference Notes, 20Apr60.

on operational use of TIROS observations was expected.

During the attitude change period, AWS learned that NASA had reworked the TIROS aspect program, so as to use an identifiable landmark as initial data. It was expected to enhance considerably the usefulness of TIROS photos over ocean areas.[65]

Headquarters AWS, commenting on the value of the satellite's observations, noted that:

> Recognizable features of cloud systems have been and are being located accurately with respect to points on the earth's surface. From these features, major storms have been spotted and their progress watched with interest as successive passes of TIROS yielded more pictures and information.[66]

When the satellite's attitude was changed to permit Northern Hemisphere observations again, three additional AWS forecasters--Lieutenants James Giraytys, Richard Rudy, and John Hillsman--were temporarily assigned to the Camp Evans readout station to assist Major Jones.[67] All three were well acquainted with the requirements of SAC, the Air Defense Command (ADC), and general aviation forecasting. TIROS I continued to function and promised to have a longer useful life than had previously been anticipated. By the third week of May, some AWS officials were estimating that a six-month lifespan was a "good estimate."[68]

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[65] Ibid., 18May60.

[66] AWSSS Review, Vol. 2, No. 2, 10May60.

[67] Assigned respectively to Det 14, 12 WSq, Det 30, 5 WGp, and Det 2, 4 WGp. See "TIROS I, Resting After 2½ Months of Top Performance," Observer, Vol. 7, No. 6, Jun60, p. 4.

[68] AWSSS Staff Briefing Item, 25May60.

A dissemination problem cropped up in mid-May. The 2d Weather Wing advised AWS that the Deutscher Wetterdienst was monitoring radio facsimile circuit 21x19 to pick up TIROS displays. Since AWS had promised NASA that TIROS informational dissemination would be controlled to keep it within official channels, it appeared that transmission of the data on that circuit would have to be discontinued. In effect, it would have denied the data to the High Wycombe Weather Central. On 18 May, Major Jones and Captain Daniel H. Lufkin, from AWS' Scientific Services Directorate, met with NASA personnel on the matter.[69] NASA agreed to relax its restrictions on dissemination to permit wider transmission of the TIROS data both stateside and abroad.[70]

By late May, the spin rate--which had originally been slowed from 136 to 12 revolutions per minute (rpm) shortly after launching[71]--had decayed to 9.3 rpm because of the earth's magnetic field. Since 9 rpm was about the critical minimum speed for stabilization and photography, a pair of spin rockets attached to the satellite's base plate were fired on 27 May upon command from a New Jersey ground station as TIROS I made its 819th pass. The spin rate achieved by the firing was 12.85 rpm.[72]

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[69] AWSSS Staff Briefing Item, 18May60.

[70] Interview with Capt Lufkin, 23Aug60, by MSgt Charles A. Ravenstein, Hist Div, Directorate of Info, HQ AWS. Hereafter cited as "Lufkin Interview."

[71] See Appendix A.

[72] "TIROS Spin Rate," Aviation Week, 6Jun60, p. 30; RCA advertisement, "TIROS Ground Stations--Nerve Centers For a Satellite," Aviation Week, 11Jul60; and "Tiros Scores

The End of TIROS I

Early in June, AWS learned that TIROS I's television equipment would be turned off because the cameras were beginning to point toward the sun during part of the orbit. If the shutter opened with the sun in the field of view, the vidicon plate would be ruined. It was estimated that the equipment would be turned on again about mid-July. AWS personnel at the readout stations were directed to return to their parent units while the television equipment was turned off.[73]

TIROS I offically closed down after orbit 1,302 on the ninety-first day of its operation, 29 June 1960. A stuck relay, probably caused by the low solar power and resultant low power level of the nickel-cadmium battery, had kept the shutter of the wide-angle camera open as the satellite looked toward the sun. As anticipated, the sun's firey image must have crossed the camera's vidicon plate and destroyed it. Although the narrow-angle, high-resolution camera still functioned, its limited--eighty-mile square--field of view did not permit practical operational use. Some limited experimental work was continued, but the main effort of the Weather Bureau and Geophysics Research Directorate's satellite sections was redirected to case analyses of the data on hand--some 22,952 photographs, of which some sixty percent were estimated to contain useful meteorological information.[74]

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[72](Cont'd) Another First--Spin Increased While In Orbit," St. Louis Post-Dispatch, 1Jun60, p. 9A.

[73]AWSSS Staff Conference Notes, 8Jun60.

[74]See AWSSS Review, Vol. 2, No. 3, 27Jul60; Lufkin,

Discrepancies appeared in some news coverage of TIROS I's death. Aviation Week, early in July, reported that satellite interrogation was discontinued "temporarily" because the batteries' weakened condition had caused erratic operation since early June. "Tiros' orbit," the magazine continued,

> recently has been keeping it in the earth's shadow a great deal of the time. Lack of sunlight reduces battery-charging capability of solar cells, and low internal temperature may have affected internal circuits. It is now in sunlight most of the time, and attempts to obtain television transmission of cloud cover photographs from its wide- and narrow-angle cameras may be resumed . . . [NASA] said.[75]

However, a United Press International release, issued about that time and similarly based on NASA information, noted that TIROS I's "useful life ended at midnight June 29 after a failure of electronic equipment."

NASA was of the opinion that a limited operational capability remained in the narrow-angle camera, but that it would be extremely difficult for meteorologists to identify and orient its pictures. Without the wide-angle camera, identifiable geographic landmarks were unavailable. Moreover, the satellite's attitude sensors were inoperable.[76] The Weather Bureau remained prepared to photograph

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[74](Cont'd) "The Background of Present Meteorological Satellite"; and Senate: Meteorological Satellites, p. 52.

[75]"Tiros Interrogation Discontinued by NASA," 4Jul60, p. 38.

[76]Final Operational Report: TIROS I Meteorological Satellite System (Princeton,N.J. : Astro-Electronics Div, RCA, 1Oct60).

a tropical storm if the occasion presented itself. Such a likelihood, however, depended not only upon the occurrence of such a storm, but on the faint possibility that the satellite would pass over the storm in the proper attitude and at the right time of day. AWS, on the other hand, planned to acquire no further TIROS I data.[77]

TIROS I Evaluated

Even while TIROS I was functioning, it was apparent that its data had made important contributions to meteorological research. NASA observed that among the most striking cloud patterns captured by the satellite were the large-scale cyclonic storms or vortices whose spiral bands sometimes reached over 1,000 miles in diameter. The frequency and extent of highly organized cloud systems associated with those vortices had not been fully realized before TIROS I. NASA also noted that some of the photographs revealed the presence of jet streams, regions of moist and dry air, thunderstorms, fronts, and other meteorological phenomena.

Of the 22,952 frames transmitted by TIROS I, 17,449 were received at Fort Monmouth--4,698 from the narrow-angle camera, and 12,751 from the wide-angle camera. Kaena Point received some 5,503 frames--1,117 from the narrow-angle camera and 4,386 from the wide-angle.[78]

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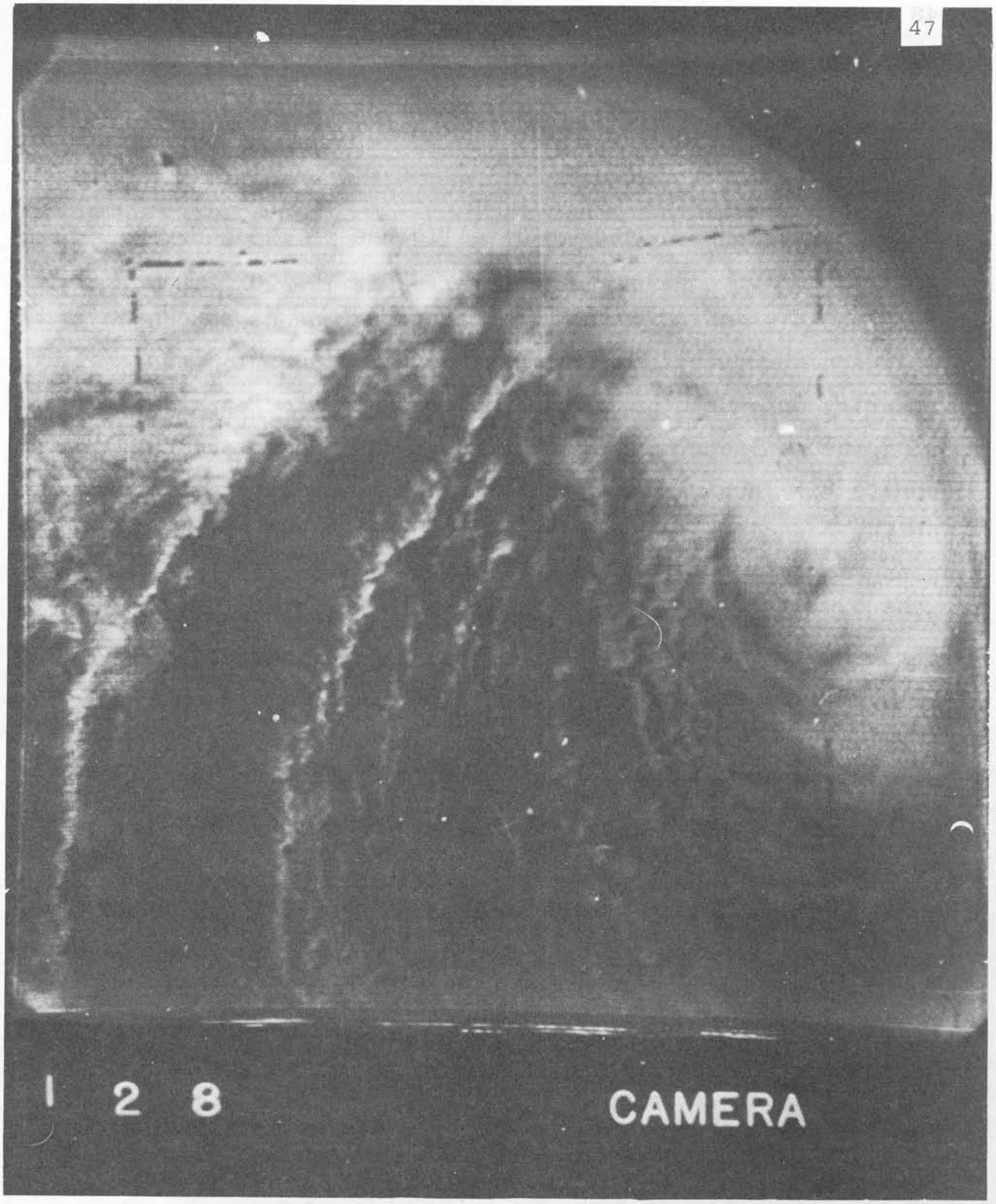
[77] AWSSS Staff Conference Notes, 6Jul60.

[78] Ibid.



TIROS I photograph of a typhoon in the South Pacific approximately 1,000 miles east of Brisbane, Australia, taken on 9 April 1960, during the satellite's 125th orbit. (NASA Photo)

Air Weather Service drew several conclusions from the TIROS I photographs. Cyclonic circulations such as tropical storms were easily recognizable. In some instances general cloud types--such as cirrus, cumulus, or stratus--were identifiable, and some intelligence on cloud-cover density could be gleaned. Finally, some motion of the more rapidly-moving cyclones could be detected, depending on the accuracy with which the clouds could be located--accuracy depending on recognizable geographic features.[79]

The AWS detachments which received TIROS cloud-pattern charts via facsimile responded enthusiastically to a survey on the uses of the observations to be utilized by AWS in planning fuller participation in future satellite programs.[80] Although crowded circuits had delayed most charts for an average of nearly ten hours, some forecasters cited actual missions which benefited from TIROS data, including the launch of at least one Bomarc missile.[81] "Very little

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[79] AWSSS Review, Vol. 2, No. 3, 27Jul60.

[80] An unidentified "Air Force official" was quoted by correspondent John W. Finney in The New York Times ("Weather System To Use New Tiros; 2d Cloud-Filming Satellite Set for Fall--Plan Beats Schedule by 3 Years," 17Jul60) as saying that "the success of Tiros I caught us with our plans down."

[81] In ibid., Finney described a "B-52 refueling incident" as one where "Air Force meteorologists showed how they could have steered a B-52 bomber away from a cloudy rendezvous with an aerial tanker over the Atlantic" by using TIROS I photographs. The reference to their use with Bomarc launches was found in MATS Form 44, "Quikcom," Mr. John D. Rugg, Dir of Info, AWS, to AWSCS (chief of staff, AWS), "Recommendation for News Release on Use of TIROS Data," 3Jun60. See also "TIROS I Resting After 2½ Months of Top Performance," Observer, Vol. 7, No. 6, Jun60, p. 4.

operational meteorological data was obtained . . . from the project," a 1st Weather Wing report read which generally reflected the field's viewpoint,

> even though the Kaena Point Tracking Station is located on Oahu. The major reasons were lack of communications and reluctance of project authorities to release information which might be misinterpreted. The positioning of cloud systems on the earth was considered by some authorities to be inadequate for operational use and highly vulnerable to misinterpretation. Late in the project, however, valuable operational data was relayed on at least five separate occasions by telephone from Kaena Point to the Pearl Harbor Weather Central and the Kunia Weather Center.[82]

In addition to providing assistance to the teams at the readout sites, AWS supported Dr. Ligda's and Mr. Bastian's radar scope photography projects described above. Participating in research under the direction of Dr. Ligda and the Stanford Research Institute were the AWS detachments at Eniwetok, Kadena, Schilling, Ramey, Brize Norton, Keflavik, Hahn, Lowry, Albrook, and Kindley bases. While fuel cell problems grounded them for much of TIROS I's functional life, aircraft of both the 55th and 56th Weather Reconnaissance Squadrons were used to make special radar observations.[83] Cooperating with Mr. Bastian and the Army Signal Corps' Research and Development Laboratory were the weather detachments at Pope Hunter, Robins, Patrick, and McDill Air Force Bases.[84]

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[82] "Historical Report, 1st Weather Wing," 1Jan-30Jun60, pp. 20-21.

[83] See Vol. I, "Narrative," pp. 143, 511-31, of "History of Air Weather Service," 1Jan-30Jun60.

[84] "TIROS I, World's Photographer," Observer, Vol. 7, No. 5, May60, p. 5, and "Brize Norton Weathermen in

Briefings on AWS' experiences with the TIROS I data were presented to Military Air Transport Service--MATS--officials by Major Glover, and to ADC, TAC, and SAC by Major Jones and Captain Lufkin. At each presentation the officers discussed the operational utility of the satellite pictures to both the forecaster and operator.[85]

Captain Lufkin, right, discussing a working RCA model of TIROS II with Mr. Max Roby--a television newscaster with Channel 4, KMOX, St. Louis--at headquarters AWS in 1961. (USAF/AWS Photo)

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[84](Cont'd) Operation Weather Watch," Observer, Vol. 7, No. 7, Jul60, p. 6. The work of Detachment 12 of the 2d Weather Wing's 28th Weather Squadron at Brize Norton consisted of mounting a polaroid camera to one of their radar scopes. Each fifteen minutes the camera took a scope photograph, indicating weather at and near the base. At the end of each day the photos were shipped to the Stanford Research Institute for analysis and comparison with TIROS I pictures. The same procedure was followed by each of the detachments participating in the program with radar sets.

[85]Lufkin, "The Background of Present Meteorological Satellite."

In June 1960, the commander of AWS, Brigadier General Norman L. Peterson, visited the 2d Weather Wing and took with him a collection of TIROS I photographs. So much interest was generated by the striking views of the earth that the general was invited to appear as a special feature speaker at the annual SHAPE--Supreme Headquarters Allied Powers, Europe--commanders meeting--SHAPEX-60. In addressing more than 300 NATO--North Atlantic Treaty Organization --commanders, the AWS commander labeled TIROS I "one of the most valuable tools in the memory of the military meteorologist."[86] A fully operational <u>system</u> of such satellites, he said, would "bring to the field commander of a few years hence a view of the battlefield which has until now been reserved for the historians." He pointed out some of the satellite's potential advantages, including that of forecasting the weather for the earth's "silent" areas. By correlating the appearance of cloud systems as seen from space with ground weather reports, meteorologists were learning to interpret TIROS pictures in terms of surface weather. To the military meteorologist the possibilities offered by that technique had great potential value. "Here in Western Europe," General Peterson continued, "we would usually have the opportunity of examining a storm and comparing its TIROS portrait with known surface weather." "Later, after the storm had moved into Eastern Europe or the Baltic," he concluded, "we could, by examining later

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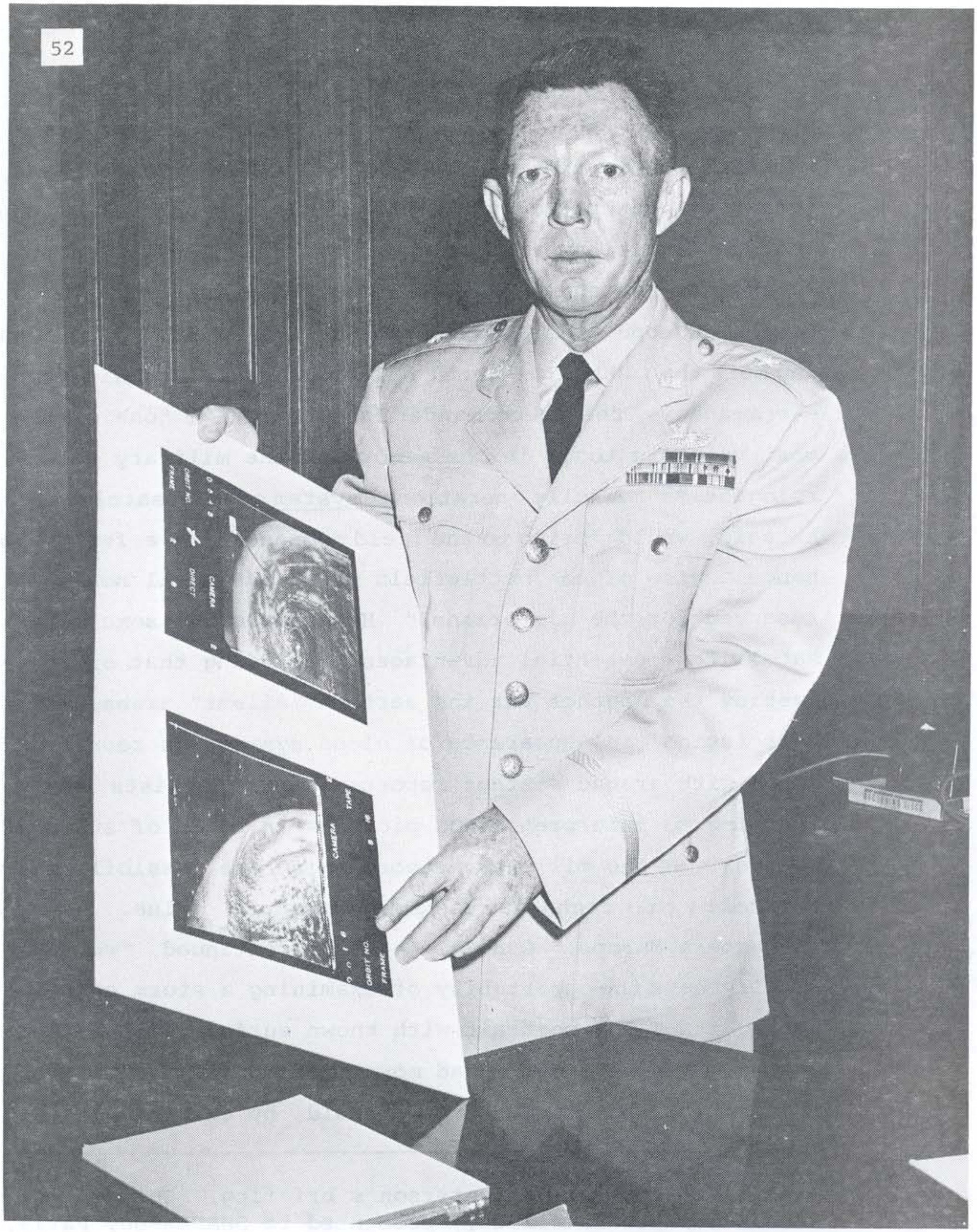
[86] See text of Gen Peterson's briefing, "The Weather Reconnaissance Satellite," presented to SHAPEX-60, Paris, France, 21Jun60. See also Capt Theodore R. Strum, "Eyewitness. . . . To Weather," <u>The Airman</u>, Nov60, pp. 42-46.



General Peterson and the TIROS photographs.
(USAF/AWS Photo)

TIROS pictures, determine weather conditions even though we were to be denied reports from that area."[87]

The SHAPEX-60 attendees reportedly received General Peterson's briefing enthusiastically. Many were eager to examine at close range the TIROS I pictures of their home countries, and nearly 200 such photographs were distributed for use in later staff briefings.[88]

The most important result of the TIROS I observations, of course, was to show that cloud patterns as observed from space displayed a much higher degree of organization than had ever been suspected.[89] Centers of lows, fronts, waves, squall lines, cumulus cells, etc., were all readily identifiable from TIROS I pictures. That property of organization permitted a detailed analysis of the state of the atmosphere based strictly on satellite observations.

Air Weather Service's survey or post-analysis of TIROS I surfaced the problem of what form the observations should be presented in to the ultimate users--the field forecasters. Most of the TIROS I pictures were disseminated as schematic diagrams which delineated areas of more or less homogeneous cloud cover and added sketchlines to show the essential features of cloud patterns. That method of presentation, it was believed, did not do "full justice" to the immense amount of information available from good

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[87] Ibid.

[88] Capt Lufkin, "NATO Commanders Briefed on TIROS by General Peterson," Observer, Vol. 7, No. 7, Jul60, p. 1.

[89] Senate: Meteorological Satellites, p. 71

satellite pictures. AWS officials felt that although communications would probably always limit the amount of information which could be disseminated by the ground station to less than a thousandth of the informational content of the original pictures, well thought-out methods of interpretation and presentation could make that fraction "most effective."[90]

Rapid dissemination of the data was critical because TIROS I pictures were as perishable as all other forms of weather data. Consequently, much of the data actually transmitted to field stations was unusable because of late receipt. Nearly six hours of the average ten-hour delay was attributed to "waiting time," _i.e._, to the time the data had to wait for an open transmission period on the communications circuits.

As for the personnel needed to man the readout stations, AWS believed that it was unnecessary to have highly-trained research specialists. In fact, there appeared to be some advantage in having men who were primarily "practicing weather forecasters." It was believed that such a meteorologist would be more keenly attuned to the needs of the operational weather service than the research-oriented meteorologist.

In summation, AWS believed that its experience with the first purely meteorological satellite was worth while. Observations from space appeared to point toward changing procedures for the future. In regions for which the usual synoptic observing network was sufficiently dense--as in

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[90] Lufkin, "The Background of Present Meteorological Satellite."

the United States, with its surface, upper air, and radar networks--satellite observations would be useful mainly for displaying the mesostructure of the atmosphere in a way no other mode of observation could match. In that large portion of the globe for which only sparse observations were available, if at all, the value of satellite observations increased; here, they offered an information-gathering system of essentially unlimited range which was, in the long run, competitive in cost with conventional aircraft reconnaissance.[91]

Air Weather Service made a computer run in late July 1960 using TIROS I data to determine its value for silent-area forecasting. In the first run, the clouds were used to estimate the streamline directions which were, in turn, used to alter the analysis in the silent area. Work continued on the use of such data in hopes of eventually making an input into the basic analysis of the Joint Numerical Weather Prediction Unit at Suitland, Maryland.[92]

By mid-1960 it appeared as if scientists of the Weather Bureau and cooperating meteorological agencies would be analyzing TIROS data for many months in the future. "Thousands upon thousands of man-hours of research lie ahead of us," said David S. Johnson, chief of the bureau's satellite section.[93] Dr. Francis W. Reichelderfer, the

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[91] Ibid.

[92] AWSSS Staff Conference Notes, 27Jun60.

[93] Jonathan Spivak, "Tips From Tiros II: Next Weather Satellite May Help Pave Way for Automatic Meteorology; It Will Aid Forecasts for Fliers; Later Satellites May Flash Storm Warnings; A Computer Predicts Wind," The Wall Street Journal, 11Oct60, p. 1. Spivak's article hereafter cited as "Tips From Tiros II."

bureau's chief, went to Congress for a $36,000 emergency appropriation to permit indexing and classification of the photographs. In a preliminary analysis of the data, the bureau's Drs. Fritz and Harry Wexler reported that it revealed a large degree of organization in cloud systems, and that spiral-banded clouds existed around well-developed, extra-tropical storms. "But one of the significant results from Tiros," they cautiously noted, "is the clear indication that although storms have similarities, there may also be very marked differences."[94] Satellite "cloud pictures give us a tip-off days ahead when new storms are getting started," said Charles M. Woffinden of the bureau's extended forecast section, "and they can tell us how quickly a storm will clear."[95]

Some overly-exuberant press reports claimed that meteorological satellites would "revolutionize weather forecasting." While such claims were unrealistic, satellites did promise to become revolutionary observing systems. Some immediate improvement could be expected in weather analyses over the vast areas where few current observations were available, but basic improvements in forecasting would evolve only from a careful study of cloud pictures, radiation data, and other measurements from meteorological satellites. An increased understanding of atmospheric processes from these studies was expected to contribute to the solution of some forecast problems.

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[94] Fritz and Wexler, "Cloud Pictures from Satellite Tiros I," Monthly Weather Review, 88-3, Mar60, pp. 79-87.

[95] Spivak, "Tips From Tiros II," The Wall Street Journal, 11Oct60, p. 1. In October 1972, Mr. Woffinden was assigned to AWS as the National Weather Service's liaison officer.

A TIROS I photograph taken on 19 May 1960, as the wide-angle camera scanned the southern plains, revealed a bright, "square" cloud centered about fifty miles west-northwest of Wichita Falls, Texas, close to the Texas-Oklahoma border. Weather Bureau satellite specialists discovered the striking and unusual photograph during the course of their TIROS analysis. From cloud analysis and locations obtained through the use of a cloud schematic, the "square" cloud mass was determined to be precisely in the area of heavy thunderstorm activity reported at the Texas towns of Hobart, Childress, and Wichita Falls late on the afternoon of 19 May. The analysis also produced strong evidence that this cloud mass later expanded and spread northeastward, spawning tornadoes and hail in central Oklahoma.[96]

Satellite meteorologists considered the discovery a stroke of luck. Mr. Johnson, chief of the Weather Bureau's satellite section, declared that not every isolated cloud mass seen from a satellite would warn of impending severe weather. However, he pointed out that detection of unusual cloud masses, when considered with their geographical location, the climatology of the region, and the existing weather situation, might well enhance the meteorologist's ability to recognize and pinpoint small-scale severe weather situations.[97]

On 19-20 May also, several of TIROS I's orbits crossed

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[96] "Weather From Above," Time, 1Aug60, p. 56.

[97] See "Birth of Tornado Filmed by Tiros I; Lucky Photo of a Square Cloud Mass Gave Clue on Oklahoma Storm," The New York Times, 24Jul60. See also "Tiros I Concludes Mission; Tiros II Readied," Weatherwise, Vol. 13, No. 4, Aug60.

The photograph of a "square" cloud over Texas, taken by TIROS I on 19 May 1960, which was published in many of the nation's leading newspapers and magazines, including The New York Times and Time. (NASA Photo) the North Pacific, the United States, and Central America. Its pictures showed with unusual clarity a series of frontal storms that extended from north of Japan eastward across the Pacific to the western United States. Meteorologists for many years had known the general nature of storms, but had lacked a measure of their individuality--a cloud "print" of a storm to identify it uniquely. The 19-20 May pictures made excitingly clear the details of cloud patterns as well as the general structure of storms.[98]

In general, the Weather Bureau's evaluation of TIROS I could be summed up in the words of its chief, Dr. Reichelderfer, who was quoted as saying that the "spectacular operation of Tiros I had opened a new era in weather surveillance."[99] His declaration reflected the general attitude among meteorologists of almost every weather agency. "In the meteorological satellite the meteorologist has been provided with an observational tool that far exceeds his wildest dream of a decade ago," read a subsequent Senate subcommittee staff report.[100]

Satellites vs Reconnaissance Aircraft

Confusion about the capabilities of meteorological satellites and the aims of the satellite program prompted differences of opinion between partisans of aircraft reconnaissance and those of meteorological satellites. On the

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[98]"Tiros Pictures a Pacific Frontal Storm," Weatherwise, Vol. 13, No. 5, Oct60.

[99]"Tiros I Concludes Mission; Tiros II Readied," ibid., Vol. 13, No. 4, Aug60.

[100]Senate: Meteorological Satellites, p. 87.

one hand, satellite enthusiasts were prone to believe that satellite observatories were capable of supplying all of the remote observations required to define completely the state of the atmosphere. Those with reconnaissance experience scoffed at the theory.

Actually, the AWS position was that neither side was right or wrong. The two systems complemented one another almost ideally, the strong points of each making up for the other's shortcomings.

Satellite observations covered a very broad area but were, so to speak, indifferent to the data's worth. On the other hand, reconnaissance aircraft observed a relatively small area, but crew personnel were capable of varying their mode of observing to suit particular meteorological or operational circumstances.

On 1 June 1960, General Peterson, prompted by arguments on the subject making it necessary to clear the air, forwarded AWS' position regarding it to all the field units, AFCRC, and USAF. It would be helpful, he related, if people thought of the total process of acquiring weather data from remote regions as two separate operations: surveillance and reconnaissance. The former carried a connotation of close watch under relatively fixed conditions, of sentry duty or vigilance. On the other hand, reconnaissance implied a more active seeking-out of information; a sortie out of home territory to discover the opponent's disposition. Considered together, the two words encompassed the whole of the classical military information-gathering process. The AWS commander proposed that Air Force people carefully discriminate between the two words when describing the collection of meteorological data. "We should make it clear in speech and writing that there is a fundamental difference between these two processes," he concluded, "and that satellites do not in the least compete [editor's italics] with reconnaissance aircraft, but rather free them from routine sentry duty for more important and more productive tasks."[101] "In a normal refueling mission you must send out planes to observe conditions," said Major Jones succinctly, as quoted by The Wall Street Journal, but "with Tiros pictures you can often save a weather sortie."[102]

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[101]Ltr, Peterson to AWS Wgs and Gps, HQ USAF (AFOWX), and HQ AFCRC, "Meteorological Surveillance and Reconnaissance," 1Jun60.

In truth, Peterson's letter was not altogether altruistic regarding meteorological satellites because, in one sense, they represented ill-timed "competition" to his dwindling aircraft reconnaissance resources. By mid-1959 AWS was well aware that, unofficially, USAF had a low regard for the AWS weather reconnaissance function--it was an expendable luxury that could be drastically reduced and eventually eliminated. To solve budget problems compounded by its money-hungry missile program, USAF planned to cut fat from the support forces. Accordingly, in late 1959, it directed AWS, by March 1960, to reduce its reconnaissance resources by approximately forty percent. And on USAF's books the entire function was to be scrapped by July 1963. Further complications arose for Peterson and AWS in April 1960 when MATS grounded all of the remaining WB-50s because of fuel cell leaks. By the time of his letter only a handful of Peterson's WB-50s had completed the costly fuel cell repair. Therefore, the general's letter was as much or more a plea for the retention and modernization of his reconnaissance fleet as it was for a unified Air Force position vis-a-vis meteorological satellites. See Vol. I, "Narrative," pp. 37-48, of "History of Air Weather Service," 1Jul-31Dec59, and Vol. I, "Narrative," pp. 46-50, 121-25, 171-80, 511-31, and 577-96, of "History of Air Weather Service," 1Jan-30Jun60.

[102]Spivak, "Tips From Tiros II," 11Oct60, p. 1.

NASA Planning For New Satellites

A series of NASA-Weather Bureau meetings was held in Washington, D. C., late in May 1960 to review TIROS I's value and to make plans for its successors--the remainder of the TIROS and Nimbus families. AWS' views and requirements were ably presented thereat by Major Jones.[103] In its role of supporting SAC, the 3d Weather Wing supplied AWS its evaluation of TIROS I, suggesting several areas for improved presentation, improved dissemination of analyses to within three-to-six hours of orbit time, and a means for annotating storm systems to provide future continuity. The wing believed that the TIROS data was of questionable value to individual base weather stations.[104]

The TIROS Family

NASA officials visualized many satellite applications including weather observing, radio communication, geodesy measurements, and navigation. TIROS I was, of course, merely the first in a series of meteorological satellites they planned. It was a part of a meteorological program designed to explore the type and use of parameters that could be acquired by means of satellite techniques. An extremely important part of that research effort, in NASA's opinion, was to determine what could be learned from TIROS' cloud cover pictures and, where possible, to relate evidence from them to heat-balance measurements obtained from the Explorer VII satellite, and observations made with

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[103] AWSSS Staff Briefing Item, 25May60.

[104] AWSOP--DCS Ops., AWS--Staff Briefing Item, 27May60.

sounding balloons and rocketsondes. Only after the proper groundwork was laid by such research and development and correlation did NASA plan to proceed with the design and development of a "truly-operational meteorological satellite system."[105] The launch of TIROS II, originally programmed for August 1960, was slipped to mid-autumn.[106] It was to be followed by TIROS III, originally scheduled for launch in the late fall of 1960, but subsequently slipped to July 1961.

Late in July 1960, NASA held a conference in Washington, D. C., to provide industrial representatives with an overall picture of the NASA program. Among the subjects discussed were experimental satellite applications in meteorology and communications. NASA emphasized that, while TIROS I was a milestone in meteorology, its value was limited because of its spin stabilization problem and because it could only photograph the earth's sunlit areas. Thus, the infrared equipment--used to measure radiation and the earth's heat balance--deleted from TIROS I because of slippages, would be aboard both TIROS II and III.[107]

The Nimbus Family And Beyond

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[105]NASA Release No. 60-202, 24May60--speech by Dr. Homer E. Newell, Deputy Director, NASA Office of Space Flight Program, 24May60, at the International Symposium of Rockets and Astronautics, Tokyo, Japan.

[106]"NASA Reorients Delta Launch Schedule," Aviation Week, 4Jul60; "Lufkin Interview."

[107]NASA script, "Satellite Applications," portion of NASA-Industry Program Plans Conf., 28-29Jul60, Wash., D.C.

The Nimbus series of meteorological satellites--four launches planned during the period 1961 to 1963--were under development by 1960. NASA reported that a Nimbus package would weigh from 600-to-700 pounds and would be orbited by a Thor-Agena launch vehicle. Its stabilization system was designed to keep the cameras pointed earthward continually--differing in that regard from the TIROS family. Sensors aboard the improved vehicle would include not only television cameras, but wide area, and scan-type, radiation-sensing equipment as well as other experimental sensors. Considered for later in the series were a simplified radar for observing precipitation, a spectrometer for measuring temperature, and an image orthicon camera for observing night cloud cover. Paddles that could be continuously oriented sunward would carry solar cells to provide power for the Nimbus sub-systems.[108]

The Nimbus project, including the writing of specifications, was under the management of NASA's Goddard Space Flight Center. Early in 1961 the General Electric Company was named the system integration contractor with RCA as the sub-contractor for the television equipment. Mid-1960 NASA plans called for the initial Nimbus launch in late 1961. However, by early 1961 it became apparent that the first launch would not occur until sometime in mid-1962.

Programs beyond Nimbus were "very tentative" according to NASA. Experience gained from it and the remainder of the TIROS family would have a large influence on future planning. The Centaur launch vehicle would provide the

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[108] Ibid.

METEOROLOGICAL SATELLITE PROGRAM

	1959	1960	1961	1962	1963	1964	1965
TIROS							
R & D	—	—					
Launchings		2	1				
Data Analysis		—	—	—			
NIMBUS							
R & D		—	—	—	—		
Launchings			1	1	2		
Data Analysis			—	—	—	—	
AEROS							
R & D				—	—	—	
Launchings						2	2
Data Analysis						—	—

capability for placing meteorological satellites into a 23,300-mile orbit and such a satellite in an equatorial orbit would appear to stand stationary over a point on the earth because its orbital period would coincide with the earth's rotational period. NASA estimated that three such "stationary" satellites would view most of the earth's surface and thus permit continuous observation on an operational basis. The moniker "Aeros" was selected for the twenty-four hour satellite in mid-1960, although the project still had not been officially approved for implementation. NASA believed that work might be initiated on Aeros during 1962 with a possible launching in 1964.[109]

The entire NASA program for meteorological satellites was predicated upon rapid advancement in the state-of-the-art with regard to launch-vehicle development, instrumentation, analytical techniques, and communication. The level of effort being supported directly by NASA, exclusive of vehicle funding, was expected to be about $15 million for fiscal year 1961.

NASA was anxious to receive ideas from industry regarding feasible methods and devices for observing and measuring atmospheric parameters such as cloud cover and storm location, precipitation, temperature, wind direction, heat-balance, and water vapor. Measuring those elements from a satellite was both a unique and challenging task. As of mid-1960, most of the instrumentation and techniques for measuring such parameters either did not exist or were in very early stages of development. Automated data-

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[109] Ibid.

processing systems aboard the satellites and at the ground readout stations was another area in which NASA needed industry help. That problem was a principal consideration in the development of an operational system. When sufficient experience was gained with in-being experiments, and meteorologists had analyzed the problems, then specific requirements for specialized equipment and methods would be forthcoming.[110]

Proposal For A USAF Meteorological Satellite

From the very earliest indications of TIROS I's successes, Air Weather Service's leaders openly coveted an "operational meteorological satellite system" of their own, under Air Force control, completely independent of NASA or the Weather Bureau. In late April 1960, while many were preoccupied with TIROS I's unique pictures, General Peterson laid the groundwork for formally proposing such an idea by alerting the MATS commander to the "unusual significance and importance" of the satellite, and to the "immediate operational use [editor's italics]" AWS was making of its photographs. "Even at this early date it is obvious that this is the most significant development affecting meteorology since the introduction of weather analysis and forecasting by . . . computers," he wrote, and "I believe that its eventual significance will far surpass our most optimistic hopes."[111]

Heartened by the initial reactions to his trial balloon, General Peterson chartered his staff to draft a

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[110] Ibid. [111] Ltr, Peterson to Tunner, 26Apr60.

formal proposal for an operational meteorological satellite system while he, Captain Lufkin, and Majors Glover and Jones attempted to enlist the support of other major air commands by hitting the road with a briefing on the lessons from TIROS I.[112] On the day the general briefed the NATO commanders in Europe, as noted above, Major Jones briefed the NORAD--North American Air Defense Command--staff.[113] Following the reception given his presentation in Europe, Peterson briefed TAC officials in mid-July, advising them that "TIROS I has . . . provided us with a sound basis for the development of a comprehensive plan for a meteorological satellite program to support future Air Force operations." "My headquarters is presently working on this plan," he said, and "I hope that Tactical Air Command will support the need for this program."[114]

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[112]Not all within the Air Force were enraptured by AWS' avant-gardism, including an AWS' alumnus in a key position. GRD's Meteorological Satellite Branch and the 433L--Weather Observing and Forecasting System--system project officer, Col George A. Guy, were also interested in an operational weather satellite since all the observations from such a vehicle would eventually be an input into 433L--the long-range, AWS modernization program then being expanded through Federal Aviation Administration and Weather Bureau participation into a national meteorological system. Col Guy expressed his opinion to the Air Research and Development Command that an operational system could be developed, but he favored a joint effort rather than a system solely for USAF use. See AWSSS Staff Meeting Notes, 3-and-31Aug60.

[113]See Appendix No. 1, "History of 4th Weather Wing, Detachment 1," pp. 3-4, to "History of 4th Weather Wing," 1Jan-30Jun60.

[114]See text of Gen Peterson's briefing, "The Weather Reconnaissance Satellite," p. 11, presented at Langley AFB, VA, on 13Jul60. See also the following articles from

Two weeks later a similar pitch by Peterson to General Thomas S. Power evoked the SAC commander-in-chief's full personal support.[115] General Power believed that when TIROS was declared an operational system, it should be USAF's project instead of NASA's.[116]

Backed by such testimonials, Peterson, on 26 August 1960, submitted through MATS a formal AWS proposal for an organic Air Force weather satellite which had been drafted by Majors Glover and Stanley E. Pearse.[117] AWS suggested an earth-stabilized satellite with a polar orbit to give global coverage. AWS estimated that costs for construction and operation of a meteorological satellite would be around $26 million for the first year, and about $19 million for subsequent annual operations.[118] MATS strongly endorsed AWS' proposal on to USAF, commenting that "development and employment of a meteorological satellite system would contribute immeasurably to the advancement of the application of meteorology to existing and future weapons systems."[119]

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[114](Cont'd) The Times-Herald of Newport News, VA: "Air Weather Chief Slates Visit Here," 12Jul60, p. 12; "Weather Chief Speaks," 13Jul60, p. 15; and Virginia Biggins, "Langley Briefing: Tiros Satellite Uses Explained," 14Jul60, p. 11.

[115]AWSSS Staff Meeting Notes, 3Aug60.

[116]Following Peterson's visit to SAC, the 3d Weather Wing drafted a letter to USAF for Power's signature recommending the feasibility of a military-controlled meteorological satellite to support Air Force operations. Unexplainably, it was never posted. See "History, 3d Weather Wing," 1Jul-31Dec60," p. 46.

[117]Ltr and atch., Peterson to HQ MATS and HQ USAF, "An Air Force Meteorological Satellite System," 26Aug60.

[118]Appendix C, Glover and Pearse, "A Proposal for an Operational Meteorological Satellite System."

[119]1st Ind., MATS to USAF, 12Sep60, to ltr, Peterson

In the meantime, a 19-September NASA letter to the Defense Department on the subject of operational meteorological satellites created "a flurry of activity in the Pentagon," and resulted in an October meeting to establish a Defense Department position. The position was presented to NASA on 10 October at a meeting attended by NASA's Drs. Glennan, Hugh L. Dryden and Robert C. Seamans, Jr., the Secretary of Commerce, and others. The meeting was to consider the various agencies' responsibilities in regard to operational meteorological satellites and the best way of financing them.[120] Because of decisions made at the 10-October meeting, which General Peterson attended as the Air Force representative and at which AWS' proposal was used as a guide in preparing USAF's position, the recommendation for an Air Force satellite system was turned down. Although USAF officials agreed that there was an urgent requirement for the data obtained by such a meteorological satellite, they did not believe it essential that the system be USAF controlled. Further, it appeared to be in the national interest to have a single meteorological satellite system rather than separate systems for each weather agency.[121]

Toward a Common Operational Met Satellite

Following the 10 October meeting, and in line with

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[119](Cont'd) to HQ MATS and HQ USAF, 26Aug60.

[120]AWSSS Staff Meeting Notes, 6Oct60. See also Appendix D, Reichelderfer, NACCAM Chairman, "Resume of Action Toward NACCAM Coordination of Operational Meteorological Satellite Developments," n.d. (circa Nov60).

[121]2d Ind, USAF to MATS, 16Nov60, to ltr, Peterson to HQ MATS and HQ USAF, 26Aug60.

NASA's view that it was the responsibility of the user agencies to determine the nature of the system, the Weather Bureau proceeded to develop a national plan for a "Common System of Meteorological Observation Satellites"--COSMOS.

It was agreed at the 10 October meeting that the Joint Meteorological Satellite Advisory Committee--JMSAC[122] --established by NASA in 1959, would continue as the interdepartmental coordinating group on research and development of meteorological satellites. In November, NASA suggested that an "Interagency Meteorological Satellite Planning Committee"--IMSPC--be established to coordinate the planning for an operational meteorological satellite system. The committee's objectives, NASA said, would be to review the requirements submitted by the various weather agencies and incorporate them into a technical, operational, and management plan responsive to both civil and military requirements.

On 25 November Lieutenant General Donald N. Yates,[123] Deputy Director of Defense Research and Engineering, met with Dr. Reichelderfer to discuss possible revisions to the NASA suggestion. During that meeting it was agreed that development coordination of the meteorological satellite would be continued by JMSAC.[124] However, the general

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[122] In June 1960 AWS asked for permission to designate an official to serve on JMSAC and subsequently named Maj Jones as the principal observer with Capt Lufkin as the alternate. The appointment expanded official recognition of AWS' role in planning and operation of meteorological satellite systems.

[123] A former Air Weather Service commander.

[124] Ltr, Yates to Dr. Glennan, 6Dec60.

feeling was that any further plans or activities in which interagency coordination would be necessary would relate basically to operations and uses of satellite output. Those matters were largely identical to questions already being treated by the Joint Meteorological Group--JMG--of the Joint Chiefs of Staff, for responsibilities that were primarily military, and the National Coordinating Committee for Aviation Meteorology--NACCAM--for matters of common concern for civil, military, and general public interests.

Regarding NASA's proposed IMSPC, General Yates advised Dr. Glennan, the NASA Administrator, that:

> For preparation of the operational plan . . . I feel we have the best solution through our agreement that such should be accomplished by the National Coordinating Committee for Aviation Meteorology (formerly ACCMET) which in the past has effectively coordinated matters of general meteorological support to both civil and military interests. It is my understanding that the Chairman of the NACCAM has invited NASA membership on this committee and in addition has recommended the establishment of a NASA-chaired sub-committee to treat with the operational plan itself, particularly with respect to those items . . . which fall primarily into NASA's area of responsibility.
>
> The Department of Defense recognizes the tremendous potential value of a meteorological satellite system and hopes that NASA will be able to develop a single operational system to meet the total national requirement. We trust that a workable plan for final operation can be evolved within the agreed framework and that you will encourage maximum exploitation of the useful results of your extremely successful development program during the transition period.[125]

Meanwhile, work began to update a 1959 statement of requirements for a meteorological satellite system, adopted

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[125] *Ibid.*

by the Joint Meteorological Group in December 1959.

In view of the coordinating framework in existence within NACCAM and the JMG, NASA concurred with suggestions that coordination for an operational meteorological satellite could be handled effectively without establishing the proposed IMSPC. However, NASA believed it desirable to establish a working committee on satellite meteorology within NACCAM to proceed as rapidly as possible with the development of an operational plan.[126]

On 2 December 1960, Dr. Reichelderfer, in his capacity as chairman of NACCAM, advised General Peterson that while coordination of the requirements for an operational meteorological satellite, until then, had been accomplished at the departmental level, NACCAM was committed to the establishment of a working committee composed of representatives from the many user agencies directly involved.[127]

The first meeting of the committee, subsequently known as the Panel on Operational Meteorological Satellites, National Coordinating Committee on Aviation Meteorology (POMS/NACCAM), was held on 8 December 1960, and was chaired by a NASA representative. Membership included representatives from NASA, the Departments of Defense and Commerce, and the other interested agencies represented on NACCAM.

Colonel Clarence E. "Ed" Roache, the Deputy Chief of Staff for Operations, represented AWS and helped develop USAF's guidance on COSMOS. The guidance was to be used by all Air Force agencies in connection with future develop-

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[126] Appendix D.

[127] Ltr, Dr. Reichelderfer to Peterson, 2Dec60.

ment and use of such an operational system. USAF supported the common system so long as military requirements were not subordinated to routine civilian requirements. It was USAF's policy that the Nimbus and Aeros research and development programs should be exploited fully as a source of operational data prior to implementation of any comparable operational system.[128]

AWS requirements for observing data from an operational satellite were based on the equipment capabilities that could reasonably be expected to materialize within the time period that AWS hoped to have an operational system effective--1962-1963. Basically, AWS requirements were for a vehicle designed to observe detailed daytime cloud, snow, and ice coverage of sufficient resolution to identify cloud types, and nighttime cloud cover through high-resolution infrared.[129]

Although AWS believed that its requirements should be included, it recognized that any attempt to saturate the initial operational satellite with additional observing capabilities would probably result only in unnecessary delays in implementing the proposed system. Therefore, AWS asked that the earliest possible launch date be met; that all data readout be accomplished without loss or delay; that data from one orbit be processed and made available at a military weather central within one and one-half hours after the completion of a given pass; that global coverage be accomplished on a daily basis; and that direct readout be available. Whereas the initial operational

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[128]Appendix E, "USAF Guidance on Common Meteorological Observation Satellite System," n.d. (circa Dec60).

[129]Memo for record, Maj Pearse (AWSOP/OR--Forecstg and Concepts Br, Op Rqmts Div, DCS Ops, AWS), "Data

satellite would be limited in its capability to meet those criteria, AWS expected that, as equipment improved, additional requirements would be added to the operational system.[130]

Although USAF had turned down AWS' proposal for an Air Force meteorological satellite, COSMOS continued to receive AWS support. However, control and funding problems in respect to meteorological satellites had to be resolved. In October, for example, AWS learned from General Yates that the Navy was spending money on meteorological satellites not specifically budgeted for that purpose. The general became aware of it when requests for $1.7 and $14.3 million appeared in the Navy's fiscal 1961 and 1962 budgets. The Navy built a 78-pound satellite which they proposed to launch with a Scout vehicle. It had no storage capability but, upon command, it scanned in the near infrared and transmitted one picture. It then shut off until another command was received. Yates was of the opinion that it would not meet the national needs. Additionally, a Weather Bureau radiation expert had viewed cloud photographs from an infrared package parasited on the Navy's "Transit" communications satellite. But the practical value of the infrared pictures was nil, seemingly, because their location could only be determined by matching them with conventional nephanalysis.

AWS also learned that Dr. Suomi had a new, twenty-

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[129](Cont'd) Requirements for an Operational Meteorological Satellite," 14Dec60.

[130]*Ibid*.

pound, infrared package he was anxious to orbit. He planned to submit it for NASA's consideration. The package had a six-hour storage capacity. With a readout station on the west coast and one in England, the package aboard a satellite in a near polar orbit could provide global coverage of the synoptic-scale infrared pattern.

Aware of such proposals, AWS believed that considerable money and effort would be wasted by different agencies proceeding in different directions. It was therefore imperative, AWS opined, that an early decision be made on a common system.[131]

Any common system for meteorological satellites had to consider not only AWS' requirements, but also those of the Naval Weather Service, the Weather Bureau, the Federal Aviation Administration, and others. The general consensus of most agencies--reached at an early-December, American Rocket Society meeting on future expectations in space flight--was that satellites would not offer any war capability in the near future, that the two satellite programs which offered the greatest promise for being operational in the near future were weather and communications, and that satellite launching costs would have to be reduced significantly.[132]

Whether AWS' proposal, the Navy's, or a composite of all proposals would be adopted remained unsettled at the close of 1960. The Panel on Operational Meteorological

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[131] AWSSS Staff Meeting notes, 19Oct60.

[132] Memo for Record, Capt Leonard L. DeVries (Tech Rqmts Br, Tech Rqmts and Svcs Div, Dir of Scientific Svcs, AWS), "Future Expectations in Space Flight," 13Dec60.

Satellites was a forum where the pertinent agencies could air and coordinate their individual requirements so that JMSAC and NASA could proceed with development action. Through it all, AWS deliberately made its requirements for an operational system as simple as possible, recognizing that too many requirements would result in excessive delays.

Further Developments and Experiments

While planning progressed toward an operational meteorological satellite common to all users, there was no slackening in the work connected with the developmental weather satellites. Each of the NASA-sponsored satellites yet to be launched--the remainder of the TIROS family and the Nimbus series--received careful attention. Preparations for TIROS II's launch in the fall of 1960 continued at a steady pace. At the same time, work continued on the data gathered by TIROS I and Explorer VII.

During the period between TIROS I and II, the Explorer VII heat-budget package developed by Dr. Suomi continued to send back valuable meteorological information. In August, Captain Blankenship again visited the University of Wisconsin to observe the progress made on interpreting Explorer VII infrared data. Lieutenant Colonel Melvin Weinstein of the AWS, located at the University for doctorate-level training, had completed a preliminary study of the relationship between the radiation data observed by the Suomi package and the general surface synoptic pattern. His findings were encouraging, indicating that infrared observations could be of value in oceanic and other silent area analyses. More important, perhaps, were the techniques of data-handling and analysis which the university's satellite laboratory had developed. What once appeared to be a hopeless job proceeded rather smoothly, although not yet in real-time. The AWS detachment at Lajes continued its support to the Explorer VII project by operating the tape recorder and telemetry receiver noted above.[133] By early October, the long-wave, terrestrial-radiation sensors on Explorer VII had become damaged and were registering noon temperatures ten degrees too high. Plans were thus made to terminate the program effective October 15.[134]

Captain Blankenship revisited Dr. Suomi in October to determine why the outstanding work of the laboratory was not filtering through to the Weather Bureau's Meteorological Satellite Laboratory--formerly named the Meteorological Satellite Section. AWS continued urging that infrared packages be included on later TIROS satellites.[135]

TIROS II

Attention continued to be focused toward the launching of TIROS II, however. Although cloud pictures from TIROS I were given wide distribution for limited operational use, AWS hoped that TIROS II cloud pictures would be distributed quicker for use in operational forecasting.[136]

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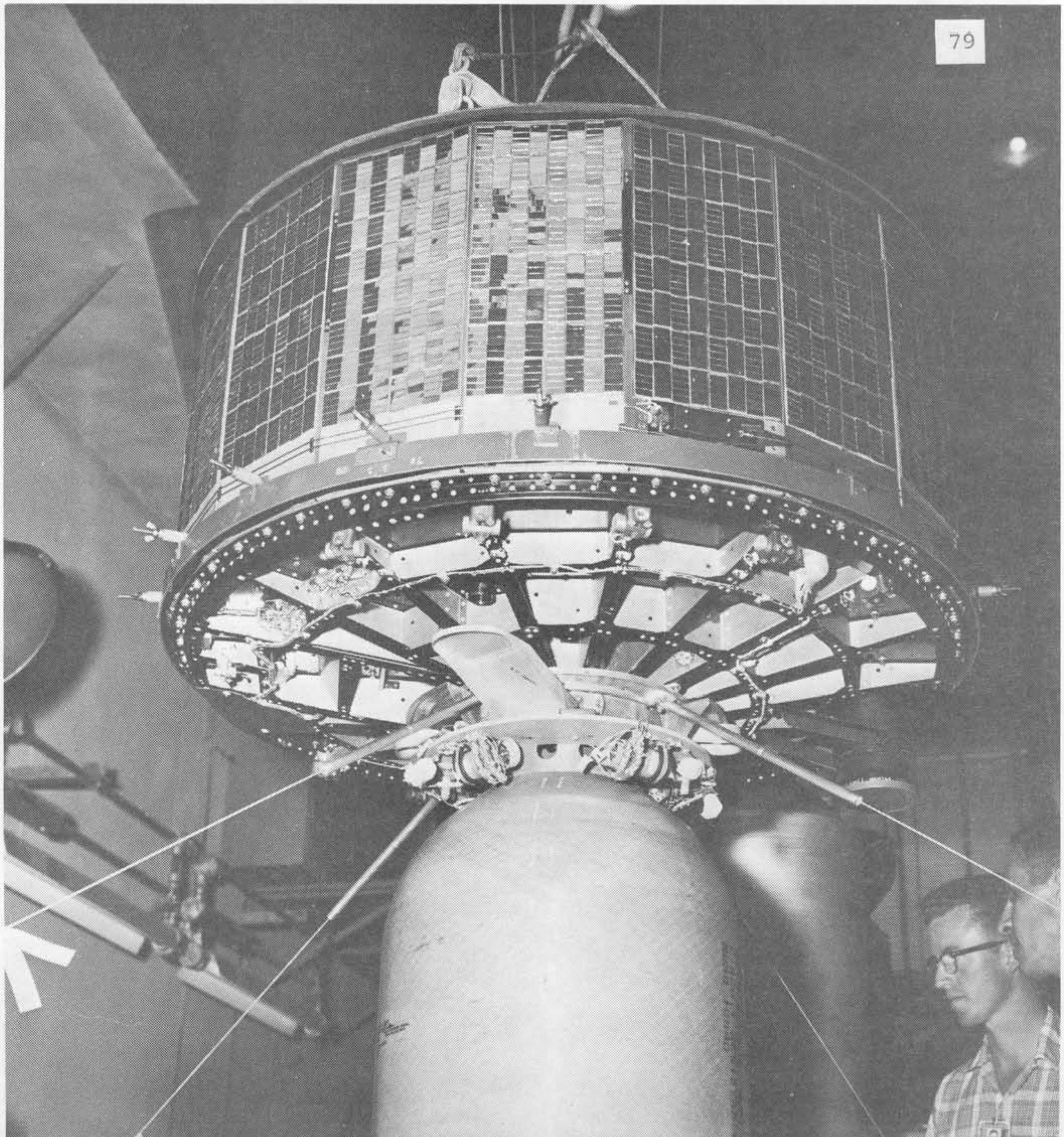
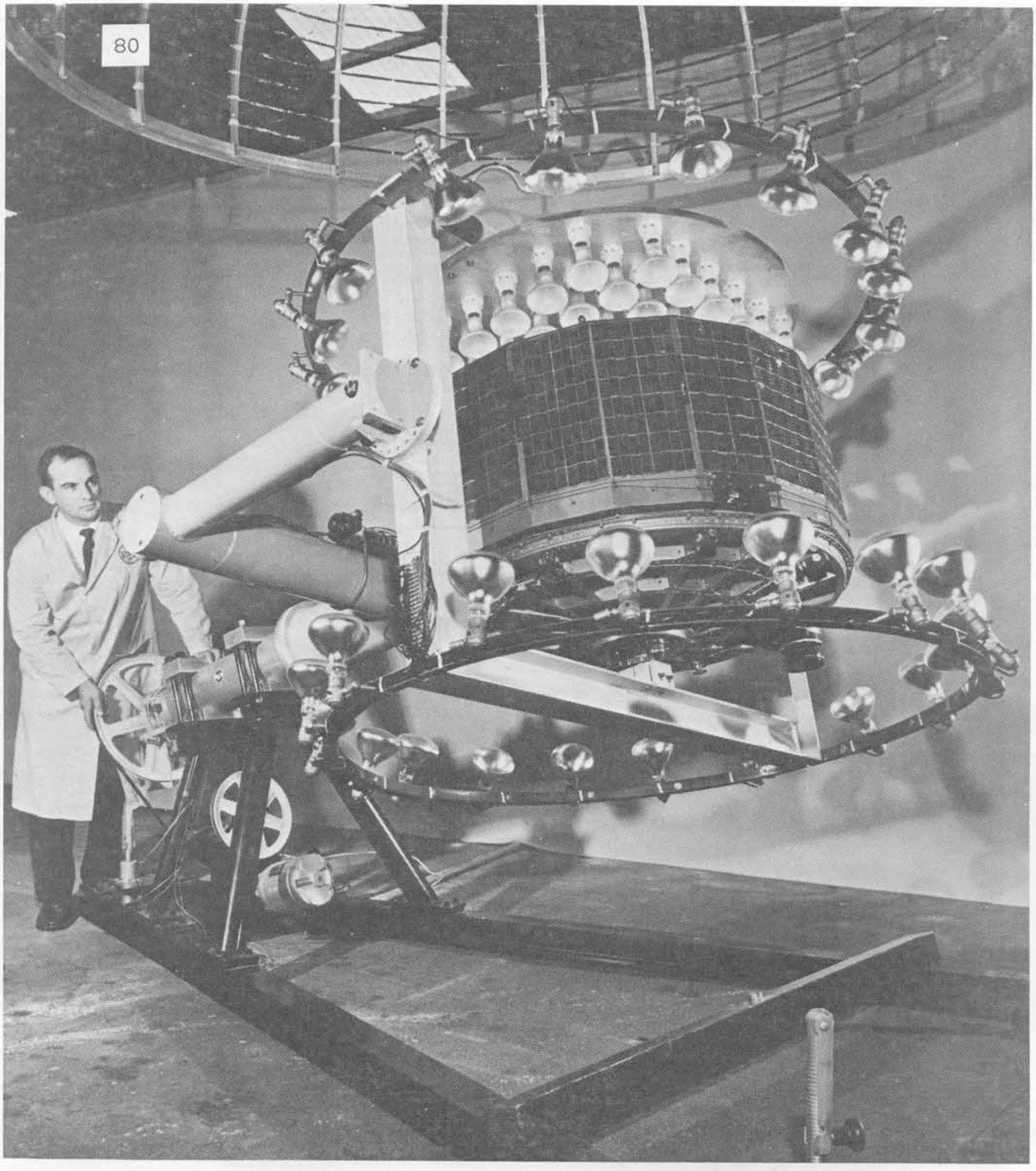
133 AWSSS Staff Meeting Notes, 24Aug60.

134 Ibid., 6Oct60. 135 Ibid., 12Oct60.

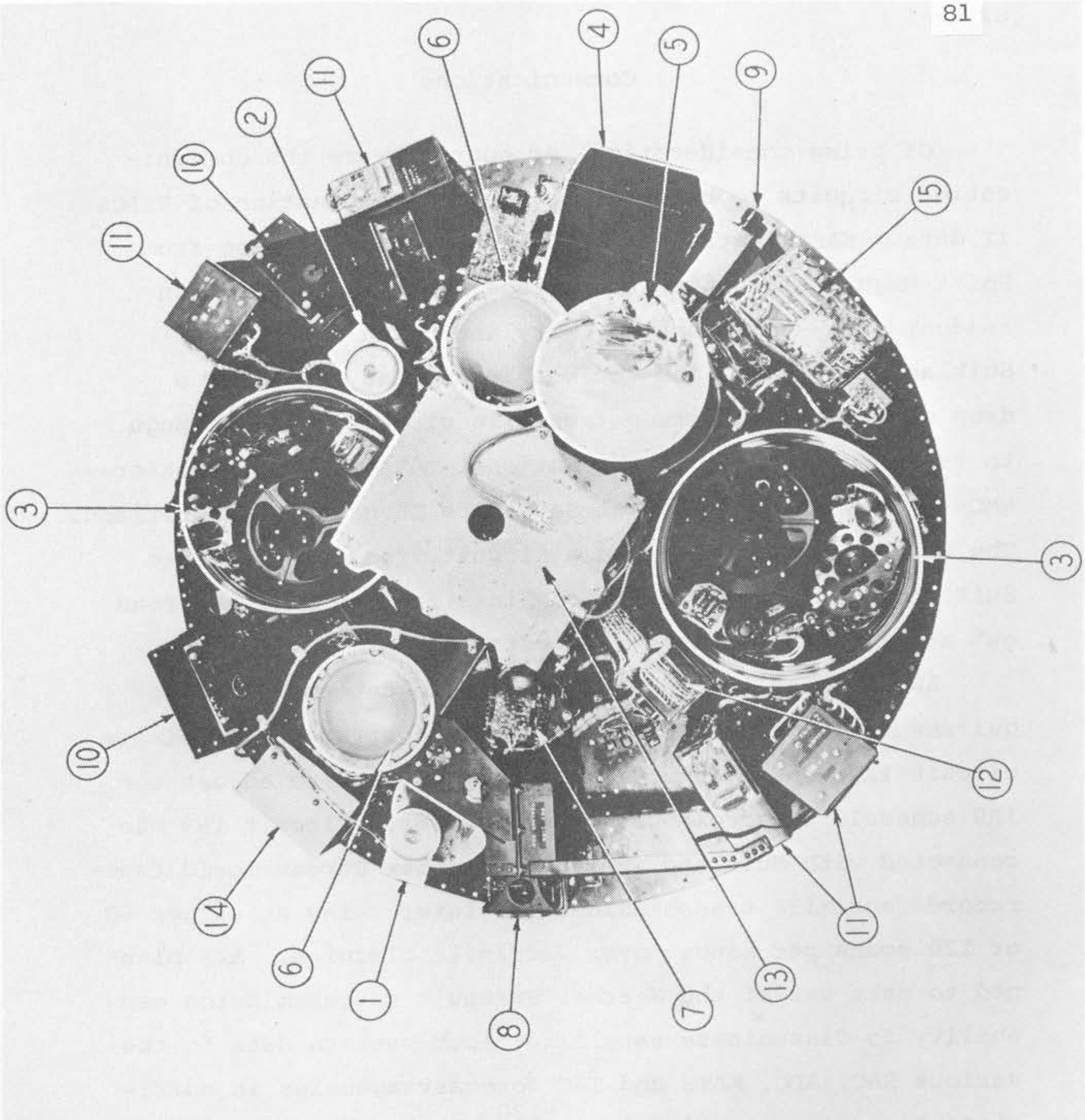
136 Historical report, AWSOP (DCS Ops--Communications), 1Jul-30Sep60.



Sin check of the 270-pound TIROS II.
(NASA Photo)



TIROS II mounted in a special test machine which checked the functioning of its stabilization system in conditions similar to those encountered in space. Lights on the test assembly permitted testing of the solar cells on top and sides of the satellite. (NASA Photo)



A view of TIROS II showing the following systems and devices: (1) wide angle TV cameras; (2) narrow angle TV camera; (3) TV tape recorders; (4) infrared system five channel radiometer; (5) infrared system electronics; (6) electronic clocks for sequencing operations; (7) relays for magnetic stabilization system controlling the satellite attitude; (8) control box for electronic systems; (9) infrared horizon scanner; (10) electronic circuits for cameras; (11) electronic circuits for TV tape recorders; (12) telemetry switches; (13) antenna diplexer (covering storage batteries); (14) automatic signal generator; (15) and fuse board and current regulator. (NASA Photo)

Communications

Of prime consideration, of course, were the communication circuits to be used for rapid dissemination of TIROS II data. NASA installed a 120-scan, facsimile line from Point Mugu, California--to replace Kaena as the western readout site--to Greenbelt, Maryland, with a drop at Suitland, Maryland, and the Weather Bureau installed a drop on its high altitude facsimile circuit at Point Mugu to relay information to the National Meteorological Center--NMC--and the Meteorological Satellite Laboratory at Suitland. The Weather Bureau also had a circuit from Camp Evans to Suitland. Thus, communication links from both of the readout stations to Suitland were established.[137]

AWS queried the 3d Weather Wing to determine its requirements for TIROS II products on the strategic facsimile circuit 1R9 and to determine if they planned to adjust the 1R9 schedule to accommodate the pictures. Circuit 1R9 was connected with Suitland where the Weather Bureau could tape-record facsimile transmissions for later relay at either 60 or 120 scans per minute over facsimile circuits. AWS planned to make use of the Weather Bureau's retransmission capability to disseminate satellite cloud-pattern data to the various SAC, ADC, MATS and TAC forecast agencies in sufficient time for operational use.[138] Consequently, AWS requirements for TIROS II data would largely be met by monitoring transmissions on the NASA and Weather Bureau

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[137] Staff Briefing Item, AWSOP (OR), "Preparation for TIROS II," 14Sep60.

[138] Historical report, AWSOP (Communications), 1Jul-30Sep60.

circuits from the readout stations to Suitland, editing and consolidating the data, and retransmitting it on circuit 1R9 from Suitland.[139]

It appeared as if the technique would work because NMC's tape recorder had passed several operational tests prior to mid-October 1960.[140] However, to assure its success, AWS arranged for the installation of two RJ-3 facsimile recorders at the 4th Weather Group's Suitland detachment to record separately the transmissions from the California and New Jersey readout sites. The precaution was vindicated when, by early November, the Weather Bureau's tape recorder was not functioning to AWS' complete satisfaction. Since its interests extended beyond the Weather Bureau's, AWS had to be able to reproduce the charts for retransmission--manually if necessary.[141] Coded nephanalyses for teletype dissemination would be transmitted to stateside and overseas areas on an unscheduled basis.

Data Evaluation Plans

Within Air Weather Service special observations were planned in connection with the correlation of TIROS II data. In August 1960 USAF had asked AWS to evaluate the TIROS II and Nimbus operational data and the headquarters started work to develop a program which would include

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[139] Staff Briefing Item, AWSOP (Communications), "TIROS II Fax Support," 25Oct60.

[140] AWSSS Staff Meeting Notes, 12Oct60.

[141] Staff Briefing Item, AWSOP (OR), "Dissemination of TIROS II Data," 8Nov60.

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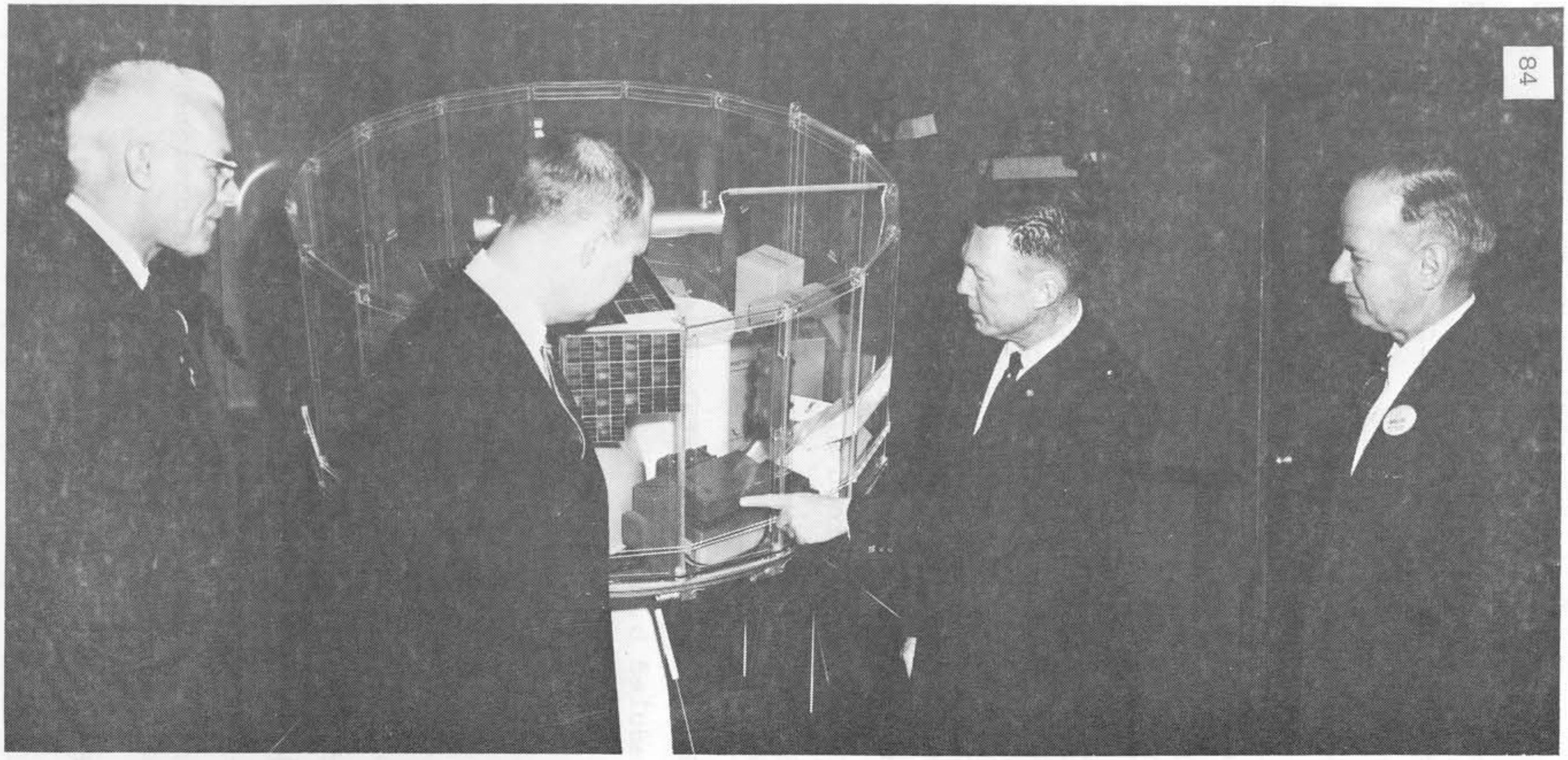
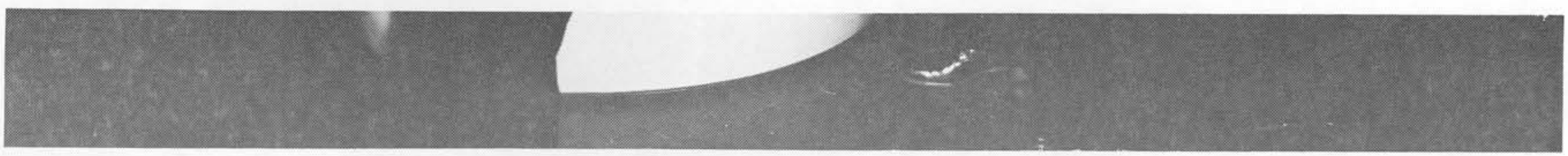


General Peterson--second from right--pointing to a feature on the TIROS II scale model after addressing an early-1961 meeting of the Armed Forces Communications and Electronics Association in Belleville, Illinois. Left to right are: Colonel (USA retired) C. W. Evans, a Southwestern Bell Telephone Company military communications engineer and AFCEA vice president; Colonel David W. Baugher, 157th Tactical Control Group, Missouri Air National Guard, and AFCEA president; and Major General Daniel C. Doubleday, commander, Airways and Air Communications Service. (USAF Photo)



specific examples of the data's operational use, its correlation with comparable data gathered by conventional means, and examples of applying the infrared data.[142]

One phase of the AWS evaluation program called for special cloud reports from observers. Accordingly, a special postcard reporting form was developed. From sketches made by AWS observers of cloud patterns as seen from the ground, AWS, the Weather Bureau, and GRD would be able to locate the observation point in the TIROS II pictures. AWS officials hoped that rules for interpreting features of cloud patterns as seen from satellites could be developed in terms of actual surface weather. Once pictures were calibrated in this way, AWS would be able to use satellite observations more advantageously in various programs, including silent-area forecasting.[143] Special instructions on using the postcard reporting form were sent to AWS field units prior to TIROS II's launch, and the November Observer ran a feature on it.[144]

All news releases concerning TIROS II were controlled tightly by NASA. Press kits were prepared and distributed by NASA to information officers at various agencies. Material concerning AWS involvement had to be cleared through normal USAF channels to the NASA information office prior to launch.[145] In late October NASA published and

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[142] AWSSS Staff Conference Notes, 31Aug60.

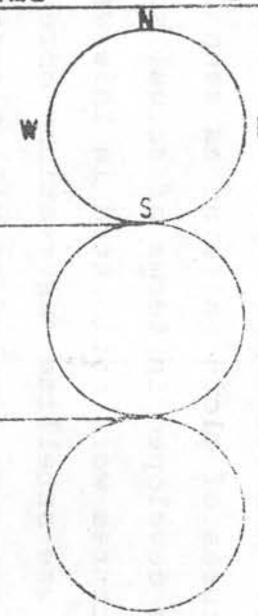
[143] AWSSS Staff Meeting Notes, 16Nov60.

[144] "AWS Prepares for Data Receipt From TIROS II," Vol. 7, No. 11, Nov60.

[145] AWSSS Staff Meeting Notes, 12Oct60.

POSTCARD REPORTING FORM

STATION	DATE	TIME Z
WIND: 7 KT	SKY	
VISIBILITY ____ MI	C_H ____ TOPS ________	
	N_H ____ BASES ________	
PRESENT Wx(ww) ____	CLOUD DENSITY (1–5) ________	
PAST Wx(W) ____	C_M ____ TOPS ________	
REMARKS:	N_M ____ BASES ________	
	CLOUD DENSITY (1–5) ________	
	C_L ____ TOPS ________	
	N_L ____ BASES ________	
	CLOUD DENSITY (1–5) ________	
OBSERVER	SHOW MOVEMENTS BY ARROWS	



Instructions

See instruction sheet. Try to make the observation within 15 minutes of the TIROS pass. Use one circle for each cloud layer. If you see more than three layers, use another card and staple it to this one. Consider each layer separately. If you can estimate what a higher layer looks like, even though it is hidden, sketch it in. N may total more than 10. Density 1 means transparent; 5 means as dense as CuNb or NbSt; 2, 3 and 4 are in-between degrees of cloud density.

distributed an information plan outlining the responsibilities for release of information about TIROS II.[146]

Major Jones prepared a news release regarding the "operational test" weathermen planned for the TIROS II data. Coordinated with NASA, it was edited to delete reference to the term "operational utility." Published in advance, it was not to be released until the conference following a successful launching. Despite editing, it contained the "meat" of the story, as evidenced below:

> A joint program to test and evaluate the utility of cloud pictures received from TIROS II has been implemented by the U. S. Weather Bureau and the military weather services of the United States.
>
> The program consists of three phases: data reduction and interpretation, dissemination to the forecaster, and an appraisal by the forecaster of the value of these data to the solution of analysis and forecasting problems. Experience gained during TIROS I has gone into the development of this program to use satellite pictures on an experimental basis.
>
> Data reduction teams composed of meteorologists from the Meteorological Satellite Laboratory and field stations of the U. S. Weather Bureau, the Air Weather Service, the Naval Weather Service, the Geophysics Research Directorate, and Allied Research Associates are presently at the data readout stations near Belmar, New Jersey, and Oxnard, California, where the pictures from TIROS II will be received. Prior to reporting for duty at these readout stations, the teams received intensive training for a period of one to two weeks at the Meteorological Satellite Laboratory. Making use of a completely equipped data reduction facility and film from TIROS I, the space age weathermen were schooled in procedures for data reduction, interpretation, and presentation to be used during TIROS II.

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[146] NASA Information Plan, "Tiros Meteorological Satellite (A-2)," 27Oct60.

These teams will prepare maps from the TIROS II pictures showing schematically the cloud distribution and organization relative to the earth. Interpretation in terms of cloud form and standard weather patterns such as storm centers and frontal systems will also be made part of the presentation where possible. A manual prepared by the Office of Forecast Development, U.S. Weather Bureau, comparing cloud pictures from TIROS I with clouds observed from the ground, has been distributed to the readout stations to serve as a guide in making these interpretations. Copies of this manual will also be distributed to operational forecast units to assist the forecasters in the use of the cloud maps.

After the accurate analysis of the cloud images, the most important phase of the program is dissemination of the information to the forecaster. When intended for operational use, weather information is a perishable item; its value drops off rapidly when time is lost in delivery. To move the data quickly from the readout stations, full period facsimile circuits connect the two stations with the Communications Center and the National Meteorological Center of the U.S. Weather Bureau in Washington. Via these circuits, cloud maps will be available for use in the National Meteorological Center and nearby weather facilities of the Navy and Air Weather Service within a few hours after the basic pictures are taken by TIROS II. These agencies, which will serve a long list of customers, will test the value of the TIROS data in preparation of analyses and forecasts over a large part of the northern hemisphere. To expedite further dissemination of the cloud maps, available time on existing weather facsimile circuits of the Air Force, Navy, and Weather Bureau has been rescheduled to minimize delays in delivering the data to forecast centers outside the Washington area. To reach units not served by these facsimile circuits, selected cloud analyses will be summarized for relay on landline and radio teletype circuits on a space available basis. Forecast centers outside the U.S. will receive the maps via radio facsimile and teletype. It must be emphasized that circuits on which time is available for relay of the TIROS data reach a representative sample of forecasters. Indeed, through the joint use of available communications, the operational test of TIROS II assumes global proportions. U. S. weathermen in Australia, supporting the resupply mission to the Antarctic expeditions, will receive word summaries of the cloud observations made by TIROS II over the vast ocean areas between Australia and Antarctica. Weathermen stationed at installations in many foreign countries as well as those within the United States will have an opportunity to participate in the evaluation of the satellite experiment.

Forecasters who use the TIROS II data in their daily routine will be on the lookout for answers to questions of operational importance which may be provided by the satellite. For example: Did the satellite find a storm center hitherto undetected with the conventional observing network? Was it possible, using satellite data, to provide a better picture of the weather significant to a commercial air carrier?

Examples of operational utility similar to those mentioned above were noted during the operational life of TIROS I. It is emphasized, however, that TIROS II is still experimental both from the standpoint of hardware and methods for using the data. The operational evaluation is being conducted in this spirit. Review and evaluation of the experimental operational use of the satellite data is another in a series of steps which may lead to a better understanding of the world's weather and to improving the design of future weather satellite systems.[147]

AWS personnel assigned to teams at the two TIROS II readout stations were selected prior to the launch. Each team was composed of three forecasters and an observer. Team chief at Point Mugu was the 4th Weather Group's Captain Leo S. Bielinski.[148] Captain Dwight R. Goodman,

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[147] NASA News Release No. 60-301, "Weathermen to Experiment and Test Satellite Pictures," 23Nov60.

[148] Other AWS personnel at San Nicholas Island, Point Mugu--a Navy installation that was part of the Pacific Missile Range--were: CWO John C. Garlock, MSgt Seymour M. Fonnesbeck, and SSgt Jack E. Sams. CWO Garlock was from the 3d Weather Wing while the enlisted men were from the 4th Weather Group.

of the 2d Weather Group, was the AWS team chief at Camp Evans.[149] Both officers visited Suitland in late September for indoctrination under the tutelage of Major Jones, and all team personnel were in place at the readout stations by 14 November, well in advance of the TIROS II launch.[150]

International Invitations

Invitations to foreign governments to participate in meteorological research connected with TIROS II were extended by the United States in September 1960. NASA and the Weather Bureau joined in the effort by tendering invitations to scientists of twenty-one different nations. It was suggested that if TIROS II was a success, weather agencies of other nations might obtain "useful synoptic results by intensifying standard meteorological observations, or by arranging for special observations, coordinated in time with passes of the satellite."[151]

The efforts were part of the United States program of encouraging international cooperation in space research and meteorology. Meteorologists abroad would thus have an opportunity to correlate cloud cover data as observed both below and from high above the clouds. In addition, the cooperation would provide NASA and the Weather Bureau

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[149] Other team members there were SMSgt Mervin L. Snyder, MSgt John J. Pappas, and A/1C Ramon C. Batts. Pappas was from the 2d Weather Group; Snyder the 3d Weather Wing; and Batts the 4th Weather Wing.

[150] Shortly before Christmas, AWS decided the workload did not support so many personnel and therefore, transferred SMSgt Snyder and SSgt Sams from the readout sites.

[151] NASA News Release No. 60-268, "U.S. Invites Over-

with a wide collection of meteorological research data.

NASA would provide orbital information to participants in the project to assist them in timing local weather observations. After processing, TIROS cloud cover photos would be sent them for comparison with their supplementary observations.

The invitations were sent to those countries having national space committees or membership on the international committee on space research. The nations to which invitations to participate were extended were: Argentina, Australia, Belgium, Canada, Czechoslovakia, Denmark, England, West Germany, France, India, Italy, Japan, Mexico, Netherlands, Poland, South Africa, Spain, Switzerland, and the Soviet Union. Norway and Sweden were also invited, although the satellite's orbit--with an inclination of about forty-eight degrees to the equator--was expected to make their participation marginal.[152] Countries expressing an interest in participating were Australia, Belgium, Denmark, England, West Germany, France, India, Japan, Mexico, Netherlands, South Africa, Switzerland, Norway, and Sweden.[153] No communist country responded.

Another Success

TIROS II was launched at 0613 Eastern Standard Time, 23 November 1960, by a Thor-Delta rocket from Cape

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151 (Cont'd) seas Participation in Next TIROS Experiment," 26Sep60.

152 Ibid.

153 "AWS People at Readout Stations Are Working To Provide Useful Data," Observer, Vol. 7, No. 12, Dec60, p. 1.

Canaveral. Two hours later, NASA announced that it achieved a successful orbit at 98 minutes, close to the planned height of 400 miles.[154] Initially it attained an apogee of 435 miles and a perigee of 415 miles, but on 25 November NASA revealed that the apogee was actually 453 miles and the perigee 387 miles.

TIROS II's launch was entirely satisfactory, although the attitude and poor illumination on the first pass was unfavorable for video pictures. Radio signals from the satellite picked up at the Belmar, New Jersey, receiving station were "strong and clear."[155] Subsequently, it was discovered that the spin rate deceleration was too great, slowing the instrument package below the stabilization point. Two days after launch, during the thirty-first orbit, two of five pairs of spin rockets attached to the satellite's base plate were fired to increase the stabilization spin rate and eliminate a wobble. They increased the spin rate to 10.8 rpm on the initial firing and to 13.9 rpm on the second firing.[156]

On the day of the launch, Major Jones indicated that remote scanning by the satellite was programmed for the sixth orbit from Point Mugu, and that information

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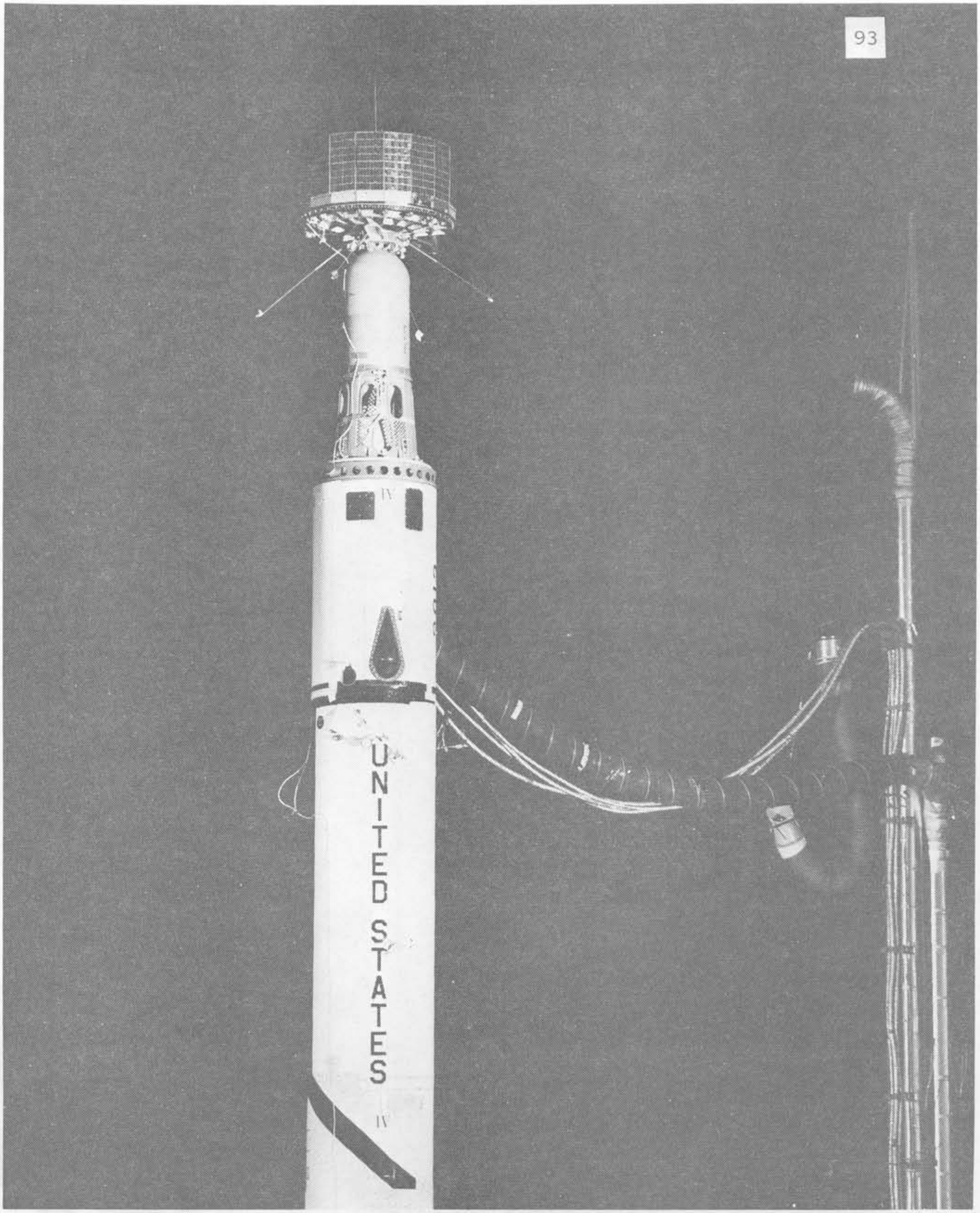
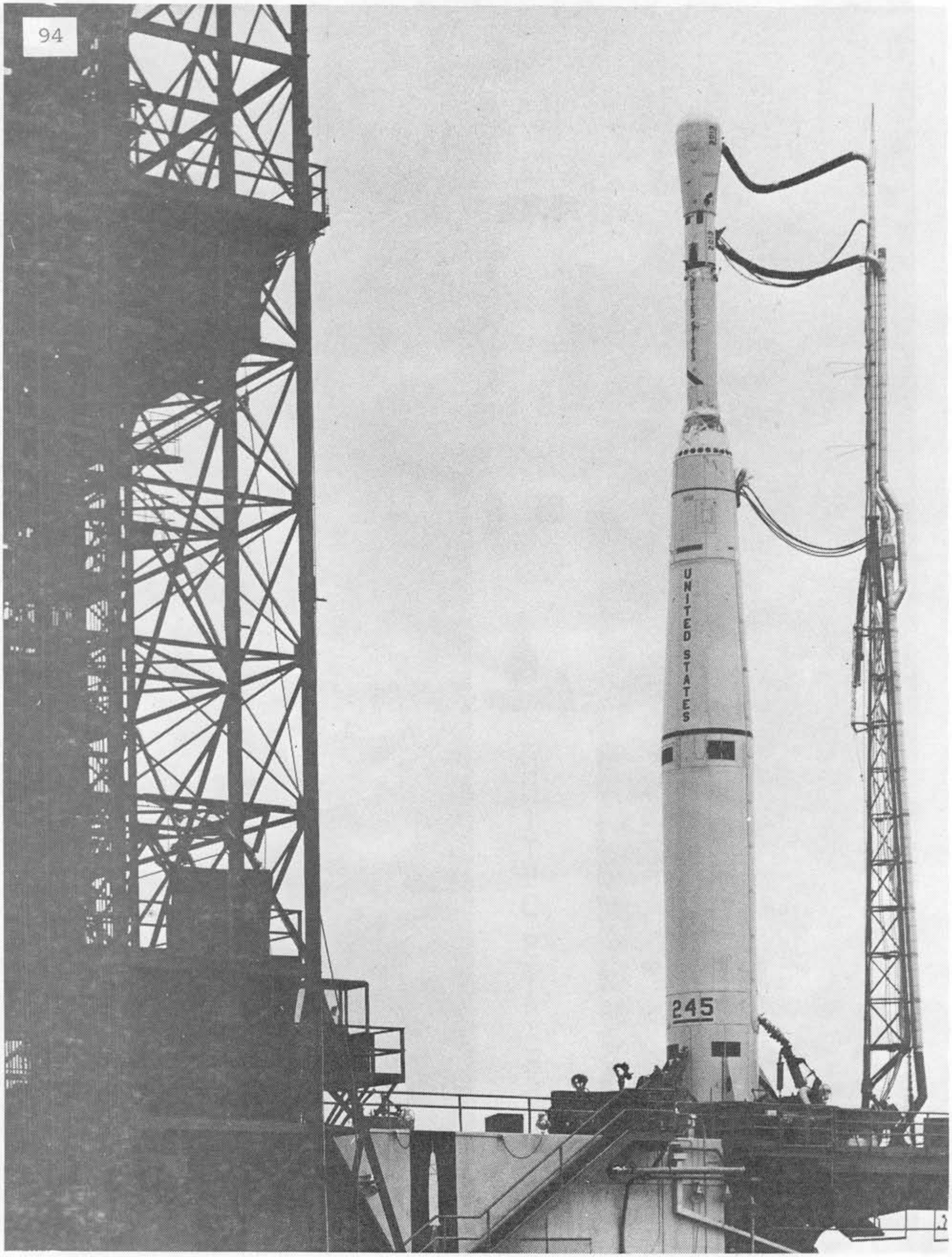
[154] "New Weather Satellite Fired into Orbit for Forecast Use; Meteorologists Plan to Start Reading Tiros II Cloud Photos Immediately--Nearly Circular Path Achieved," St. Louis Post-Dispatch, 23Nov60, p. 1A; "Tiros in Good Orbit But Cloud Shots Are Fuzzy," St. Louis Globe-Democrat 24Nov60, p. 4A; Finney, "Tiros Success Spurs Drive for World Forecast Chain," The New York Times, 25Nov60, p. 1A.

[155] AWSSS Staff Meeting Notes, 23Nov60.

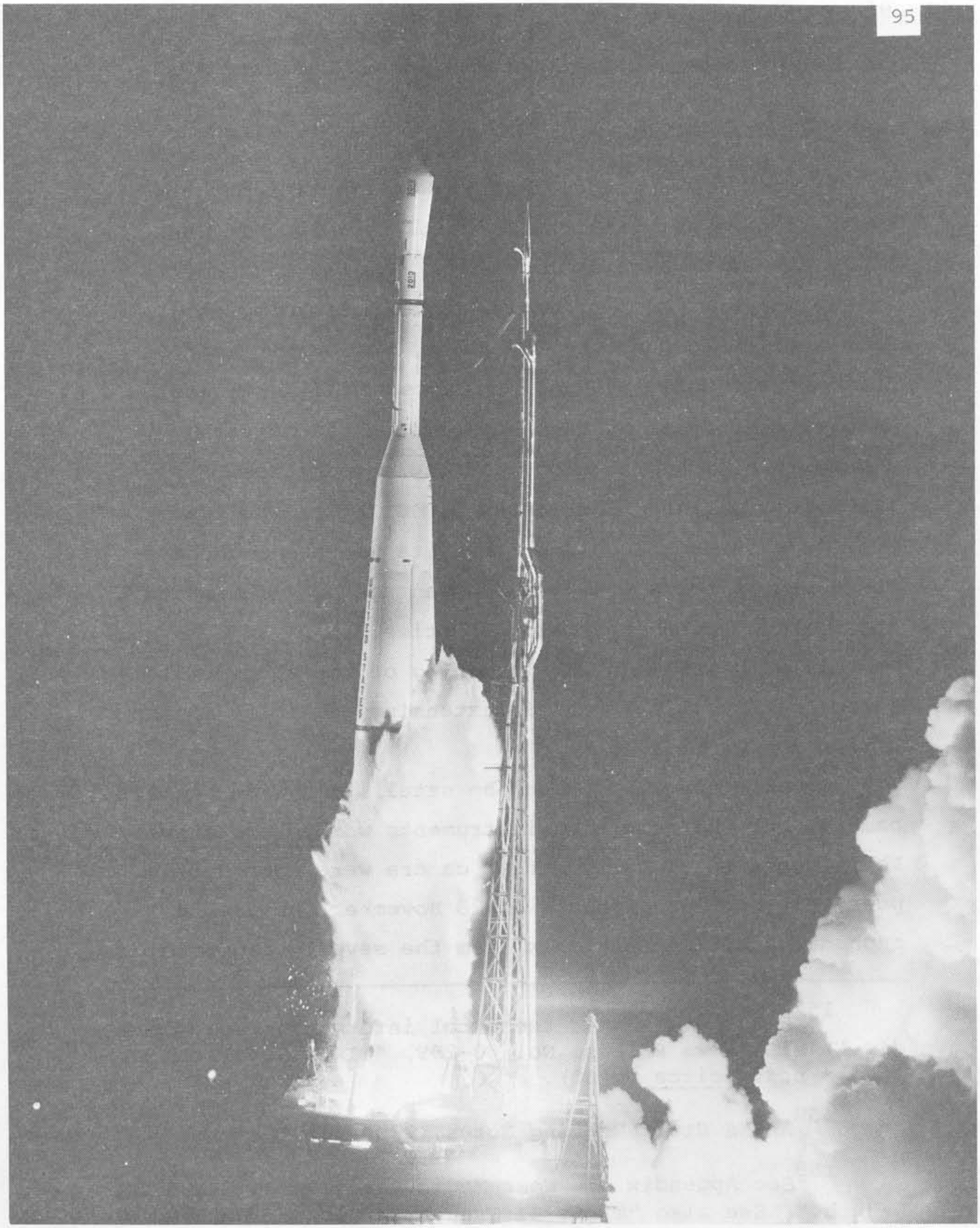
[156] "Tiros II Has Wide-Angle Camera Trouble," Aviation Week, 5Dec60, p. 28.



TIROS II atop the Thor-Delta rocket with cover removed. (NASA Photo)



TIROS II on the pad poised for launch. (NASA Photo)



The launch of TIROS II from Cape Canaveral on 23 November 1960. (NASA Photo) from the passes would be entered on national and AWS communications circuits as quickly as possible thereafter.[157]

From the AWS standpoint, it was imperative that TIROS II data get into the circuits rapidly. It was badly needed at several locations. At the detachment in Panama, for example, where normal meteorological data was inadequate, the TIROS data would help improve the forecast quality. TAC transoceanic flights could also make good use of TIROS-observed cloud patterns, and Ramey AFB, Puerto Rico, had expressed a need for TIROS information. AWS wanted TIROS II data to reach Guam as soon as it could so that its weather reconnaissance people there could take advantage of cloud-pattern information to schedule storm sorties.[158]

As with TIROS I, the launching of the second meteorological satellite received extensive publicity in the nation's news media.[159]

Trouble developed with the satellite's wide-angle camera, but the remaining instruments worked effectively. Photographs received from that camera were considered poor, although good enough by 28 November for use in nephanalysis. Nephanalysis from the seventy-fourth orbit,

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[157] For the TIROS II technical information see Appendix F: NASA News Release No. 60-299, "TIROS Satellite Payload," n.d. (circa Oct60).

[158] AWSSS Staff Meeting Notes, 23Nov60.

[159] See Appendix G, "News Media Reaction to TIROS II Launch." See also "Tiros II Transmits Cloud, Infrared Data," pp. 14-15, and "Global Forecasting System Planned With Network of Weather Satellites," p. 27, Aviation Week, 28Nov60.

covering the northeastern United States and western Atlantic Ocean, was transmitted to AWS field units that day, seven hours and fifteen minutes after observation time. That particular analysis was accepted for transmission by the Weather Bureau's Meteorological Satellite Laboratory without a thorough check and was the source of some embarrassment because later examination uncovered an error of two minutes--about 500 miles--in the location of the analysis. A correction was then transmitted.

The error resulted from the satellite's tape recorder not recycling completely. Consequently, on readout, four frames from the previous orbit and twenty-eight from the orbit in question were received. The error source was clearly identified the following morning and, for the next several days, the Meteorological Satellite Laboratory made a check of the analyses to ensure accuracy. The check required about five minutes.[160]

Nephanalysis of the European and Mediterranean area was transmitted on 29 November.

The reduction of a sampling of the Channel 4, broadband (7-30 microns), infrared data indicated that the data made sense. Cloud and clear areas were readily distinguished. It was the same wave band Dr. Suomi had used in his Explorer VII experiments.[161]

By 30 November it appeared that the tape recorder

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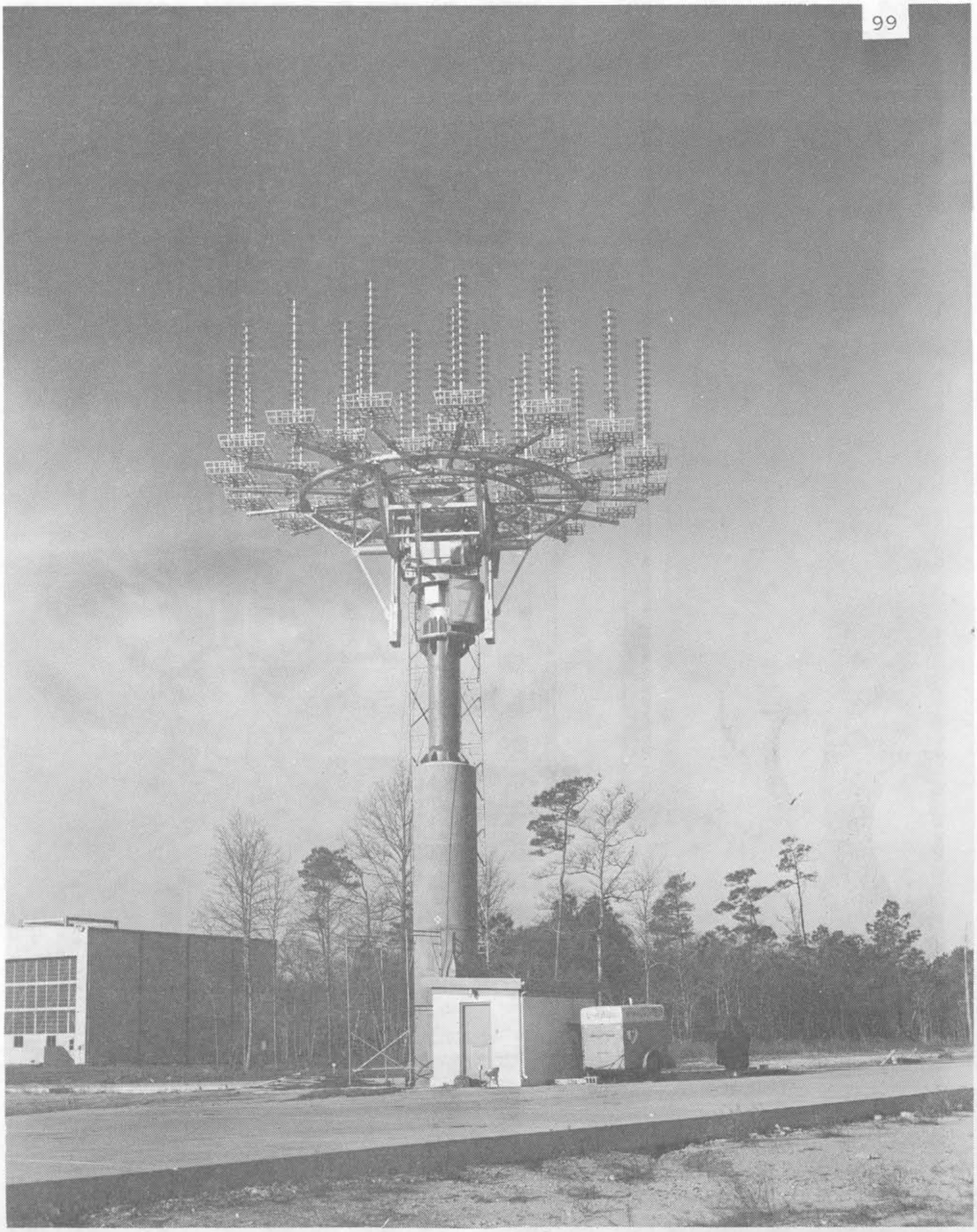
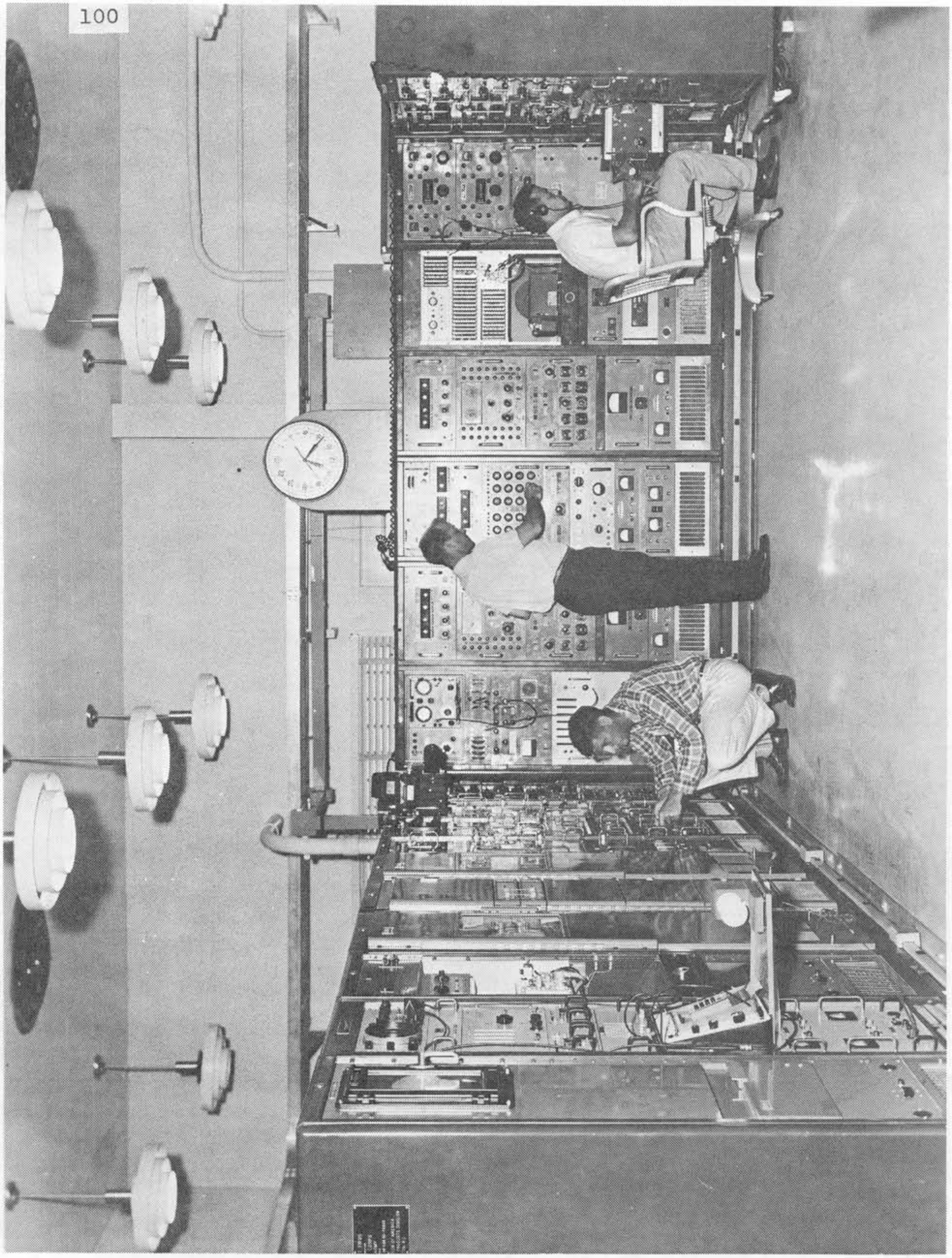
[160] AWSSS Staff Meeting Notes, 30Nov60.

[161] On 28 November Lt Col Weinstein, at the University of Wisconsin, advised AWS that he had considerable success in determining the upper-level winds from Explorer VII radiation charts. He sent the data to AWS for further study.

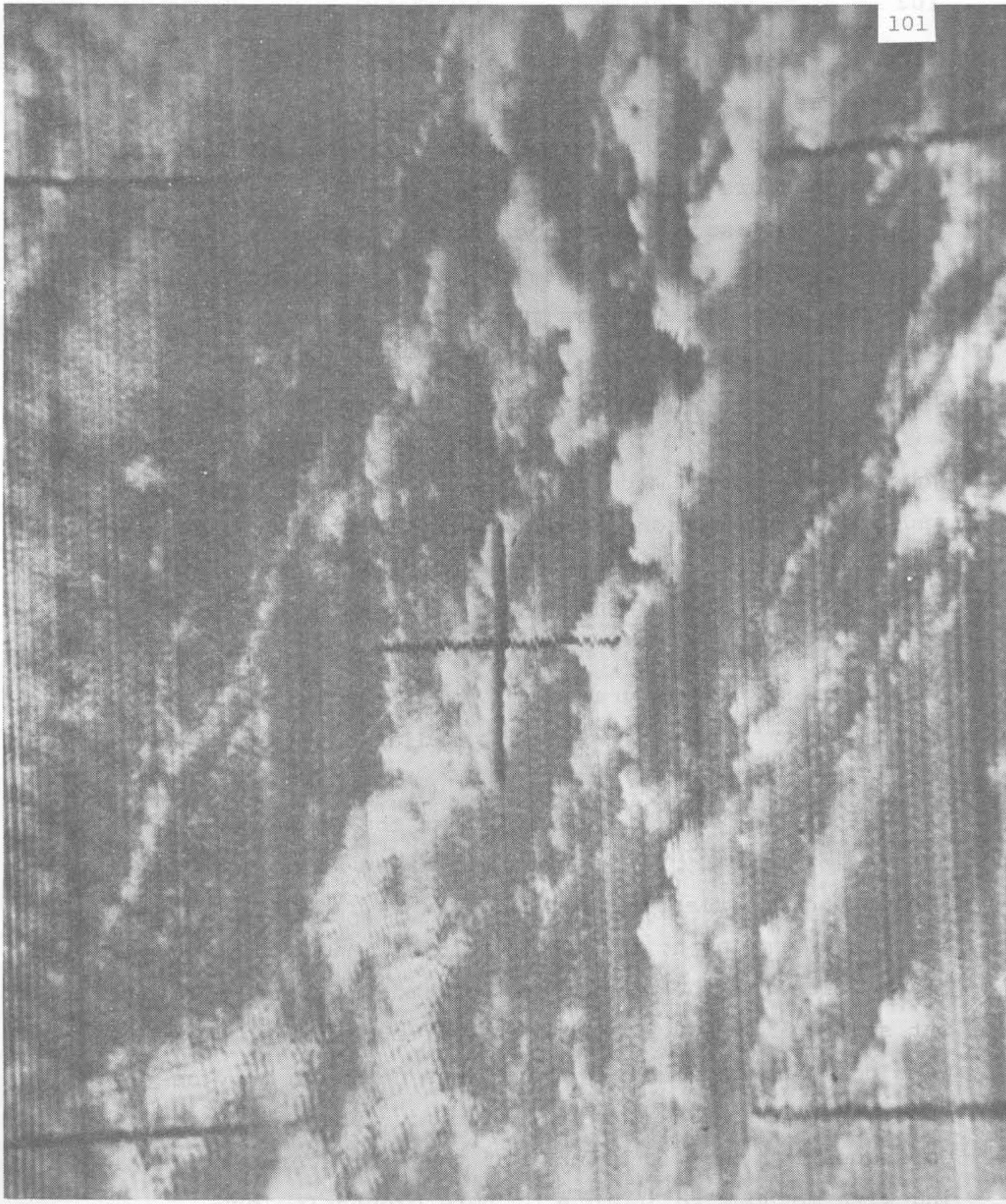
NASA's Wallops Island, Virginia, tracking station. The two antennas immediately left of the photo's center were used with TIROS satellites, while the tower in the photo's center was a boresight tower used to calibrate the antennas. (NASA Photo)



The high-gain, receiving antenna at NASA's Wallops Island facility used to receive data and track TIROS II. (NASA Photo)



General view of the receiving station interior at Wallops Island where thousands of TIROS pictures were received. (NASA Photo)



An example of the poorer quality, TIROS II pictures. Using the narrow-angle camera the picture was taken on 28 November 1960, as the satellite was northeast of Los Angeles pointing west. (NASA Photo) problem was working itself out. The satellite's power source was functioning properly. The AWS field units were expected to receive nephanalyses approximately every two hours during most of the day.[162]

TIROS II soon experienced further troubles. By 7 December, two weeks after launch, the picture quality from the wide-angle camera system had improved only slightly and was far below the standard established by TIROS I's camera systems. While many of the pictures were good enough for making nephanalyses, they were not good enough to be of much value in refining the attitude and orbit computations through direct observation of landmarks. And, the satellite's magnetic, attitude-control device had malfunctioned--the control switch kept slipping out of the neutral position, resulting in undesirable attitude precession. But the infrared system kept functioning and some radiation fields were plotted from the data.

Captain Bielinski reported that the Navy was very active in support of TIROS activities at Point Mugu. Senior ranking reservists were given a TIROS familiarization course as active duty training, and almost every flag officer in the naval district had visited the read-out station for a briefing. Air Force personnel there were doing an excellent job but were not kept busy because they processed only three or four passes a day. Consequently, they spent much of their time experimenting with methods to improve picture processing procedures.

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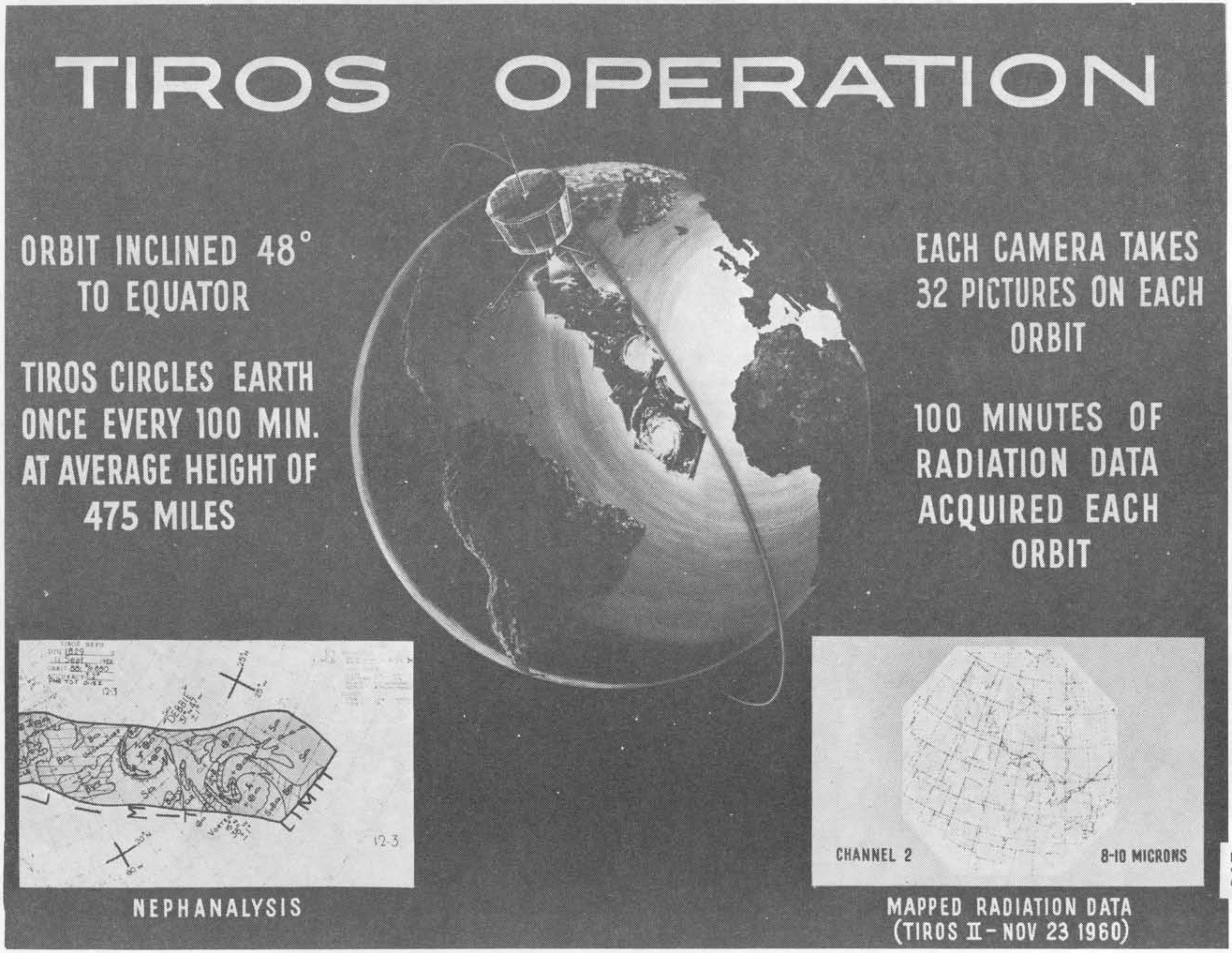
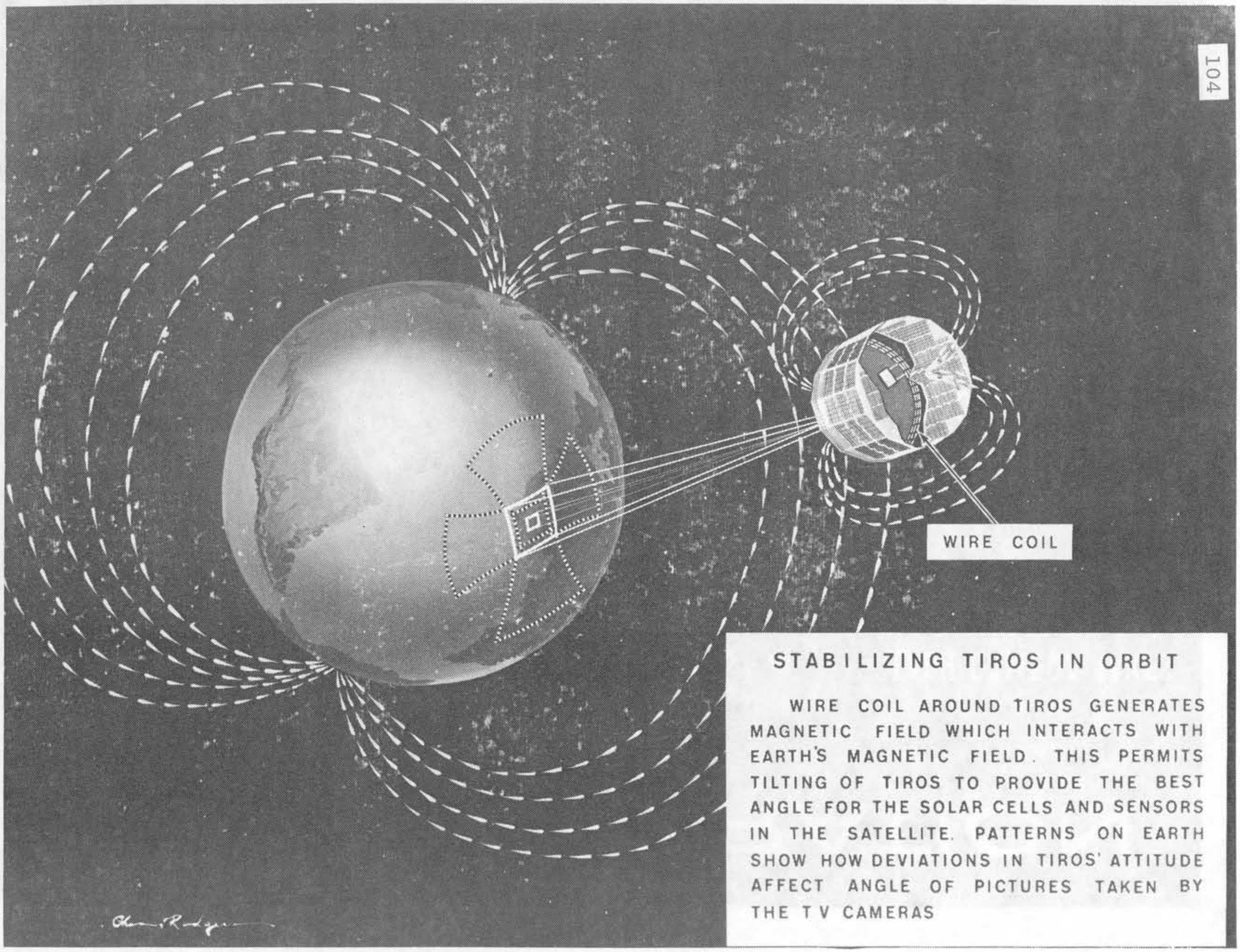
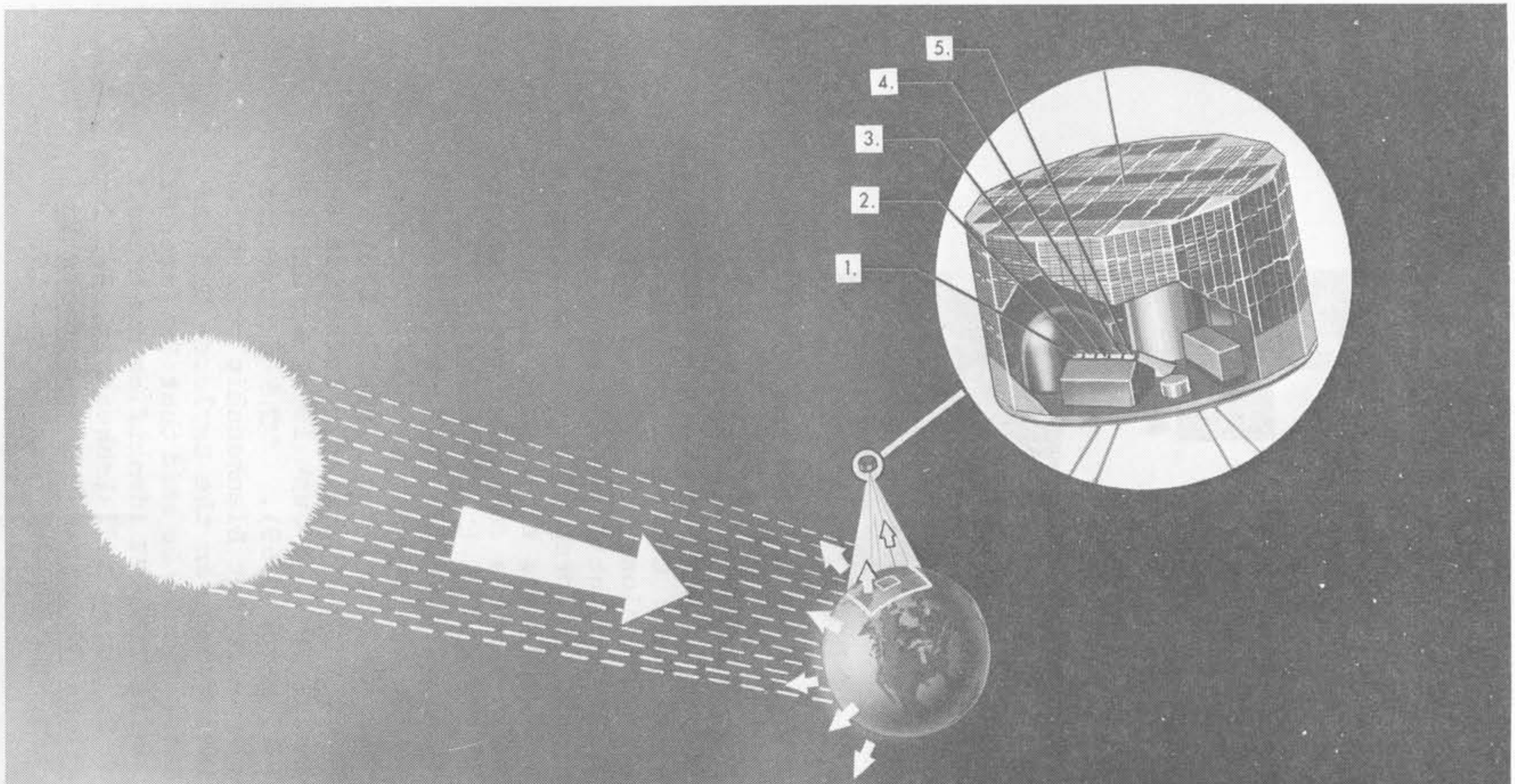
[162] AWSSS Staff Meeting Notes, 30Nov60.


TIROS OPERATION
ORBIT INCLINED 48° TO EQUATOR
TIROS CIRCLES EARTH ONCE EVERY 100 MIN. AT AVERAGE HEIGHT OF 475 MILES
EACH CAMERA TAKES 32 PICTURES ON EACH ORBIT
100 MINUTES OF RADIATION DATA ACQUIRED EACH ORBIT
NEPHANALYSIS
CHANNEL 2
8-10 MICRONS
MAPPED RADIATION DATA (TIROS II - NOV 23 1960)



STABILIZING TIROS IN ORBIT

WIRE COIL AROUND TIROS GENERATES MAGNETIC FIELD WHICH INTERACTS WITH EARTH'S MAGNETIC FIELD. THIS PERMITS TILTING OF TIROS TO PROVIDE THE BEST ANGLE FOR THE SOLAR CELLS AND SENSORS IN THE SATELLITE. PATTERNS ON EARTH SHOW HOW DEVIATIONS IN TIROS' ATTITUDE AFFECT ANGLE OF PICTURES TAKEN BY THE T V CAMERAS



INFRARED SYSTEM IN TIROS II

INSTRUMENTS IN TIROS II DETERMINE THE AMOUNT OF RADIATION REFLECTED OR EMITTED BY THE EARTH AND ITS ATMOSPHERE. CONSTANT KNOWN AMOUNT OF RADIATION STRIKES EARTH FROM SUN, LEFT. IN TIROS, RADIATION IS MEASURED IN DIFFERENT PARTS OF VISIBLE AND INFRARED SPECTRUM TO SHOW

1 REFLECTED SUNSHINE;
2 TOTAL RADIATION OF EARTH AND ATMOSPHERE;
3 RADIATION DIRECT FROM EARTH'S SURFACE OR CLOUD TOPS;
4 RADIATION FROM EARTH'S WATER VAPOR LAYER;
5 VISIBLE SPECTRUM FOR REFERENCE;

By 9 December, sixty-two TIROS II nephanalyses had been transmitted over the strategic facsimile circuit 1R9 with an average delay between observations and relay of 8.7 hours. The average, however, included five charts prepared from pictures stored with the satellite for 8-to-10 hours before readout. Waiting for free time on circuit 1R9 resulted in a delay estimated at 42 hours total for the 16 slowest moving charts. Had that particular delay been avoided, the average delay would have been reduced to about 7.3 hours. It compared favorably with regular, upper-air analyses, but was considerably short of AWS' goal of three hours from observation to transmission.

Scanty information received by AWS from NASA in December indicated that TIROS II's infrared data was good. Accuracy was estimated at plus-or-minus one degree centigrade from the broad-band, high-resolution infrared sensors. Dr. Suomi was quite enthusiastic about the data he saw. Beginning late that month, his laboratory at the University of Wisconsin planned to make balloon-borne, radiometer flights, timed to coincide with TIROS II passes.[163]

AWS input to the programming of TIROS II's picture taking was effective. The satellite's coverage of the Atlantic Ocean during a TAC aircraft deployment late in November was good, and its pictures of the recovery area

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[163] Soundings were made at Weather Bureau stations at Miami and San Juan; cooperative hurricane observation stations at Curacao, Grand Cayman, and St. Martin Islands in the Caribbean Sea and West Indies; at the Naval Air Station at Trinidad; and the AWS detachment at Albrook AFB, Canal Zone.

near Hawaii aided in the successful air-catch of the reconnaissance satellite, Discoverer XVIII.[164]

Acting on the USAF request above, AWS continued evaluating the operational utility of TIROS data. It included the correlation between satellite observations and actual surface weather conditions, and the winds and temperatures aloft, as well as other weather elements of military importance. AWS was also responsible for preparing an estimate of the degree to which an operational meteorological satellite system would improve AWS forecasting capability. Such an evaluation had to be based upon the most complete information obtainable. No amount of theoretical speculation would replace actual operational experience with satellite data. For that reason, many of its units were participating in several tasks which would give AWS scientists the information needed to make a valid judgment on the applicability of TIROS observations for operational use.

The major task, from the viewpoint of total participation, was the cloud pattern sketching program carried out by some 130 base weather stations across the United States. At year's end, most of the difficulties related to distribution of time and track information were overcome and AWS expected that all stations would receive adequate notice of each day's observation schedule. In addition to coded messages disseminated over weather teletype, maps showing satellite-pass schedules were transmitted over the 1R9 facsimile circuit.

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[164] See AWSSS Staff Meeting notes, 15Dec60, and Klass, <u>Secret Sentries in Space</u>, pp. 103-04.

A parallel task was accomplished with a JB-57 special reconnaissance aircraft of the 55th Weather Reconnaissance Squadron that was flown along a track below the satellite while strip photographs were taken of the clouds below for correlation studies.

In addition, a number of AWS units took photographs of their AN/CPS-9 weather radarscopes so that areas of precipitation captured by the TIROS II pictures could be properly analyzed.

Most important of all the evaluation programs, however, was that being made by AWS recipients of the TIROS II nephanalyses in applying the satellite observations to their daily weather forecasting activities. Despite a lack of specific guidance originally, many AWS units cited examples of improved analyses, especially over oceanic areas, resulting from an intelligent interpretation of the nephanalyses.[165] AWS advised its field units at the close of 1960 that some guidance would be forthcoming soon on the nephanalyses' use.

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[165] "TIROS II - A Preliminary Report on the Nephanalysis Program," AWSSS Review, Vol. 2, No. 4, 30Dec60, pp. 2-3.

APPENDIX A

TIROS I
Technical Data

The Launch Vehicle[1]

TIROS I was boosted into orbit by a THOR-ABLE launch vehicle very similar to the THOR-DELTA that NASA expected to launch for the first time during 1960. Like DELTA, the TIROS THOR-ABLE carried a Bell Telephone Laboratories radio command guidance system designed for the TITAN ICBM. This Bell Telephone system was also used in THOR-ABLE phase two nose-cone re-entry tests. The Aerojet-General second stage used in the TIROS launch was a surplus stage from the re-entry test program.

The Douglas THOR first stage (150,000-lb. thrust) burned approximately 160 seconds and, just before burn-out, the plastic fairing around the third stage and payload was jettisoned. The second stage Aerojet-General liquid-propellant AJ10 (7,600-lb. thrust) with its Bell Telephone Laboratories guidance system, powered the vehicle for about 100 seconds and, at burn-out, spin rockets stabilized it at 136 rpm. The second stage separated 1.5 seconds after the spin rockets fired. The third stage Hercules-Allegany Ballistics Laboratory X248-A7 solid-propellant rocket (3,050-lb. thrust) coasted for about 400 seconds before it ignited. The third stage separated from the payload 25 minutes after it burned out. The third stage carried a beacon designed by Lincoln Laboratory and built by Texas Instruments. For the first time in a NASA satellite launching, the third stage could be beacon-traced by radar.

The Orbit Achieved[2]

The orbit achieved by the TIROS I package was almost circular. TIROS I had a perigee of 435 statute miles and an apogee of 468

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1. "Tiros I Will Scan Cloud Cover, Earth Temperature," in Aviation Week magazine, March 14, 1960; and "NASA Tiros I Demonstrates Potential Satellite Reconnaissance Utility," in Aviation Week magazine, April 11, 1960.

2. "NASA Tiros I Demonstrates Potential Satellite Reconnaissance Utility," by Craig Lewis, in Aviation Week magazine, April 11, 1960; and "Weather by Satellite," Time magazine, April 11, 1960.

statute miles. Inclination to the equator was 49.326 degrees -- a value within .003 degrees of the intended inclination. Velocity at burn-out of the third stage was within 22 feet per second of the desired value. The orbital period was 99.15 minutes. Thus, its furtherest point from the earth was only 33 miles higher than the lowest point. This feat of orbital precision, unequaled by either U. S. or Soviet satellites to that time, was attributed to the Bell Telephone guidance system in the rocket's second stage.

Package Configuration and Power Supply[3]

TIROS I had been developed for NASA by the Radio Corporation of America's Astro-Electronic Production Division under technical direction of the Army Signal Corps' Research and Development Laboratory. TIROS I was drum-shaped with a diameter of 42 inches and a height of 19 inches, and weighed 270 pounds. Power was supplied by nickel-cadmium batteries charged by 9,200 solar cells, yielding about 19 watts of electricity. Cells were mounted in a series arrangement in groups of five on printed circuit boards, each accommodating 80 cells. A total of 63 nickel-cadmium storage batteries were aboard the satellite, supplied by Sonotone Corporation and with DC-to-DC power converters by Sorenson and Company. The solar cells were made by the International Rectifier Corporation for RCA.

Spin Rate[4]

The spin rate of the instrument package when it achieved orbit was too high for the television cameras to arrest the view. Slow-down to 12 rpm was achieved with a yo-yo device -- a pair of 180-degree-apart, cable-attached masses which were extended by centrifugal force radially from the satellite. When proper rotational speed was reached, the masses were released. Because of its spin rate, TIROS I was gyroscopically stabilized, keeping its axis pointed in a single direction as it circled the earth. Because the satellite was spin-stabilized, areas of the earth which could be seen were limited, since the TV

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3. "Tiros Satellite is Powered by 9200 Solar Cells," in Space and Aeronautics magazine, May 1960; "Weather by Satellite," in Time magazine, April 11, 1960; and "Tiros I Will Scan Cloud Cover, Earth Temperature," in Aviation Week magazine, March 14, 1960.

4. "Weather by Satellite," in Time magazine, April 11, 1960; "Tiros I Will Scan Cloud Cover, Earth Temperature," in Aviation Week magazine, March 14, 1960; and advertisement (sponsored by RCA Corp.), "TIROS I...mission accomplished," in Aviation Week magazine, June 20, 1960.

cameras looked at the earth only during a portion of each orbit. Spin-up rockets manufactured by the United States Flare Corporation and Associates were mounted around the base perimeter of the satellite, to be used when necessary to restore the satellite's spin rate to the optimum value of 12 rpm.

Photographic Systems [5]

Two TV cameras in the satellite photographed cloud cover in a relatively wide north ea[illegible] belt. The camera frame size was 1/4 by 1/4 inch. Each camera had 500 lines per frame, speed was 1/2 frame per second, shutter speed was 1.5 milliseconds, video band width was 62.5 kc. and power consumption was 9 watts. The wide-angle camera had a lens speed of f/1.5 and the narrow-angle camera a lens speed of f/1.8. Both TV camera systems were similar except for the specific optical systems. Each camera functioned as an independent unit and failure of one did not affect the other. Information from both cameras was transmitted in sequence to the ground receiving station. The projected field of the wind-angle camera was a square area, 800 miles on each side. The narrow-angle, high-resolution camera focused on a relatively small area (80-mile square) within the 800-mile square area.

For picture taking while within range of a ground station, the cameras could be commanded to feed their information directly to the transmitters, by passing the tape storage. Various programs of picture taking for each orbit could be pre-set by command into the clock mechanism that triggered the cameras at the proper points.

Each camera was connected to a magnetic tape recorder that could record as many as 32 pictures at 30 second intervals while the satellite was out of transmission range of ground stations, although the camera did not necessarily take 32 photos on each pass. By passing of the recorder was followed after the stored pictures had been transmitted to a ground station and while TIROS was still in range. The two camera systems and their associated equipment operated independently and transmitted data through 2-watt telemetry systems operating on 235 mc. These 330-ounce FM telemetry transmitters were built by Radiation, Inc.

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5. "NASA Tiros I Demonstrates Potential Satellite Reconnaissance Utility," by Craig Lewis, Aviation Week magazine, April 11, 1960; "Tiros Satellite is Powered by 9200 Solar Cells," in Space and Aeronautics magazine, May 1960; and advertisement (sponsored by RCS Corp.), "TIROS I...mission accomplished," in Aviation Week magazine, June 20, 1960.

The tape recorders were the heart of the satellite's remote picture storage capability. The castings were produced and machined by the Bridge Tool and Die Works, Inc., according to specifications supplied by RCA Corporation. Recorder tapes were 400 feet long and moved at 50 inches per second in recording and playback.

The photographic programs were run through a General Time Corporation electronic clock system that could be set as much as five hours in advance as TIROS passed over one of the ground readout stations. The clock system triggered the cameras at the proper time and controlled the picture-taking and recording program.

Programming[6]

TIROS I was programmed for succeeding orbits while within range of a ground station. Pulses received by the command receiver (the antenna protruding from the top of the package) established the time interval to start the clock in the satellite and also start the clock "alarm," which triggered the picture taking operation. The maximum interval which could be programmed between "start" and "alarm" signals was five hours. In operational sequence, the ground station sent a command signal to the satellite at some specific point in orbit to set the clock. A short time later the clock-setting phase was complete, and in a succeeding position in orbit the clock was started. At still another pre-determined orbital position, the clock signaled the "alarm" and the cameras began to scan.

Ground Stations[7]

A radar station at Millstone Hill, Mass., pinpointed the position in the trajectory where the satellite entered its orbit. Minitrack stations tracked the satellite and sent back position data to NASA's computation center, where subsequent orbits were calculated. NASA's Goddard Space Flight Center planned the actual program the satellite cameras would follow. Instructions were then sent to the two main ground stations which instructed the satellite system and received its photographs. Projected programs were coordinated with data compiled by the USWB's Meteorological Satellite Section.

Ground readout stations were at Fort Monmouth, New Jersey, and Kaena Point, Hawaii -- the former operated by the Army Signal Corps

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6. "Tiros I Will Scan Cloud Cover, Earth Temperature," in Aviation Week magazine, March 14, 1960.

7. Ibid. Also, "NASA Tiros I Demonstrates Potential Satellite Reconnaissance Utility," by Craig Lewis, in Aviation Week magazine, April 11, 1960.

and the latter by Lockheed Missile and Space Division. Back-up stations were at NASA's Cape Canaveral, Florida, facility and the RCA site at Princeton, New Jersey. These back-up stations could receive data but could not instruct the satellite.

After processing by the readout stations' photographic laboratories, TIROS photos were sent to the U. S. Weather Bureau for study and archiving.

APPENDIX B

News Media Reaction to TIROS I Launch

St. Louis (Mo.) Post-Dispatch[1]

WASHINGTON, April 2 (AP)--The first weather-eye satellite raced on today in one of the most perfect global orbits ever achieved, ready to feed back more pictures of how clouds cover the earth.

The first cloud pictures radioed yesterday by the new satellite launched by the United States brought an expression of "marvelous" from President Eisenhower. Needless to say, they delighted scientists who had fired the satellite, called Tiros, into its round-the-world orbit.

The first photographs, taken from 450 miles in the sky, were regarded as remarkably clear for such an experimental forerunner of what may be a network of weather watchers that could forecast big storms all over the world.

They took in an enormous quadrant of the earth, centered on the Gulf of St. Lawrence. Fleecy clouds spread over much of the United States-Canadian area.

Everything about the Thor-Able launching rocket and the 270-lb satellite worked in fine style after they rose from Cape Canaveral, Fla. All three stages of the rocket fired with split-second precision.

Tiros was supposed to go into a circular orbit 450 miles out. When the checking was finished, scientists found it varied from this ideal by less than 20 miles at its high and low points.

The angle of inclination from the equator, which determines what part of the earth the photo scanners will cover, was off less than three one-thousandths of a degree.

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1. News story, St. Louis, Mo., Post-Dispatch newspaper, edition of April 2, 1960.

"I think it's a marvelous development," said President Eisenhower when the first pictures were shown to him at the White House by T. Keith Glennan, head of the National Aeronautics and Space Administration.

The name Tiros stands for Television and Infra-Red Observation Satellite. It is pronounced Tie-ross.

The infra-red sensors, which can detect differences in temperature in the earth's atmosphere, were not ready in time to go into Tiros. They may go into Tiros II this summer.

The two television cameras for Tiros were both ready and working. They can snap up to 32 pictures on command, a few seconds apart. These can be relayed instantly to earth stations, or stored on magnetic tape to be sent back on command. When the tapes are full, they can be erased to start all over again.

Although Tiros, shaped like an oversized hatbox, is covered with solar energy cells, its batteries will play out in about three months because of the heavy demand on them.

Because of its near-perfect 100-minute orbit, Tiros may continue to orbit for many years.

Though it swings over much of the Communist world, Tiros is not likely to raise the temperatures of Russian leaders. Its pictures are not nearly detailed enough to show military installations on earth.

Belleville (Ill.) News-Democrat[2]

WASHINGTON (UPI)--The spectacular photos flashed back to earth by America's new Tiros TV satellite made it clear today that such eyes-in-the-sky eventually could be used to spot Russian military moves.

Scientists emphasized that the 270-pound Tiros, carrying two television cameras, was designed only to snap pictures of the earth's cloud cover that will lead to more accurate weather forecasts and could help man control the climate.

But Tiros pictures--whose clarity surprised even scientists working on the project--plainly were a giant first step toward a military reconnaissance satellite.

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2. News story, Belleville, Ill., News-Democrat newspaper, edition of April 2, 1960.

President Eisenhower exclaimed, "A marvelous development," when he was shown four photos of the gulf of St. Lawrence area just seven hours after they were taken by Tiros from an altitude of 450 miles.

The drum-shaped Tiros was launched into orbit at 6:40 a.m., e.s.t. Friday by a three-stage Thor-Able rocket from Cape Canaveral, Fla. It is circling the earth once each 99.15 minutes.

The Tiros pictures released for public viewing were not sharp enough to disclose details on the ground that would be of military value.

But there was no way of knowing how many possibly clearer photos were withheld on security grounds. The satellite's orbit takes it over Russia.

The Tiros project--standing for television and infrared observation satellite--is not connected with military reconnaissance satellite programs. Scientists, however, are sharing data.

The Defense Department is planning a Midas infrared satellite to detect the flaming exhaust of Russian intercontinental ballistic missiles almost as soon as they are launched and a Samos military spy-in-the-sky satellite.

Even without its military implications, Tiros opens new vistas for weather forecasting and control.

/The obvious "slant of the UPI dispatch was toward greater military reconnaissance capability than TIROS possessed. Within a few days subsequent to the launching, the AWS statement for use in answering queries from news media was worked up to specifically point out how AWS was using the data./

AWS Statement for Answering Questions from the Press[3]

Unlike the Army Signal Corps and the Office of Naval Research, AWS possessed no R&D capability of its own, and thus was concerned mainly with operational utilization of any available observation sensor, including the cloud-cover photographs from TIROS I. The statement worked up to answer questions from news media representatives, therefore, discussed only operational use of the data. News media representatives were to be informed, if and when they queried AWS officials, that data received from TIROS I was being fed into the

3. "Statement for Press Use of TIROS Data," Hq AWS, undated (about 8-10 April 1960).

regular transmission system of AWS for use of AWS forecasters; that such data provided valuable information regarding cloud coverage in remote areas. Further, it was possible to relate the satellite's cloud coverage data to other factors such as rain and wind. Although AWS made no news release about TIROS I as such, the statement to be used in answering questions read as follows:

(Statement)

The Air Weather Service has been able to collect cloud photographs transmitted by TIROS I and to send them to field forecasting stations on a real-time basis. That is to say, the cloud information was in the hands of the forecaster about, on the average, ten hours after TIROS passed over the area which it photographed.

On a number of occasions the accuracy of specific predictions was considerably improved because the forecaster had been provided cloud-coverage information over remote areas from which such information otherwise would have been unattainable. As an example, the forecaster at Eglin AFB, Florida, secured timely photographs of cloud formations over the Gulf of Mexico from which he had only a few widely scattered spot observations of clouds overhead from surface vessels. Because of the vastly greater cloud-coverage information provided by TIROS, the forecaster was able to predict cloud coverages, several hours in advance and with accurate detail, required by rocket-test personnel at Eglin.

Air Weather Service will continue its assessment of satellite cloud photographs during the coming tests of TIROS and NIMBUS vehicles. It will do so for two purposes. The first is to avail itself, on a real-time basis, of cloud information for use in forecasting for current Air Force operations. The second is to isolate system deficiencies, from the operational point of view, which must be overcome in order that a successful, economical, operational system can be launched at a later date.

Air Weather Service suspected at the outset, and then found from experience, that cloud-cover data from the vantage point of the satellite would greatly augment the sources of data otherwise available. It also found that the value of the new data depended considerably on the number of other cloud observations made in a particular area of interest. As suspected, it turned out that the accuracy of forecasts over remote ocean and land areas were the most enhanced. Air Weather Service believes that, for at least the near future, the greatest value of the meteorological satellite will continue to be its provision of cloud-cover, and cloud-type, data.

Experience has also shown that cloud-cover and cloud-type information by no means obviates other kinds of weather observations.

Other systems (such as the present operational ones) are required for data on ceilings, visibilities, turbulence, rainfall, and other factors of great significance to aviation. Other systems, too, are needed for measurement of winds which affect the in-flight time of aircraft and which, in the form of severe storms, can cause great damage to ground installations. These other systems include radiosonde installations for measurement of upper-air conditions and aircraft reconnaissance systems which probe the winds and other elements of storms such as hurricanes. In connection with the latter phenomena, it must be remembered that TIROS can tell precisely where the hurricane center is located and what its cloud coverage is, but that it can not tell how strong the winds are throughout the storm, nor where it will be in the future. Here, the satellite and aircraft must act as a team--the first vehicle telling the second one where to go to make its detailed measurements and, at the same time, freeing the aircraft from its former inefficient function of searching more or less blindly for significant weather features.

In summary, the satellite is a tremendously important augmentation to other observational tools insofar as cloud coverage is concerned, especially for remote areas. Cloud data derived therefrom definitely provides the means for preparation of more accurate and detailed predictions of cloud coverages as well as, to a somewhat lesser degree, of other phenomena (such as rain) which can be indirectly, and with some amount of error, related to cloud cover.

Other News Media Reaction[4]

Practically all of the major magazines featured TIROS I in editions subsequent to the launching. Life and Time news magazines featured the satellite in April 1960 issues, in a more carefully researched and objective manner than some of the initial press syndicate dispatches. Business and Commercial Aviation magazine included data in its June issue which highlighted the AWS use of TIROS data. And, finally, the AWS Observer -- AWS's own internal publication -- reported on the initial success of the satellite in its April 1960 edition.

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4. "TIROS Begins a New World of Weather," Life magazine, April 11, 1960; "Weather by Satellite," Time magazine, April 11, 1960; "Intelligence" section of Business and Commercial Aviation magazine, June 1960 issue; and "TIROS I, Pioneer Weather Satellite, Proving Successful," in AWS Observer newspaper, Vol. 7, No. 4, April 1960.

 C O P Y

APPENDIX C

A PROPOSAL FOR AN OPERATIONAL METEOROLOGICAL SATELLITE SYSTEM

I. Requirement

The Air Weather Service in providing required specialized meteorological service to the United States Air Force must be prepared to support the command and control systems and operations within the aerospace. To provide this meteorological support we rely on observations from specific points on or near the earth's surface where a small percentage of these observations include a sounding of the lower atmosphere to measure wind, temperature, pressure, and humidity. From measurements at these discrete points we make certain assumptions and convert point values to a continuous pattern designed to represent the actual continuous motions and activity of the meteorological atmosphere. Where observations are plentiful we have achieved reasonable success in partially describing the lower atmosphere. However, the cold hard fact which has always faced the meteorologist is that by far the greater portion of the earth's surface is covered by water or ice. Ironically, it is over these areas where most of our air masses originate, yet it is also here where our surface and atmospheric sounding data are generally the sparsest.

We are particularly concerned about the increased number and frequency of operations and proposed activities over these sparse data areas requiring rather detailed descriptions and forecasts of cloud cover. For example, aerial refueling, missile firings, DISCOVERER and DYNASOAR shots, and reconnaissance satellites are all sensitive to cloud cover. Typhoons and hurricanes originate over these same areas and with our restricted reconnaissance capability we are faced with an even greater dearth of critical observational data essential to the protection of military life and property. The Air Weather Service cannot be expected to provide accurate forecast service over areas where little or no data are available. An accurate forecast requires accurate and existing observed weather information.

The advent of TIROS I has suggested that a very promising means of supplementing our current observational network with cloud-picture data is now operationally feasible. We can, for the first time, obtain more complete essential weather information from normally sparse data areas. In addition, if we are forced into hostilities with any nation and are denied the use of data from its national weather network, the meteorological satellite will offer the meteorologist relief from such war-imposed "silent areas."

II. Application

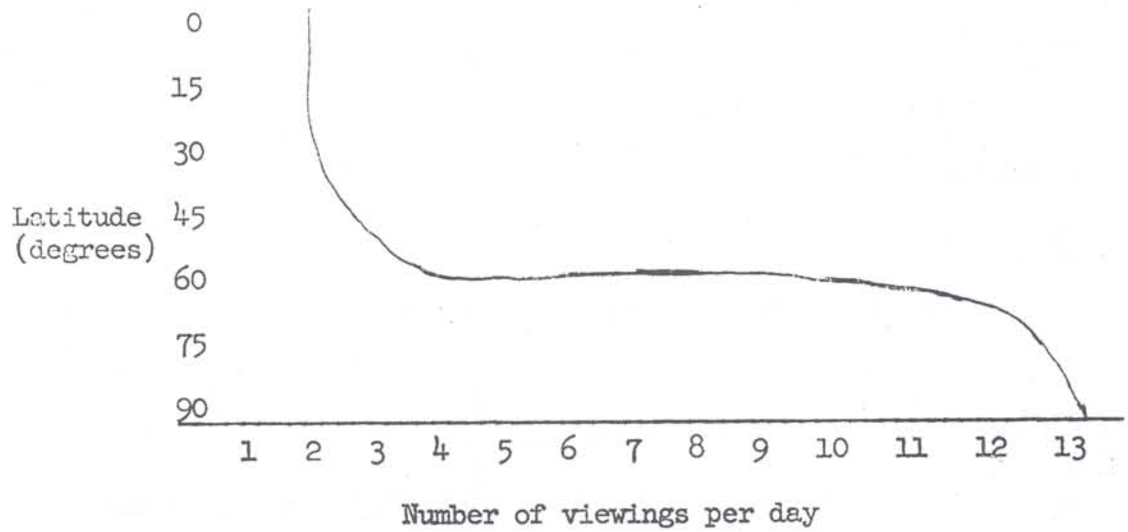
The information to be available from the follow-on vehicles to TIROS I will be directly applied to our forecast support activities. As of the present time with suitable communications we can use the data for direct weather support to refueling activities, down-range requirements for missile firings, DISCOVERER activities, and typhoon and hurricane surveillance.

In addition, development efforts are already underway so that wind direction and apparent wind speed will be extracted from cloud pictures for input to computer prognostic programs. Success in these efforts will materially improve our capability to forecast upper level winds over sparse data areas. Over wartime "silent areas" we could, for the first time, accurately indicate cloud cover for low altitude bombing, reconnaissance, and damage-assessment missions. The improved wind forecasting capability could be directly applied to route, target, and ballistic wind forecasts.

Although data from the several NASA research meteorological satellites will be extremely useful to us, these satellites will not necessarily cover and/or read-out data over the areas of primary military interest. Blank periods must be expected between launchings when no transmitting meteorological satellite will be in orbit. Further, we are not aware of any attempts or plans, on the part of NASA, to develop supporting components necessary to an operational system. We do not feel that we should be in the position of a supplicant to a research organization. Plans should be made for an operational meteorological satellite system to provide a more complete and continuing global observational coverage. If meteorological support is expected to evolve consistent with the accuracy and timeliness demanded by aerospace vehicles and the command and control systems, we must plan for such a program now.

III. Concept

Our concept for operation of a meteorological satellite system is that an earth-oriented satellite will be placed in a near-polar orbit. This type of orbit will provide complete global coverage twice daily over low latitudes, once near noon with high resolution and once around midnight with infra-red. Over high latitudes, regions may be viewed several times a day because of overlapping of the viewing swaths.



Cloud-picture information from the read-out sites will be processed so that the cloud patterns are properly located on a flat map. Next, information will be derived for input to the AWS IBM 7090 at Offutt AFB. In addition, mapped cloud data in the form of facsimile charts will routinely flow from Offutt Weather Central over military circuits to forecast centers and detachments.

An automatic picture-taking and direct read-out feature, included in the meteorological satellite system, would make data in the area of any read-out station available to that station. This feature would satisfy the requirements of ships at sea and overseas elements of the U. S. Armed Forces. As an instrument of peace in the cold war, the system could satisfy the commitments of this nation to the United Nations and the World Meteorological Organization by making data in the area of a read-out station available to any nation who wishes to build and operate such a station. This feature could give the USSR pictures of their own area only, and even this feature could be denied by command control.

More detailed information on some of the system requirements as we know them plus cost estimates are specified in Appendix A.

IV. Control Responsibility

Doubtless there are enough gaps in meteorological knowledge for NASA to conduct fruitful experiments and research for the next decade. The Weather Bureau, although vitally interested in the meteorological satellite program, is primarily concerned only with forecasting for the United States and monitoring those nearby regions from which weather directly affects the U. S. Therefore, we feel that the operational meteorological satellite should be under military control to support adequately the global interests of the United States Air Force.

APPENDIX A - SYSTEM REQUIREMENTS

1. Orbit.

A 600-n.m. circular orbit is desired with a retrograde 80.1° inclination and a period of 108 minutes. Launched at the proper time, the satellite would cross the equator going northward at local noon and going southward at local midnight. This orbit has the property of using the equatorial-bulge effect to maintain the plane of the orbit properly oriented in relation to the earth and the sun. The 108-minute period produces 13-1/3 passes each 24 hours with the subsatellite path described across the surface being repeated once each three days.

2. Instrument Capabilities Aboard the Satellite

Cloud patterns of the entire globe must be viewed. Because of the rate at which weather systems move and change and new systems develop, cloud observations must be made at least twice daily. The conditions for televising are best near local noon to identify cloud types. The second of the two daily observations (at low latitudes), accomplished by use of infra-red around local midnight, needs only to depict the gross cloud picture to measure weather system motion and development.

a. Power Subsystem. Chemical storage batteries sufficient to run the control, sensing, and transmission subsystems are required. Sufficient auxiliary nuclear power or solar cells will also be necessary to keep the chemical batteries charged.

b. Control Subsystem. IR horizon scanners and a rate gyro are required to sense attitude and rate of attitude correction along the three axes. Pneumatic or small rocket power will provide rough correction, and inertia wheels fine corrections. Automatic-attitude correction should maintain an earth-oriented attitude with an accuracy of $\pm 2^{0}$ on all axes for a period of six months - the estimated active life of each satellite.

c. Sensory Subsystem.

(1) Automatic Picture-taking Camera. No storage is required for this camera which is an 800 lines-to-the-inch vidicon type with 105° field of view. The camera automatically takes a picture for immediate transmission every 4 minutes. From a position 600-n.m. above the earth, this produces a picture 1000 n.m. square with an overlap between pictures of about 200 n.m. The resolution capability is $1\frac{1}{2}$ miles.

(2) Electro-static Tape Camera. A 100° X 6° field is viewed with a resolution of 0.3 mi. From 600 n.m. this camera will scan and record a swath 1620 n.m. wide. Storage is required for 1/2 orbit.

(3) Infra-red Scan-type Sensor. A 100°-long field is viewed to cover a 1620-n.m. swath with a 2-n.m. resolution. It will operate at the wave-length required to sense cloud cover at night. Storage is required for 1/2 orbit.

d. Transmitter Subsystem. This system should be capable of "dumping" data stored from one orbit in 5 minutes. Separate transmitters will be required for the automatic camera and tracking beacon.

e. Instruction Subsystem. A clock and instrumentation to store and put into operation instructions for 7 orbits is required. This is so that only one read-out station need to be equipped to send instructions.

3. Data Read-out Stations.

Only two read-out stations with 1200-n.m. pick-up range are needed to receive all passes of the proposed 80.1° inclined (near polar) orbit provided they are properly located. It is proposed that the stations be located at Fairbanks, Alaska, and in northern Norway. The TLM 18 with 60 foot steerable dish is capable of 1200-n.m. range reception from a powerful transmitter aboard a vehicle 600 n.m. above the earth. The Alaskan station should have the added capability of transmitting a half-day's set of instructions twice a day. No transmit capability is required of the Norway station.

4. Communications.

The satellite will transmit a voluminous amount of data which must be rapidly relayed and reproduced in accurate detail. High-quality communications support will be required between the read-out stations and the processing center.

5. Rectification.

The laborious task of transposing cloud images by hand from one map projection (spherical) to another (mercator) and finally to a chart for facsimile transmission is not only time-consuming but much of the original picture is lost in the process. Rectification equipment is required to faithfully reproduce the cloud picture from the original electrical message. This equipment, by adding the feature of removing the earth's curvature, could then retain the quality of the original observation and, at the same time, provide a much more useful product. Such rectifying machines can be based on either an optical or electronic principle. There are some being built for the Air Force which probably could be modified to treat a larger geographical area. (The original TIROS concept included a rectifier; but it was dropped in an economy move.) Rapid communications and a rectifier will provide cloud-cover data in a useable form in 1/2 to 2 hours after observation time.

6. Cost Estimates.

a. Equipment.

These figures must be regarded as rough estimates based, where possible, on comparative costs of TIROS.

(1)	The launch vehicle, one THOR-AGENA B each 6 mos	$5,200K
(2)	Launching costs at the rate of one each 6 months including post-launch support	200K
(3)	The satellite, one each 6 months	3,000K
(4)	Engineering test and check-out facility	300K
(5)	Read-out stations - original construction of two TLM 18-type tracking stations with facilities for forwarding data once received	6,500K
(6)	Annual operating expenses of the read-out stations	150K
(7)	Communications to Offutt, annual cost	10,000K
(8)	Annual ground-control center costs	75K
(9)	Picture rectifier, original cost	100K

b. Manpower not Including Launching Personnel.

(1) At the two read-out stations .. 60 men - about the size of a small AC&W site. (It may be possible to have Norway man the Norwegian read-out station as a NATO contribution.)

(2) Increase at existing ground-control center — 7 men

(3) Data handlers at Offutt — 10 men

(4) Extra weather analysts — no increase

c. Total Outlay.

First year, construction and operation — $26 million

Subsequent annual operation - $19 million plus 77 men.

APPENDIX D

RESUME OF ACTION TOWARD NACCAM COORDINATION OF OPERATIONAL METEOROLOGICAL SATELLITE DEVELOPMENT

Events leading up to the present status stated on page 3 are essentially as follows. A BACKGROUND SUMMARY is given on page 3.

On October 10, 1960, a meeting was called by NASA and attended by the Department of Commerce, Department of Defense, U. S. Air Force, U. S. Navy, FAA, and NASA for the purpose of

a. exchanging views on policy questions relating to both the R&D and the operational aspects of meteorological satellites;

b. exchange of information of related activities in the several agencies; and

c. to consider methods of consultation, advice and coordination.

Following this meeting and in line with NASA's view that it is the responsibility of the user agencies to determine the nature of the system, the Weather Bureau proceeded to develop a National Plan for a Common System of Meteorological Observation Satellites.

Pursuant to the meeting of October 10, NASA by letter of November 14, 1960 and Enclosure B thereto suggested a course of action for planning for an operational meteorological satellite system. The major action recommended was the establishment of an Interagency Meteorological Satellite Planning Committee (IMSPC). The objectives of this committee would be to review the requirements submitted by the individual departments and incorporate them into a technical, operational and management plan responsive to civilian and military requirements.

Discussion

It was recognized at the October 10 meeting that it was desirable for the Joint Meteorological Satellite Advisory Committee (JMSAC) established by NASA in 1959 to continue as an interdepartmental coordinating group on research and development of meteorological satellites.

With the R&D functions thus coordinated through that committee (JMSAC) under NASA leadership, it was subsequently concluded that any other plans or activities with respect to meteorological satellites in which interagency coordination would be necessary will relate basically to operations and uses of satellite output. These matters immediately involve meteorological service functions and in many ways are identical to matters now treated by the Joint Meteorological Group (JMG) of the Joint Chiefs of Staff for responsibilities that are primarily military, and the National Coordinating Committee for Aviation Meteorology (NACCAM) for matters of common concern for civil, military, and general public interests. As regards requirements for meteorological satellites, the Joint Meteorological Group in December 1959 adopted a preliminary statement of requirements which are presently under review.

Based on existing meteorological coordination arrangements including work currently under way by JMSAC and the JMG and recognizing that NACCAM is responsible for general interagency coordination in all common service activities in meteorology in the Federal Government, NASA concurs with the Weather Bureau's suggestion that certain proposals or items listed in their Enclosure B to their letter of November 14, 1960, be coordinated within the framework of JMG and NACCAM. Many of these items involve operating plans which from the standpoint of overall coordination it would be best to have considered by these committees along with other meteorological matters of the same general nature. Accordingly, NASA agrees that it would be desirable to establish a working committee on satellite meteorology within NACCAM and to have this committee proceed as rapidly as possible with the development of an operational plan.

Because of budget considerations and the need to have a comprehensive plan ready to turn over to the new Administration, NASA has urged prompt action, and NACCAM is considered the responsible interdepartmental committee.

Background Summary

The value of meteorological satellite output anticipated in articles published in 1954 and subsequently has been abundantly verified by the photographs transmitted through TIROS I and later developments. Photographs and other information given by TIROS satellites bring important new knowledge, not only for research purposes but also for daily weather analysis and forecasting for aviation and many other operations and for storm warnings to the public. The possibilities imply that a new era is beginning in many features of weather service.

Because satellite data will vitally amplify synoptic weather data from other sources and will be most useful if integrated into the common flow of weather reports from surface and upper air stations, ships at sea and other national and international sources representing many different agencies, coordination in planning and operating activity in meteorology is very important. Only in this way can best use be made of all data pertaining to weather analysis and wasteful gaps in coverage or duplication be avoided. For many years it has been the function of the interdepartmental committee on meteorology dating back to the mid-40's, to bring about the necessary coordination and this committee has been very successful in accomplishing this function. From time to time the name of the committee has been changed to adjust to other departmental machinery. The committee is now designated by the name - National Coordinating Committee for Aviation Meteorology (NACCAM). By the nature of things with no sharp dividing line possible between the various applications of synoptic meteorology, the committee has functioned as a general coordinating committee in meteorology with special attention to aviation aspects.

Present Status

1. In view of the urgency, action has been taken by telephone to establish a Working Committee on Satellite Meteorology under NACCAM to be chaired by the

NASA representative on NACCAM and to be composed of members from NASA, DOD, Commerce, and other agencies represented on NACCAM who have an interest.

2. Because of the urgency involved, the Chairman (Mr. Cortwright--NASA) plans to hold a meeting of the Working Committee on December 8 at 3:00 p.m.

3. The above action will be presented for further review and formal action at the next meeting of NACCAM. A special meeting will be called next week for this purpose if desired by a majority of the members of NACCAM but present discussion by phone indicates that the action outlined above is satisfactory and will be taken up at the next regular meeting of NACCAM.

(signed) F. W. Reichelderfer

F. W. Reichelderfer
Chairman, NACCAM

APPENDIX E

USAF GUIDANCE ON COMMON METEOROLOGICAL OBSERVATION SATELLITE SYSTEM

1. USAF policy guidance on the proposed Common System of Weather Observation Satellites (COSMOS) follows:

a. The Air Force supports a common meteorological satellite system operated by a non-military agency provided the system meets military satellite data requirements.

b. The agency designated as the National Executive Agency for the operation of this common system should:

(1) Anticipate departmental budgetary support;

(2) Recognize that the military application potential of meteorological satellites cannot be subordinated to normal civilian data requirements.

(3) Appreciate the need for, and be prepared to insure interdepartmental coordination of:

(a) Launch facilities.

(b) Orbit scheduled and characteristics.

(c) Tracking and read-out facilities.

(d) Data processing and utilization operations.

c. The Air Force prefers to have a single agency budget for the entire satellite system. However, the plan must include management and coordination mechanism that will insure the budgeting agency is responsive to overall requirements.

d. If it is absolutely necessary to the success of the system, the Air Force will participate on a minimum funding basis. In this connection we are exploring the economic feasibility of launching meteorological satellites as a by-product of other funded USAF space activities.

f. The NASA NIMBUS and AEROS R&D Program should be fully exploited as a source of operational data prior to implementing comparable operational systems.

g. The Bureau of Budget should participate in drafting the operational plan to assure that budgetary planning is consistent with policy and resources availability.

h. Air Force representatives should not agree to any plan provision which violates the foregoing guidance without prior Headquarters USAF approval.

APPENDIX F

C O P Y

NASA News Release No. 60-299 (Hold for Release Until Launch)

TIROS SATELLITE PAYLOAD

Today's launch from Cape Canaveral will attempt to place a 280-pound meteorological satellite into a circular orbit, 400 miles above the earth. Primary satellite instrumentation consists of two television cameras to photograph cloud cover and infrared sensors to map radiation in various spectral bands. Launching vehicle is a Delta rocket.

With the exception of the infrared equipment, this spacecraft is similar to TIROS I launched April 1, 1960. Tiros is a contraction of Television and Infrared Observation Satellite.

Shaped like a round pillbox, the satellite measures 42 inches in diameter and 19 inches high. Its top and sides are covered with over 9000 solar cells. Extending beneath the payload are four transmitting antennas. A single receiving antenna is located on the top.

The Delta launching vehicle is programmed to place the satellite in a circular orbit, about 400 miles high with an orbital inclination to the equator of 48 degrees. Travelling at nearly 17,000 mph, the satellite will circle the earth about every 100 minutes.

Following is a description of the Tiros Meteorological satellite experiment.

POWER SUPPLY. The 9260 solar cells supply electrical energy to 63 nickel-cadmium storage batteries which in turn provide power to operate the experiments within the satellite package. Power conservation is expected to average about 20 watts.

TRANSMITTERS. There are five transmitters to relay data from the satellite to ground stations.

a) Two 235.0 mc transmitters operating with a power output of 2 watts; one associated with each TV system and operated by ground command.

b) One 3-watt 237.8 mc transmitter for the infrared experiments; operated by ground command.

c) Two 30-mw tracking beacons operating continuously on frequencies of 108 and 108.03 mc; beacon frequencies will be modulated by ground command to relay satellite environmental data such as temperature, pressure and battery charge. For backup purposes, both frequencies carry the same data.

TELEVISION SYSTEM. The satellite's two TV cameras, identical except for lens equipment, are each the size of a water glass and use a $\frac{1}{2}$-inch Vidicon tube especially designed for satellite use. The cameras, which peer through the baseplate of the Tiros, are aligned parallel to the satellite spin axis. Each camera consists of a Vidicon and a focal plane shutter which permits still pictures to be stored on the tube screen. An electron beam converts this stored picture into a TV-type electronic signal which can be transmitted to ground receivers. Characteristics of the camera systems are:

	Narrow Angle	Wide Angle
Lens speed	f/1.8	f/1.5
Shutter speed	1.5 millisec.	1.5 millisec.
Lines per frame	500	500
Frames per second	1/2	1/2
Video bandwidth	62.5 kc	62.5 kc
Coverage (cameras vertical to earth)	75 miles (app.)	750 miles(approx.)
TV resolution (cameras vertical to the earth)	0.15-0.2 mile	1.5-2.0 miles

Connected to each camera is a magnetic tape recorder and timer. Out of ground station range, each TIROS camera can record up to 32 pictures on the storage tape for later relay; this can be done by programming the timer. Or, picture data from the cameras can be commanded to by-pass the tape for direct transmission to the ground when within the range of a station (1000-mile radius). The plastic tape is 400 feet long and moves 50 inches per second during recording and playback. The two TV systems operate independently of one another.

Photo data are transmitted from one camera at a time. Tape readout from both cameras will take about 3 minutes. The satellite will be within transmission range of ground stations up to 10 minutes. This means TIROS can transmit directly over 3 minutes of photo data collected by each camera while within range of the ground station.

HORIZON SENSOR. An infrared sensor, mounted on the rim of the spinning satellite, senses when its field of view crosses the earth's horizon. This data is carried continuously by the two tracking beacons unless they are commanded to transmit environmental information. The horizon sensor can be used to determine the satellite's attitude in space.

NORTH INDICATOR. Around the sides of the payload are nine solar cells. These cells generate impulses which measure the position of the satellite with respect to the sun. This data is transmitted with the TV transmission to the ground stations, where it is processed by a computer to show which direction is north in each picture.

MAGNETIC ORIENTATION CONTROL. A satellite spinning in space can develop a magnetic dipole which is equivalent to a small bar magnet. This is caused by closed circuit loops in circuitry and by any magnetic materials present in the satellite. The magnetic dipole, interacting with the earth's magnetic field as the satellite orbits, produces torque -- a turning force. This slowly changes the direction of the satellite's spin axis in space, and so changes the direction in which the TV cameras are pointing. This effect was discovered in the changes in direction of the spin axis of TIROS I.

Scientists say the strength of the magnetic dipole, and therefore the spin-axis direction changes, can be controlled to some extent by programming by ground command various steady currents through a coil of wire wound around the outside of the satellite. An experiment to test this thesis has been incorporated in this TIROS satellite, and attempts will be made to orient the spin axis to obtain optimum performance from the TV and infrared systems.

An aluminum wire is wound around the sides of the satellite, just above the baseplate. Current from the TIROS' power supply will be fed at ground command through the coil. The current can be turned off or on or varied when the satellite is under control of one of the ground stations.

INFRARED RADIATION EXPERIMENTS. There are two radiation experiments. One consists of five infrared detectors. These are oriented at 45 degrees to the spin axis and scan through a combination of the satellite's rotation and its movement along the orbit. The spectral bands and objectives of these detectors are:

1. Earth's albedo -- the percentage of reflectivity of radiant energy or light: 0.2-5 microns.

2. Infrared radiation emitted by earth and atmosphere combined: 7-30+ microns.

3. Emitted radiation through the atmospheric "window" (where the atmosphere is quite transparent): 8-12 microns. Information here should include: (a) cloud detection, especially at nighttime and over areas where the TV cameras are not operated; (b) cloud top temperature and, accordingly, a rough measure of cloud top height; (c) surface temperatures over cloud-free areas.

4. Radiation from water vapor band: 6.3 microns +5%. This will measure the geographic distribution of water vapor at the tropopause, which is about 25 to 30 thousand feet altitude.

5. Visual range: 0.5-0.7 micron. This visual channel is intended to give a map similar to the other radiation maps which could be used to relate the TV pictures and radiation maps.

The second IR experiment consists of two sensors, one white, the other black, which together measure the heat balance of the area of the earth viewed by the wide-angle TV camera. The white body measures the heat radiation from the earth while the black body measures both visible (reflected solar radiation) and heat radiation.

The purpose behind the IR experiments is to find out how much solar energy is absorbed and emitted by the earth and its atmosphere, which may lead to a better understanding of the meteorological effects of this phenomenon.

GROUND STATIONS. The two primary ground command and data readout stations are located at San Nicolas Island, California (part of the Pacific Missile Range), and at Fort Monmouth, New Jersey. A back-up station is located at Princeton, New Jersey.

OPERATION. When the payload is separated from the third stage of the Delta launch vehicle, it will be spinning at about 126 rpm. About 10 minutes after separation, a timer will release a de-spin mechanism to slow the revolutions to about 12 rpm. The de-spin mechanism consists of two weights attached to cables wound around the satellite. As the weights unwind they slow the rate of spin, and when completely unwound they drop off, automatically.

To remain stable in orbit, TIROS must maintain a spin rate of at least 9 rpm. When spin slows to this minimum, one of five pairs of control rockets will be fired to speed up rotation. Located around the baseplate of TIROS, each pair, activated by ground command, can be used only once.

Since TIROS is spin stabilized, it will not be "looking" at the earth at all times. Based on tracking information, Ft. Monmouth and San Nicolas Island will program the cameras to take photographs only at those times when the satellite is viewing the earth and when the area to be photographed is in sunlight. Program commands can be given as much as five hours in advance. Pictures taken while TIROS is out of range of the ground stations will be stored on tape for later relay. In the remote mode, an electronic timer starts the camera, power, and transmitter functions. Each readout wipes the tape clean. It immediately rewinds for its next recording.

When the satellite is within range of a station, ground command can directly turn on the cameras and photographs taken above the station will be relayed immediately below, by-passing the magnetic tape.

Data from the infrared experiments is recorded continuously for one orbit on magnetic tape for playback on command from one of the ground stations. If not read off after one orbit, the tape will automatically start erasing its previous data as it begins recording radiation data during the next orbit. However the tape always has the last 100 minutes of radiation data stored on it for playback whenever commanded.

At the ground stations, cloud-cover pictures will be displayed on kinescopes for photographing. In addition, both photo and infrared data will be recorded on magnetic tapes.

Infrared tapes will be sent to NASA's Goddard Space Flight Center for processing and analysis. Negatives of cloud pictures will be sent to the U. S. Naval Photographic Interpretation Center for photo developing and processing.

There will be meteorological teams at both primary ground stations. They will analyze some of the most immediately useful data and some pictures will be transmitted in real time through weather communications networks for limited experimental use.

The TIROS satellite is expected to operate for about three months. When its usefulness ends, the tracking beacons can be commanded off.

This U. S. launching is part of a long-range program designed to develop a satellite capability for providing world-wide meteorological information. The ultimate goal of the weatherman is to have world-wide meteorological observations at his finger tips for analysis. Such a wealth of data would lead to a more complete understanding of our weather, and this would assist him in preparing his weather forecasts.

The three major aims behind the development of meteorological satellites are:

1. To produce global observations of the atmosphere over the entire globe -- oceanic and desert areas as well as inhabited areas.

2. To provide as completely continuous observations as is scientifically required and technologically possible.

3. To study how the sun's energy is converted into atmospheric motions by measuring the variations in the solar energy and variations in the earth's use of this energy.

TIROS I, launched April 1, 1960, demonstrated the feasibility of meteorological satellites. It transmitted 22,952 cloud cover photos during its operating lifetime of nearly three months. It relayed meteorological information from many sections of the world where weather information had been scanty or until this point nonexistent.

This later TIROS satellite is an experiment -- in itself it cannot be considered an operational weather system. Its useful lifetime is expected to be only about three months. However, the Weather Bureau, the Air Force Air Weather Service and the Navy Weather Service plan to use some of the cloud-cover data on a limited, experimental operational basis.

NASA and the U. S. Weather Bureau have invited weather agencies in 21 foreign countries to participate in meteorological research in connection with this TIROS experiment. It was suggested that weather agencies abroad might obtain useful synoptic results by intensifying standard meteorological observations, or by arranging for special observations, coordinated in time with passes of the satellite. The invitation is representative of the U. S. effort of encouraging international cooperation in space research.

NASA will provide orbital information to those countries interested in participating to assist cooperating groups in timing local weather observations. After processing, TIROS cloud cover photos will be forwarded to participants for comparison with their supplementary observations. If the infrared radiation experiment proves successful, this data will also be sent to cooperating foreign weather agencies. The cooperative effort will probably get under way about one month after successful launch.

Weather agencies which have already expressed an interest in participating are: Australia, Belgium, Denmark, England, German Federated Republic, France, India, Japan, Mexico, Netherlands, South Africa, and Switzerland. Norway and Sweden have also expressed their desire to participate although the satellite's orbit may make their participation marginal.

Other interested countries may also ultimately obtain the scientific data, including cloud cover photos, through the world data centers.

Officials concerned with the TIROS experiment include: Dr. Morris Tepper, Chief of Meteorological Satellite Programs, NASA headquarters; Dr. Rudolf A. Stampfl, Project Manager, NASA's Goddard Space Flight Center; William G. Stroud, Head of the Meteorology Branch at Goddard; Abraham Schnapf, Project Manager for RCA's Astro-Electronics Division; Dave Johnson, Project Manager for the Weather Bureau's Meteorological Satellite Laboratory; John Maskasky, U. S. Army Signal Corps Research and Development Laboratory, NASA's Senior Representative at the Fort Monmouth ground station; and John Masterson, Pacific Missile Range, Point Mugu, Calif., NASA's Senior Representative at the San Nicolas ground station.

TIROS PROJECT PARTICIPANTS

The over-all responsibility for the project rests with the National Aeronautics and Space Administration. The operational phase of the project is under the direction of NASA's Goddard Space Flight Center. Goddard will prepare the command programming which the ground stations will relay to the satellite. These programs will be based on information from NASA's Computing Center and the Meteorological Satellite Laboratory of the U. S. Weather Bureau. The radiation experiments were designed and the data storage and telemetry equipment associated with them were constructed by Goddard where the IR data will be analyzed. Operational tracking will be provided by the Minitrack network.

With the exception of the infrared experiments, the satellite was designed and constructed by the Astro-Electronics Division of RCA, Princeton, N. J., under contract to NASA. In addition, RCA was responsible for the special ground station equipment. Barnes Engineering Company, Stamford, Conn., under NASA contract, provided the radiation detectors. The U. S. Army Signal Corps monitored the payload and ground station equipment contract for NASA during the developmental phases of the TIROS experiment.

The U. S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J., operates one of the TIROS ground stations. The other, operated by the U. S. Navy, is on San Nicolas Island, California, a part of the Pacific Missile Range. A back-up station is located at RCA's facility in Princeton, N. J.

Douglas Aircraft Company is prime contractor for the Delta launch vehicle. In addition, it is responsible for launching services, supported by the Air Force Missile Test Center which operates the Atlantic Missile Range. The Delta uses a Bell Telephone Laboratories guidance system, employing Remington Rand Univac equipment.

The Meteorological Satellite Laboratory of the U. S. Weather Bureau, under NASA funding, is responsible for analysis of cloud cover data. Cooperating in the project are the U. S. Navy Photographic Interpretation Center, the Geophysics Research Directorate of the Air Force Cambridge Research Laboratories, the Air Force Air Weather Service, and the Navy Weather Service. The Weather Bureau and the military weather services will attempt to use some of the cloud cover data on a limited, experimental basis.

LAUNCH VEHICLE

The Delta vehicle used to launch TIROS II has three characteristics:

Height - 92 feet
Max. diameter - 8 feet
Lift-off weight - a little less than 112,000 pounds.

First Stage (modified USAF Thor):

Fuel - liquid (LOX and kerosene)
Weight - about 100,000 pounds fueled
Thrust - about 150,000 pounds
Burning time - 160 seconds
Guidance - radio guidance system (mounted on second stage) and roll and pitch programmers

Second Stage (Aerojet General):

Fuel - liquid
Weight - more than 4,000 pounds
Thrust - about 7,500 pounds
Burning time - 109 seconds
Guidance - radio guidance system (Douglas Aircraft flight controller plus Bell Telephone Laboratory)

Third Stage (Allegany Ballistics Laboratory X248):

Fuel - solid
Weight - more than 500 pounds
Thrust - about 3,000 pounds
Burning time - 40 seconds (after 7-minute coast)
Guidance - spin-stabilized

Orbit planned:

Circular, about 400 miles high and 48 degrees to the equator.
Launching angle - 46.5 degrees
Orbital period - 100 minutes

Firing sequence:

The first stage falls away on burnout. The second stage ignites immediately. The nose fairing which covers third stage and payload is jettisoned after 20 seconds of second stage burning. The third stage doesn't ignite until 7 minutes of coasting after second stage burnout. Then the third stage is spin-stabilized and the second stage falls away. The third stage reaches an orbital velocity of almost 17,000 miles per hour.

The second Delta launched the ECHO I communications satellite on August 12, 1960. The first Delta was unsuccessful in launching a similar satellite on May 13, 1960.

NASA Hq Delta Project Manager - Vincent L. Johnson.

Delta Technical Director, Goddard Space Flight Center - William Schindler.

Head, Goddard Field Projects Branch at Atlantic Missile Range - Robert Gray.

Delta Project Manager, Douglas Aircraft, Santa Monica, California - Horace Irwin.

Douglas Manager at AMR - Bill E. Stitt.

APPENDIX G

News Media Reaction to TIROS II Launch

St. Louis (Mo.) Post-Dispatch[1]

NEW WEATHER SATELLITE FIRED INTO ORBIT FOR FORECAST USE

First Cloud Pictures Received, Will Be Sent to Washington -- Nearly Circular Path Achieved

CAPE CANAVERAL, Fla., Nov. 23 (AP) -- The United States put a robot weatherman into orbit today and quickly started getting back cloud pictures which scientists hoped to use in actual weather forecasts.

The camera-carrying satellite, Tiros II, was launched at 6:13 a.m. from the missile test center at Cape Canaveral, Fla.

Two hours later the National Aeronautics and Space Administration announced it had achieved successful orbit very close to the planned height of 400 miles.

Then in another two hours NASA reported that pictures had been received at the Fort Monmouth (N.J.) station of the Army Signal Corps from the smaller of the two television cameras aboard.

Dr. Morris Tepper, chief of NASA on meteorological satellites, told a press conference in Washington that pictures had not yet been received from the second camera but it was expected they would be received during a subsequent pass around the earth.

Being Developed

He said the pictures already received were being developed at Fort Monmouth and would be sent immediately to Washington.

(The satellite sent eight blanks after its first pass, United Press International said, because it was tipped at an angle when the photographs were taken. The second time around it sent pictures of cloud patterns over the Dakotas and the northern plains area. The satellite still was somewhat tipped when these pictures were taken but it was expected to straighten itself out later by means of stabilizing rockets.)

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1. St. Louis, Mo. Post-Dispatch newspaper, edition of 23 Nov 1960.

Tepper said that today marked a "very happy occasion" for NASA.

He said the first look at the orbit and other characteristics of the new "weather eye" was "very good."

Tiros II was fired into orbit on the nose of a 92-foot Thor-Delta rocket.

It takes Tiros II about an hour and a half to circle the earth.

The satellite was aimed to sweep over an area stretching from 50 degrees north latitude to 50 degrees south. In the Western Hemisphere, this extends roughly from Montreal, Canada, to Santa Cruz, Argentina.

An NASA statement said: "Initial calculations show a perigee (low point) of 415 statute miles and apogee (high point) of 435 miles. The orbital period is 98 minutes."

Near Circular Orbit

The variation of only 20 miles between the near point and the far point of the orbit indicated that the satellite is in the most nearly circular orbit of any satellite yet launched.

The regular orbit also would indicate a relatively long lifetime for the satellite.

The orbit announcement came at 8:20 a.m.

Shortly before that signals from the satellite indicated that a de-spinning mechanism operated as planned, about 10 minutes after Tiros separated from the third stage.

The satellite at separation was spinning rapidly for stabilization, at about 126 revolutions a minute. Had it continued to turn at this speed, all its pictures would have been blurred.

Weights Unwind

Two weights attached to cables wound around the satellite were set by a timing mechanism to unwind slowly, gradually reducing the spin to a satisfactory rate. When completely unwound they were set to drop off automatically.

Should Tiros continue to reduce its spin rate below the nine revolutions a minute required to hold the satellite stable in its orbit, a ground command can fire control rockets to increase the spinning. There are five pairs of these rockets, for a total of five spin speed-ups should they be needed.

Tiros II, the fourteenth space success of the United States, is sending back signals on two frequencies. One was given as 235 megacycles. First information on Tiros II did not indicate what the other frequency was.

First Was Experimental

This is the second Tiros but the first was purely experimental--to see if the mechanism would work and produce anything useful. This time the plan is to use information from the satellite in regular forecasts.

Although pictures from Tiros I turned out clearer and more interesting than expected -- it found a tornado and a hurricane -- assembly and analysis of the information was too slow for any practical value in forecasting.

Tiros II, while still experimental, is expected to be of real aid because of the speed with which data will be assembled and distributed.

The satellite will pass over and take pictures of southern Russia and southern China, but will not cross the northern parts of those countries.

The original NASA invitation to participate in the Tiros weather observation program was sent to 21 countries, including Czechoslovakia and the Soviet Union.

Russia Does Not Accept

Among the 13 that have accepted the invitation, there are no Iron Curtain countries. However, Communist weather officials may still be able to join the program if they wish because the co-operative international phase will not get into full swing for three to four weeks.

Tiros II is shaped like a large drum, with two television cameras protruding from its base. It resembles Tiros I which spun into orbit last April. That satellite relayed 22,952 cloud cover pictures before its instruments went out after 78 days. Tiros II is an advanced model.

No effort was made to predict the weather with the first Tiros, but comparison of the high altitude photos with ground observations made it possible to relate certain cloud formations to cold fronts, storms and other phenomena. NASA scientists said this proves the feasibility of satellite weather forecasting.

Teams of meteorologists were stationed at two key Tiros II ground stations to process and analyze pictures swiftly. Those considered useful for weather forecasting were to be transmitted rapidly to the National Weather Center in Washington, D. C., for distribution.

Satellite Network Planned

If this weather eye in the sky works as planned, it could pave the way for an operational network of six or seven satellites which could quickly forecast big storms all over the world. It is believed such a system could be functioning within four or five years.

Major difference between Tiros I and Tiros II is that today's vehicle carried seven infrared sensors to record the temperature of the earth, clouds and oceans below, and to measure the heat balance between the earth and the sun. This information is vital to weather reporting because heat from the sun is the prime force which makes the atmosphere circulate, thus causing our weather.

Tiros II is 19 inches high and 42 inches in diameter. Its top and sides are spangled with 9200 solar cells to draw power from the sun for its estimated useful life of three months. Four transmitting antennas extend from the bottom and a single receiving antenna from the top. The inside of the package was micro-miniaturized electronic gear.

One of the TV cameras is designed to take pictures covering an area 800 miles square. The second camera narrows down the field to a square 30 miles on a side, providing an enlarged picture to enable weathermen to identify cloud types.

Belleville (Ill.) News-Democrat[2]

NEW WEATHER SATELLITE
IS FIRED INTO ORBIT

CAPE CANAVERAL, (UPI) -- The United States shot a camera-bearing Tiros II weather satellite into a near perfect orbit today and it began sending back pictures of the earth's cloud cover as a forerunner of weather forecasting from space stations.

The first Tiros satellite, sent up last April, found a tornado and a hurricane, and today's more sophisticated vehicle was expected to do even better although both are experimental devices.

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2. Belleville, Ill. News-Democrat newspaper, edition of 23 Nov 1960.

After its first pass Tiros II sent eight blank pictures because it was tipped at an angle at the time. But then it sent a series of pictures to Ft. Monmouth, N. J., where they went through processing before being sent to Washington.

The first pictures were taken by the smaller of the 280-pound satellite's two television cameras. Still to be tested was its larger, wide-angle lens camera and infrared sensors which are to be used when the portion of the earth being photographed is dark.

A Thor-Delta rocket carried the 280-pound Tiros II to America's 14th space success of the year. A Transit III - a navigation-aid satellite - was poised on a nearby pad for an attempt at No. 15 next week.

The federal space agency said initial calculations showed Tiros II was traveling around the earth once every 98 minutes. It hit an almost precisely circular orbit, carrying it 435 miles into space at its furthest point and 415 miles at its nearest approach to the earth. This was very close to the orbit scientists had hoped for.

<u>St. Louis (Mo.) Globe-Democrat</u>[3]

TIROS IN GOOD ORBIT BUT
CLOUD SHOTS ARE FUZZY

CAPE CANAVERAL, FLA. (AP)--A camera-carrying weather-eye satellite zipped into orbit Wednesday and quickly started transmitting cloud pictures which meteorologists hope to use in actual forecasts. However, there was indication of disappointment with early results.

The 280-pound robot weatherman--Tiros II--rode into space atop a thundering Thor-Delta rocket. Its near-perfect circular orbit ranged from 406 to 431 miles above the earth.

Within hours, the drum-shaped satellite transmitted pictures snapped by the smaller of its two television cameras. Officials of the National Aeronautics and Space Administration expressed satisfaction at the time and said the larger camera would begin transmitting soon.

It did, but the resulting pictures appeared disappointing. It wasn't certain whether there was an equipment malfunction or whether the poor results were a temporary situation caused by an initial power drain.

NASA was hopeful the quality of prints would improve.

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3. St. Louis, Mo., Globe-Democrat newspaper, edition of 24 Nov 1960.

The purpose is to use pictures of cloud cover over large portions of the globe in forecasting large weather systems such as snowstorms, making Tiros II the world's first working space weatherman.

The large camera takes photos covering an area 800 miles square, and the second camera snaps a zone 30 miles on a side in the center of the larger area. The enlarged photos taken by the second camera enable weathermen to identify cloud types. But without the over-all pictures of the large lens, it is difficult to pinpoint the exact portion of earth photographed by the small camera.

The first pictures relayed by the satellite were of a section of the Dakotas and northern plains and their cloud cover.

Dr. F. W. Reichelderfer, chief of the United States Weather Bureau, told newsmen in Washington that it was doubtful pictures received Wednesday would be beneficial in forecasting Thursday's weather.

He said it was too soon to make predictions because such factors as the position of the satellite at the time of exposure cannot always be read off promptly in a way that would allow immediate use of a given picture.

He said: "If a hurricane had been developing this morning and had not yet been picked up, it might be picked up by the satellite."

The indication was that day-to-day detailed forecasts such as "will it rain tomorrow?" will have to await more advanced satellites. But any major storm weather might be analyzed swiftly even with Tiros II pictures.

New York Herald Tribune[4]

B I R T H o f T I R O S I I

U.S. Agencies and Industry
In Top Roles

PRINCETON, N.J. -- How is a satellite born? It arises in the minds of men and from the work of their hands. One hundred engineers and scientists fathered Tiros II, the cloud-catching, heat-handling weather satellite now wriggling across the sky.

These men designed and built its fifty important sections composed, in all, of some 20,000 individual parts ranging from two sensitive TV cameras to 9,300 solar batteries to power the scientific equipment aboard.

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4. N.Y. City, N.Y., Herald Tribune newspaper, edition of 24 Nov 1960.

They came from four large companies and government agencies plus a dozen smaller firms. Most of the men work for the Astro-Electronic Products Division of the Radio Corporation of America which designed and built Tiros I. Others joined in from the National Aeronautics and Space Administration, the Army Signal Corps, and the United States Weather Bureau.

The Idea Man First

A scientist -- his name now lost in endless committee discussions -- germinated the original idea: he wanted a way to photograph the distribution of clouds over the earth. He also wanted to measure the amount of heat this planet lost and gained each day. With this information, he could better predict tomorrow's weather. Or so he believed.

The job of translating this idea into hardware fell to the RCA scientists, who received from NASA the prime contract for constructing Tiros (television and infrared observation satellite). Three of these satellites will cost between $10,000,000 and $13,000,000 altogether.

The Task

As did all satellite makers, from those who built the first Sputnik and the first Explorer onward, they faced the peculiar conditions of the space beyond the earth. They had to deal with the brutal shaking the satellite equipment would get from a rocket launching.

But most important of all, the delicate electronic parts had to operate for at least three months without a human being around to tinker with it should any part fail. Once the satellite is launched, no screw driver can reach it.

The Testing

The design of the various components involves the highest art of electronics. To test the performance in space conditions, the RCA scientists built a huge tin can into which Tiros (forty-two inches in diameter and nineteen inches high) would fit. They pumped all the air out of the can. They had a vacuum approaching that of space.

Inside that can they had heating and refrigeration coils to cook the satellite at temperatures of 96 degrees Fahrenheit or to chill it down to 32 degrees below zero. In that way they discovered that some parts just wouldn't work in that temperature range. New designs were made.

Man's Failings

To mimic the thunderous vibrations of take-off, the scientists placed the satellite on a shaker table in the hope of knocking something loose. Or they put the gadget on a merry-go-round to subject it to thirty-five times the force of gravity -- the force it would feel as the rocket roared aloft. (Twice the centrifuge failed, but the satellite held out.)

But the scientists' biggest hurdle was their own human failure. A wrongly placed screw, a miscalculation, a component poorly designed -- all these errors can combine with overwhelming frequency when you are dealing with 20,000 different parts.

"If only we could keep our dirty hands off things," one scientist said here with a sigh.

Yet they got Tiros I to work. In the three months its electronic gear circled aloft, the device took 23,000 pictures of the clouds around the world. It didn't work perfectly. One of the timing devices went on the blink, cutting out one of the tape recorders.

After two and a half months, a relay -- "five-cent gadget," one engineer said with disgust -- apparently clogged so that one camera was on continuously and burned out the batteries.

Tiros II has two extra pieces of gear. One is the infrared gadget that picks up the heat of the earth. The other is a coil of wire wound around its belly. This coil, intermittently filled with electricity, turns the satellite into a magnet. The magnet interacts with the earth's magnetism and in this way the scientists on the ground can steer the axis of the box.

Inevitably, too, the scientists could not help improving things in a technical way. Tiros II should work even better than Tiros I. Perhaps it will operate longer than three months. In that case it can go into the shadow of the earth for several months, come out again and be ready to take pictures.

Belleville (Ill.) News-Democrat[5]

WASHINGTON, Nov. 25 (UPI) -- Scientists today studied information radioed from the Tiros II weather satellite to determine what is wrong with one of the television cameras and whether it can be remedied.

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5. Belleville, Ill., News-Democrat newspaper, edition of 25 Nov 60.

The National Aeronautics and Space Administration reported there had been "some indication of improvement" in the quality of cloud cover pictures being transmitted by the wide-angle camera, which has failed from the start to provide clear photos.

The narrow-angle camera, meanwhile, continues to send back good pictures of weather patterns around the world as the 280-pound drum-shaped satellite circles the earth. Tiros II was launched from Cape Canaveral, Fla., Wednesday. New calculations showed the high point of the orbit was 453 miles above the earth and the low point was 387.

The small camera takes pictures of cloud areas that cover a square of 75 miles. These photos, however, need support from the large camera's photos to give scientists useful weather information.

The large cameras snap pictures of clouds that cover areas of 800 miles square. These pinpoint the locations of the small photos.

In an effort to find out what's causing the malfunctions in the wide-angle camera, NASA yesterday "interrogated" the satellite--send an electronic signal to which Tiros II responded by radioing back certain scientific information.

The data from the satellite are being analyzed at ground stations near Fort Monmouth, N.J., and Oxnard, Calif., where pictures from Tiros II are being received. An NASA spokesman said the study "may make it possible" to do something about the malfunctioning camera.

Tiros I, the predecessor in a series of satellites designed to improve weather forecasting, also worked improperly for a time.

A failure in the timer on the narrow-angle camera prevented the satellite from taking cloud cover pictures over Russia and Red China for a while. The trouble corrected itself after more than a month.

In a spectacular space feat, a scientist diagnosed a malfunction in the Pioneer V sun satellite when it was 5,500,000 miles from earth last April and sent electronic instructions to the satellite to bypass a piece of faulty equipment.

St. Louis (Mo.) Globe-Democrat[6]

WASHINGTON (AP)**Tiros II, the new weatherman satellite, was reported doing a good job Thursday in checking the heat balance of the earth.

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6. "1 Tiros Camera Doing Well," in St. Louis, Mo., Globe-Democrat newspaper, edition of 25 Nov 1960.

Also the smaller of its two cameras was working well, while scientists tried to find out, and correct, what went wrong with the bigger one.

The bigger one, taking pictures of the earth's clouds over an area of 800 miles square, was sending back photos that were too poor in quality to reveal much.

The little one covers a 30-square-mile zone in the center of the big one's field, but a wider area is needed to make it easy to spot just where on earth the camera was snapping pictures.

Tiros II was sent into orbit Wednesday from Cape Canaveral, Fla. New calculations showed its high point was 453 miles above the earth and low point was 387. Early estimates figured these at 431 and 406, whereas the desired orbit was about 400 miles.

Headquarters of the National Aeronautics and Space Administration reported Thursday that the infrared experimental equipment carried by Tiros II was doing its job.

This equipment provides information on the amounts of radiation from the earth and its atmosphere, the amount of reflected sunlight, and the amount of visible light reflected back into space.

The scientists hoped that the one spot of trouble -- with the big camera -- might correct itself. Pictures from Tiros I, purely an experimental satellite, grew better as time went on and the theory was that the power supply built up after an initial drain. Batteries get their power from sunlight.

Aviation Week Magazine[7]

Washington -- Tiros II weather satellite is providing excellent infrared data, but scientists doubt that performance of the wide-angle camera will improve much beyond its current 5-10% usefulness.

Although initial operation of the system showed high promise . . . the wide-angle camera apparently was jarred out of focus at launch, staging, or possibly by being struck by a de-spin weight.

The early difficulty in the camera was believed to have resulted from a high power drain at launch, and the situation was expected to be corrected by functioning of the solar cells. After a week of operation, with 160-170 cloud cover pictures transmitted daily, the trouble was believed to be in camera focus.

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7. "Tiros II Has Wide-Angle Camera Trouble," in Aviation Week magazine, Dec. 5, 1960.

Although Tiros is an experimental vehicle, the problems and benefits created by an operational weather satellite are being investigated by feeding Tiros data into standard meteorological communication channels for use in regular forecasts. Meteorologists in the program estimate that it is now taking between two and three hours to reduce Tiros data and make it available to forecasters. This time should become shorter as experience increases.

Tiros readout stations at the San Nicolas Island station of the Pacific Missile Range and at the Ft. Monmouth, N. J., Army Signal Laboratory collect raw data telemetered from the satellite. Information collected by the 60-ft. dish antenna on San Nicolas is relayed directly by microwave data transmission system to the meteorological analysis center at Pacific Missile Range headquarters, Pt. Mugu. Infrared readings of the earth's albedo taken by Tiros are teletyped from Pt. Mugu to Goddard Space Flight Center, which directs Tiros II operations.

Cloud photographs televised from the satellite, recorded on video tape at San Nicolas and retransmitted to Pt. Mugu are analyzed there and plotted on standard charts called nephanalysis for facsimile transmission to the U.S. Weather Bureau meteorology satellite section, and to Navy and USAF air weather services via the National Meteorological Center at Suitland, Md., and to the U.S. Pacific Fleet via Fleet Weather Facility, Alameda, Calif.

Analysts and forecasters are using a manual prepared by the Weather Bureau showing cloud pictures taken from Tiros I compared with cloud pictures taken from the ground. The nephanalyses will be used in preparing forecasts over a large part of the northern hemisphere.

Photo enhancement techniques are being used to extract as much useful data as possible from the pictures, since the wide-angle camera furnishes photographs which permit fast orientation when used with data from the narrow-angle camera. Photos from the narrow-angle camera are considered about 85% useful.

Two days after launch, two of five pair of spin rockets were fired on ground command to increase stabilization spin rate and eliminate a wobble. Atlantic Research Corp. rockets increased spin from 8 to 10.8 rpm. on the first firing, and to 13.9 rpm. on the second.

Despite a malfunction in one camera, the Tiros II satellite provided the basis last Monday for cloud charts which showed movement of a storm which brought the season's first snows to the Midwest. Charts also showed heavy seas in the North Atlantic and northeasterly movement of a large low pressure area.

Time Magazine[8]

Among the satellites so far shot into orbit, perhaps the most useful to man was Tiros I, the "weather eye," whose pictures of the earth's cloud pattern gave a valuable overall view of global weather. Last week the U.S. launched Tiros II, to improve on the work of its predecessor. The 280-lb., drum-shaped satellite, spangled with 9,260 solar cells, went into a nearly circular orbit about 400 miles above the earth. All except one of its instruments worked fine; only the wide-angle TV camera for photographing large-scale cloud cover was out of kilter.

Tiros II has two cameras. Both are water-glass size, containing midget tubes that impress electronic photographs on magnetic tape. The pictures are sent down to earth on command from stations in California and New Jersey.

The wide-angle camera was designed to cover an area about 750 miles on a side, the exact figure depending on the altitude of the satellite and the slant at which it is viewing the earth. The narrow-angle camera covers an area 75 miles on a side. Its job is to observe cloud formations in fine detail, showing individual thunderclouds and other weather minutiae.

When Tiros II went into orbit, the narrow-angle camera started right off to take good pictures, but the wide-angle camera balked. There is some chance that it will take better pictures later, or that it can be "repaired" by deft electronic twiddling from stations on earth. Even if it never does function properly, the narrow-angle camera alone will yield valuable weather information. But the scientists who interpret the cloud pictures will have to take special pains to identify the places around the earth that are covered by its Rhode Island-size snapshots.

Tiros stands for Television and Infra-Red Observation Satellite, but in Tiros I the infra-red instruments were omitted. Tiros II has five detectors that measure different kinds of infra-red radiation coming up from the earth. They are working splendidly, and their reports will give new information about the earth's albedo (reflectivity) and about the temperature and humidity of the upper layers of the atmosphere. This sort of data is precious to meteorologists.

Tiros I misbehaved in an unexpected way. Its internal electrical circuits reacted with the earth's magnetic field and made the satellite's axis swing slowly away from the desired direction. To keep this from happening again, Tiros II has turns of aluminum wire running around its girth. On signal from the earth an electric

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8. "The Second Tiros," in Time magazine, issued Dec. 5, 1960.

current can be shunted through the wire. This will modify the effect of the earth's magnetism and should keep the satellite's axis pointing properly.

Life Magazine[9]

From its orbit 400 miles over the earth, the second U. S. weather satellite -- Tiros II -- began sending TV pictures of the earth's cloud cover last week. Launched by NASA, it will be the first satellite used for actual trial forecasting by the U. S. Weather Bureau. Tiros I, launched in April, was considered purely experimental. But the 22,952 pictures it took in its three months of active life so impressed the Weather Bureau that it decided to make real use of the next satellite.

A nearly circular orbit takes Tiros II over a belt around the earth wide enough to stretch from Canada to Argentina. Besides cameras, it carries infrared sensors to study the earth's heat balance, a major factor in regulating the weather. Though one of its two cameras was not yet working properly, the Weather Bureau hailed Tiros' potential and invited 21 other nations, including Russia, to participate in the Tiros II project.

Note: More information was also presented in photo captions in the Life magazine story about Tiros II.

AWS Observer[10]

Tiros II, the second purely meteorological satellite to be placed in orbit around the earth, was successfully launched early on November 23 from Cape Canaveral, Fla. The 280-lb. satellite package was launched at a 48-degree inclination by a Delta three-stage rocket and achieved a circular orbit at about 380 miles altitude.

Primary satellite instrumentation consists of two television cameras to photograph cloud cover and infrared sensors to map the earth's heat radiation in various spectral bands. With the exception of the infrared equipment, this satellite is very similar to Tiros I, launched April 1, 1960.

NASA Vehicle

Over-all responsibility for the project rests with the National Aeronautics and Space Administration, with the operational phase of

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9. "400-Mile-Up Forecaster," in Life magazine, issued Dec. 5, 1960.

10. "AWS People at Readout Stations Are Working To Provide Useful Data," in AWS Observer newspaper, Vol. 7, No. 12, December 1960.

the project under direction of NASA's Goddard Space Flight Center. Command programming, relayed to the satellite from ground stations, is prepared at Goddard, based on information from NASA's Computing Center and the Meteorological Satellite Laboratory of the US Weather Bureau.

Under NASA funding, the Meteorological Satellite Laboratory is responsible for analysis of cloud cover data. Cooperating in the project are the US Navy's Photographic Interpretation Center, the Geophysical Research Directorate of the AF Cambridge Research Center, Naval Weather Service and Air Weather Service.

AWS Participation

The program to test and evaluate the utility of cloud pictures received from Tiros II consists of three phases: data reduction and interpretation, dissemination to the forecaster, and appraisal by the forecaster of value of this data to solution of analysis and forecast problems.

Experience gained during the life of Tiros I (April-June 1960) has gone into development of the program to use Tiros II data on an experimental basis.

Data-reduction teams composed of meteorologists from the Meteorological Satellite Laboratory and field stations of the US Weather Bureau, AWS, Naval Weather Service, GRD and Allied Research Associates are presently at the data-readout stations where the pictures from the newest weather satellite are being received.

In addition to Maj. James B. Jones, AWS liaison officer to the Weather Bureau's satellite laboratory at Suitland, Md., who has been in this job since before the launch of Tiros I, AWS people are on duty at the two readout stations.

At San Nicolas Island, Point Mugu, Calif., (a Navy installation which is part of the Pacific Missile Range) are Capt. Leo S. Bielinski, team chief, CWO John C. Garlock, MSgt Seymour M. Fonnesbeck and SSgt Jack E. Sams. CWO Garlock is from the 3d Weather Wing and the others are from 4th Weather Group.

The US Army Signal Research and Development Laboratory, Fort Monmouth, N.J., operates the other primary readout station. At this location are Capt. Dwight R. Goodman, team chief, SMS Mervin L. Snyder, MSgt John J. Pappas and A/1C Ramon C. Batts. Captain Goodman and Sergeant Pappas are from 2d Weather Group, SMS Snyder from 3d Weather Wing and Airman Batts from 4th Weather Wing.

Each AWS team is composed of three forecasters and one observer. Team chiefs went to Suitland, Md., on September 26 for a period of indoctrination under Major Jones, and all team personnel were in place at the readout stations on November 14, preparing for the satellite launch.

Readout Teams

Readout teams prepare maps from Tiros II pictures showing schematically cloud distribution and organization relative to the earth. Interpretation in terms of cloud form and standard weather patterns such as storm centers and frontal systems are part of the presentation, when possible.

A manual prepared by the Office of Forecast Development, US Weather Bureau, comparing cloud pictures received from Tiros I with clouds observed from the ground, is used at the readout stations to guide meteorologists in making interpretations. Copies are used at operational forecast facilities to assist forecasters in using the cloud maps.

Use of Data

After accurate analysis of the cloud images, the most important phase of the project is getting data to the forecaster. To move data quickly from the readout stations, full-period facsimile circuits connect the stations with the communications center and National Meteorological Center in Washington, D. C. Via these circuits, cloud maps are available for use in the NMC and nearby weather facilities of the Navy and AWS within a few hours after basic pictures are taken from the satellite.

To expedite further dissemination, available time on existing weather facsimile circuits of AWS, Navy and Weather Bureau has been rescheduled to minimize delays.

To reach units not served by facsimile, selected cloud analyses are summarized for relay on land-line and radio teletype circuits on a space-available basis.

Through joint use of available communications, the operational test of Tiros II assumes global proportions. For example, US weathermen in Australia, supporting resupply missions to the Antarctic expedition, receive word summaries of cloud observations made by the weather satellite over vast ocean areas between Australia and Antarctica.

The satellite is expected to have a useful life of about three months, after which its tracking beacons can be shut off by command from the ground.

Only an Experiment

NASA stressed that the newest weather satellite is only an experiment, although many agencies in addition to AWS will probably make operational use of the cloud pictures and infrared data.

Weather agencies in 21 foreign countries have been invited by NASA and the Weather Bureau to participate in meteorological research in connection with the experiment. The invitation indicates US efforts to encourage international cooperation in space research.

To assist cooperating groups in timing local weather observations, NASA will provide orbital information to those countries interested in participating. After processing, Tiros photos will be sent to these nations for comparison with their supplementary observations.

Countries which have expressed an interest in participating are Australia, Belgium, Denmark, England, German Federated Republic, France, India, Japan, Mexico, Netherlands, South Africa and Switzerland. Norway and Sweden also expressed a desire to participate, but the satellite's orbital inclination may make their participation marginal.

G L O S S A R Y

ADC	Air Defense Command
AFCRC	Air Force Cambridge Research Center
ARPA	Advanced Research Projects Agency
AWS	Air Weather Service
AWSSS	Scientific Services Directorate, Air Weather Service
COSMOS	Common System of Meteorological Observation Satellites
DCS	Deputy Chief of Staff
FAA	Federal Aviation Administration
GRD	Geophysical Research Directorate, Air Force Cambridge Research Center
IBM	International Business Machines
ICBM	Intercontinental Ballistic Missile
IGY	International Geophysical Year
IMSPC	Interagency Meteorological Satellite Planning Committee
JMG	Joint Meteorological Group
JMSAC	Joint Meteorological Satellite Advisory Committee
MATS	Military Air Transport Service

NACA	National Advisory Committee for Aeronautics
NACCAM	National Coordinating Committee for Aviation Meteorology
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
POMS	Panel on Operational Meteorological Satellites, National Coordinating Committee for Aviation Meteorology
RAND	Research and Development Corporation
RCA	Radio Corporation of America
SAC	Strategic Air Command
SAMOS	Satellite and Missile Observation System
SHAPE	Supreme Headquarters Allied Powers, Europe
TAC	Tactical Air Command
TIROS	Television and Infrared Observation Satellite
USAF	United States Air Force
USWB	United States Weather Bureau

AWS And Meteorological Satellites: 1950 - 1960

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