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THE SATELLITE APPLICATIONS SECTION OF THE NATIONAL HURRICANE CENTER

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The Satellite Applications Section (SAS) was formed in the spring of 1970 to combine all weather satellite picture acquisition and processing within one unit. This unit also leads in the interpretation of the satellite products, and in the development of future requirements. At present all available data from the Applications Technology Satellite No. 3 (ATS-3) and limited data from the Automatic Picture Transmission (APT) satellites are used daily. These are made available to a wide variety of interests. This note will briefly describe the operations of the SAS.

THE APPLICATIONS TECHNOLOGY SATELLITES

The Applications Technology Satellites are placed in geostationary orbits, approximately above the equator and revolving once each day with the Earth, so that they appear to remain stationary above a given geographic location. The inclination of the orbits causes a daily oscillation of 2.5 degrees for ATS-1 and 1 degree for ATS-3 north and south of the equator. These inclinations are increasing slowly due to solar wind pressure. ATS-1, the first of the series, was launched on 7 December 1966 and is still providing highly useful data from a location near 149 degrees west longitude or generally south of the Hawaiian Islands. ATS-3 (Fig. 1) was launched on 5 November 1967, and carried a Multicolor Spin-Scan Cloud Camera designed to provide pictures in color of most of a hemisphere. Blue, green, and red color channels were provided, but unfortunately the red channel malfunctioned only a few weeks after launch and is no longer utilized. The green channel only is used to provide black and white pictures. During the 1970 hurricane season ATS-3 remained west of 60 degrees west longitude, but like others of this series may be positioned east or west with considerable freedom, as long as the propulsion gas lasts. For example, it was moved to 85 degrees west longitude to photograph the solar eclipse of 7 March 1970. It is scheduled to be moved eastward to 47 degrees west longitude this winter and plans are to return it to a position near 70 degrees west longitude for the 1971 hurricane season.

ATS-3 is at a height of about 22,300 statute miles and rotating at about 101 rpm. The camera makes a narrow scan west to east with each rotation and makes 2,408 discrete steps from north to south to provide a complete picture. Twenty-three minutes 47 seconds are required for the picture, and 2 minutes 24 seconds to "retrace" or return the camera to its initial position prior to the next scanning sequence. Thus full Earth disk pictures may be obtained at intervals of about 26 minutes. A feature of the system is that the scanning sequence may be stopped upon command and a new picture begun sooner than usual, thus allowing more frequent pictures of the northern part of the hemisphere. This is of great utility in certain studies. The resolution of the camera at the subsatellite

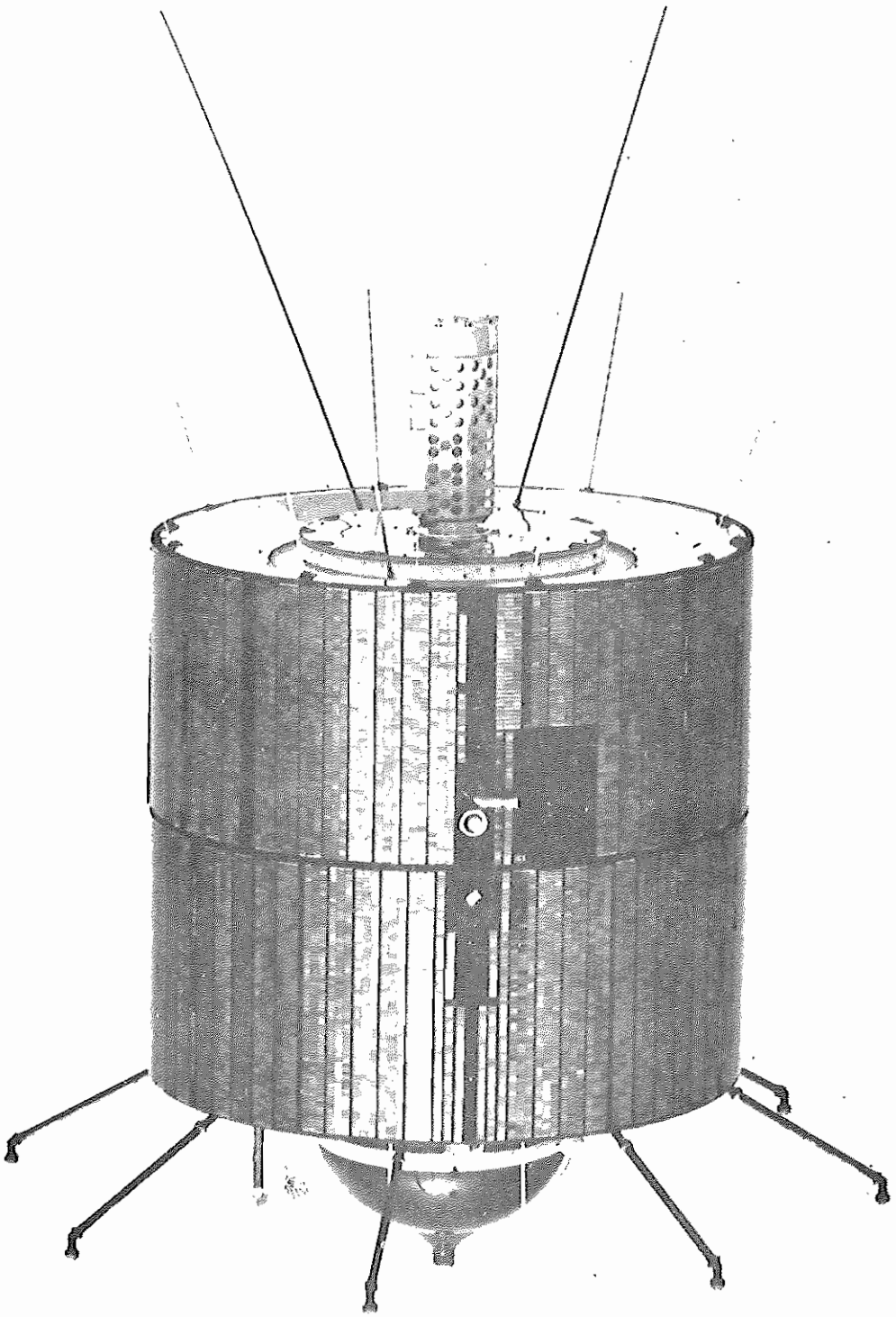

Fig. 1. ATS-3 (NASA photograph)

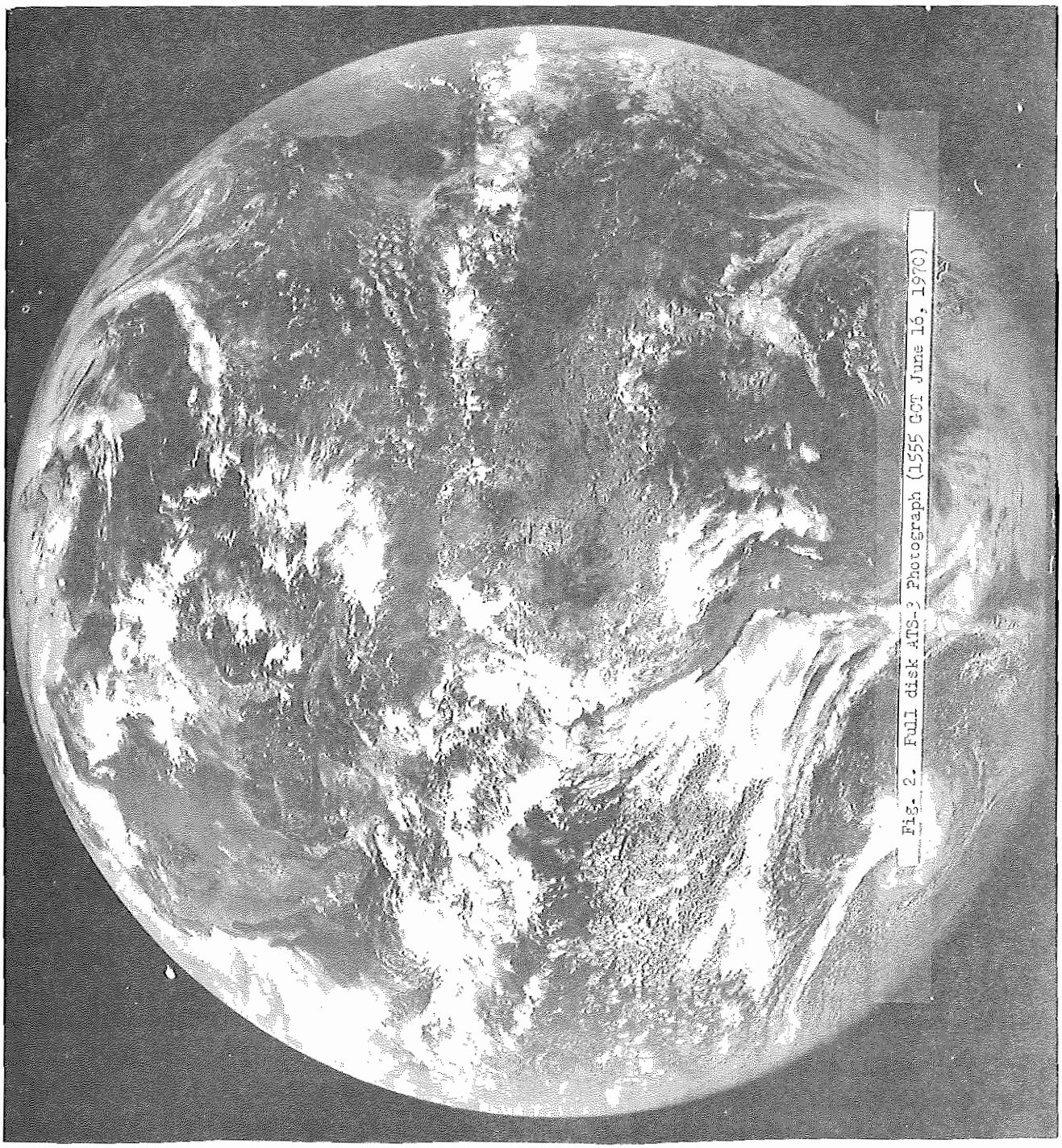

Fig. 2. Full disk ATS-3 Photograph (1555 GCT June 16, 1970)

point (location on the Earth directly beneath the satellite) is 1.9 miles, comparable with the APT satellites at much lower altitudes. Of course, the resolution is less as one departs from near the sub-satellite point, but over most of the NHC forecast area it is better than 3 miles.

Use of ATS-3 at the NHC is an experiment in the operational use of ATS cloud imagery. This experiment is being conducted with the cooperation and support of the National Environmental Satellite Center (NESC) at Suitland, Md., a suburb of Washington, D. C. The satellite command and data acquisition station is located at Wallops Island, Va. Here the signals in digital form are received from ATS-3, "stretched", and relayed by microwave link to the NESC, where they are converted to analog form and relayed by highest quality telephone line to the NHC at Miami. The equipment at Suitland that converts from digital to analog form, transmits the data from Suitland, and receives and displays the images at the NHC and the National Severe Storms Forecast Center at Kansas City is known as the "SATFAX" system. In effect, the pictures are received at Miami essentially instantaneously while the satellite camera is scanning, just as if the antenna were located close by. This system has worked very well; but it should be noted that it is an experiment and many of the back-up facilities ordinarily provided with an operational system are lacking, so that it is not completely reliable and there are occasional days when the picture taking sequence starts late or not at all.

Although seldom used at Miami, pictures from ATS-1 are also available late in the afternoon, after the ATS-3 picture taking sequence has ended and much of the Atlantic Ocean is in darkness. These may also be acquired and they give an excellent view of most of the Pacific Ocean and of storms in that region.

THE ATS-3 OPERATIONAL DAY

The picture taking sequence with ATS-3 normally begins at 1305 GCT (8:05 A.M. EST), and continues for about 7½ hours. It takes about 24 minutes to receive a single full-disk picture (Fig. 2). The exposed film cassette is immediately taken into the adjacent photographic darkroom and the 10" x 11" film is fed through a Kodak Versamat automatic film processor. The developed negative is available in a matter of minutes and taken directly to the registration stand. This is a light table where the picture negative is matched to a geographic grid underlay by reference to visible landmarks and a registration strip attached which insures that this and all other pictures in a sequence will be in the same position relative to the grid and to each other. The negative is then contact printed with the grid to yield a positive picture with 10 degree latitude and longitude lines and the coastlines of the continents and major islands indicated, ready for operational use. Many contact prints are made of an early and a late picture and distributed to the forecasters and other interested parties. These provide views of the entire area of interest, from Africa westward into the Pacific

Ocean, and the time interval between is large enough to measure movements of major cloud/weather systems, note development, etc. In addition to these two pictures printed in quantity for distribution, a print is made of each picture and kept in the SAS for examination by any party interested in changes of a smaller scale. These become a file copy for later reference and study.

In addition to this routine daily operation, upon special request to the NESC, it is possible to enjoy extended picture taking by ATS-3, beginning 2 hours earlier and ending 2 hours later. This longer picture taking day allows essentially full time surveillance of any storm during daylight hours. Half-disk pictures (Fig. 3) may also be provided on these days. This special coverage is requested in support of certain research and when a hurricane threatens the United States.

The most significant use made of the ATS-3 pictures is movie loops for various purposes. These movie loops are made by photographing successive picture negatives in sequence, and repeating the process, until a film loop of sufficient length to play through a projector is obtained. A stand mounted 16 mm movie camera is used with the negative exposed over a back-lighted box. Requirements frequently change, but at present the following movie loops are routinely produced every day:

1. An early "winds" loop using only 5 full-disk pictures (more, if half-disk) which is used primarily for measuring displacements of cloud elements at a low level corresponding to cumulus cloud bases and at the cirrus cloud level. In this way the winds are derived directly for those levels over vast regions where there are no conventional data. A loop of short duration is chosen so that the cloud elements will "live" through the entire period, and also in order that the derived winds may be corrected for camera perspective and Earth curvature in time for entry on the morning 1200 GCT analyses.

2. A "hurricane" loop is prepared for projection in the Hurricane Forecast Room using 6 or more pictures. When a storm is in process this will normally be an enlarged view of the storm. At other times it will be an enlarged view of whatever tropical system is of greatest current interest. As required, more than one "hurricane" loop may be prepared, to provide the hurricane forecaster a latest movie of any storm. A variety of camera lenses is available to permit almost any enlargement desired.

3. By late afternoon, a third movie loop is produced using all available pictures up to that time. This loop is given to television interests and other news media. The area presented here differs from day to day, but normally includes Florida and whatever else is most interesting. A hurricane presented in this way gives the viewing public a dramatic picture of the rotation, movement, and development of the storm. In winter it should be almost as striking to view a cold front or other weather system bearing down on Miami.

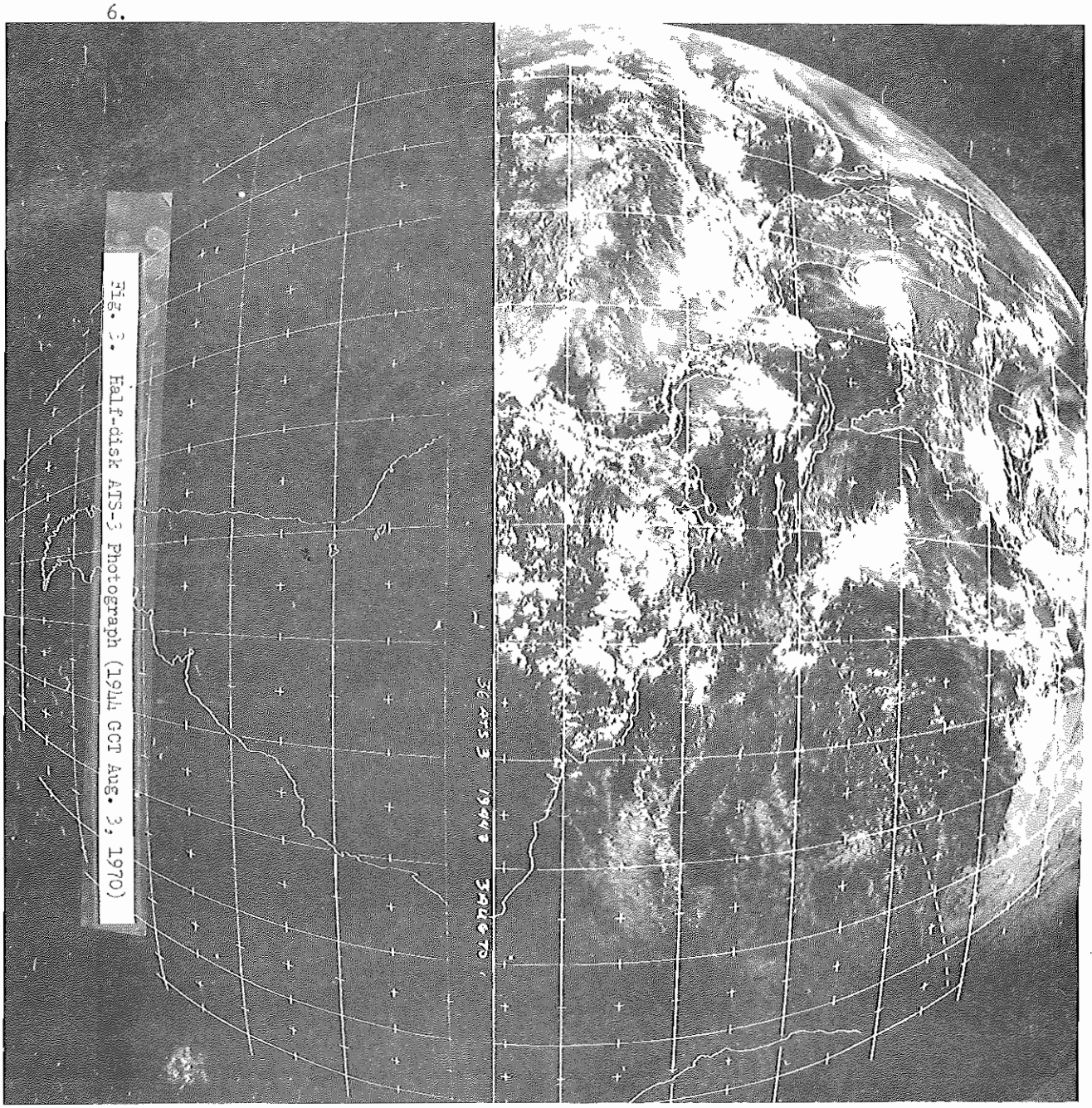

Fig. 2. Half-disk ATS-3 Photograph (1944 GCT Aug. 3, 1970)

4. At the end of the day, a final movie loop is made which includes every picture received that day. This is used extensively by the evening and "mid watch" forecasters, and becomes a permanent record of the day's weather.

SATELLITE DERIVED WINDS

Cloud imagery as made possible by geostationary satellites represents a giant step forward in our observation of global weather systems. At once a view is obtained of most of a hemisphere, and such pictures are available at frequent intervals throughout the day. Every cloud/weather system may be viewed in its entirety. Winds derived from the movie loops allow an analysis of the fields of motion at the bottom and top of the troposphere. These in turn lead to calculations of mass transport at these levels, and thence to computations of vertical motions which are the basic cause of most weather. We plan to use these data in computer-produced analyses and prognoses. Similarly, on a smaller scale, the movie loops allow a detailed analysis of the energetics of a hurricane, and are of very great assistance in forecasting these storms.

No doubt time will lead to greatly expanded use of the ATS pictures, in ways not yet imagined. Future plans call for a Geostationary Operational Environmental Satellite (GOES) system which will provide pictures with four times the resolution presently possible and also will provide infrared pictures which will allow cloud viewing at night. Then we will have total coverage, 24 hours a day.

THE AUTOMATIC PICTURE TRANSMISSION SATELLITES

For many years the NHC has had the capability of receiving pictures from the Automatic Picture Transmission (APT) satellites. These satellites are in "sun-synchronous" polar orbits which carry them north-to-south (and south-to-north) at about 900 statute miles above the Earth in slightly less than 2 hours. Pictures approximately 2,000 statute miles across are taken by television cameras and are broadcast about every 6 minutes while on the sunlit side of the Earth. Any station with the proper equipment may receive these pictures. Camera resolution at the subsatellite point is about 2 miles, comparable to ATS-3, but decreases more rapidly with distance from the subpoint. APT satellites provide better observation of very high latitudes, but at lower latitudes usually allow only one look each day at any specific location. These pictures may be composited to provide one large montage of most of the NHC area of responsibility, but different parts represent different times, and the montage is not complete until afternoon.

The capability to acquire APT pictures is retained at the NHC but not used regularly. An early eastern pass (which may be acquired by telephone link with the San Juan, Puerto Rico receiving station) is received and gridded if it precedes the ATS picture taking sequence, and all

available pictures may be acquired, gridded, and composited in the event of the unavailability of ATS pictures. Thus the APT satellites remain a valuable back-up system. And, on certain occasions, as when an APT satellite passes directly over a hurricane, especially at higher latitudes, a superior picture may be obtained by this means.

Over the past decade, many APT satellites have been launched. At present ESSA-8, Nimbus-3, and the new ITOS-1 (TIROS M) satellites may be used. Each has its special advantages and a selection is made accordingly.

AVCS SATELLITES

Yet a third type of weather satellite is used which is the base for many of the products prepared at the NESC and transmitted by facsimile to the field. These are similar in orbital characteristics to the APT series, but carry advanced vidicon cameras that take pictures and store them on magnetic tape for later read-out. A variety of products is available at the NHC from the AVCS system, but are not the direct responsibility of the SAS. Among these products are "digitized" montages of the entire Earth printed out on a chart base that matches our own in scale. These pictures are processed by computer to yield many shades of black to white, to correct tonal shading due to sun angle and picture overlap, etc., and rectified on a Mercator or polar stereographic projection. "Enhanced" charts are available which present the areas of brightest cloud, often associated with the heaviest precipitation, and there are others.

THE NEW SYSTEM

A new system is being introduced which combines both the AVCS and APT functions in one satellite. Known as the Improved TIROS Operational Satellite (ITOS), these will provide certain types of observations in addition to those mentioned previously. Among the most important at present are infrared pictures at about 3:00 A.M. local time, designed to assist the forecaster with the early morning predictions, the most important of the day. Infrared pictures not only map the cloud/weather systems at night, but allow an estimate of the height of the cloud tops.

THE FUTURE

Used together, the GOES and ITOS systems will provide a complete scheme of observation which is expected to serve for several years. Progress, which has been very rapid over the past decade, may be expected to come more slowly now that initial goals are being won. Still there is much to be done, and many new things are planned using these basic observation platforms. Such are beyond the scope of this brief discussion. The bibliography attached gives much information as released by the NESC.

ACKNOWLEDGMENTS

We wish to acknowledge with gratitude the very great assistance provided this Center by the NESC. Among the many individuals who should be mentioned are Mr. William Raynore, project leader, and Messrs. Ray Coldren and Mel Welch, electronic experts, who designed and built the ATS data distribution or "SATFAX" system at the NESC and installed the equipment at Miami. Continuing support in both personnel and supplies has been provided by the NESC Photographic Laboratory under the direction of Mr. William Plew. A photographic technician from the Photo Lab was detailed to the NHC for the duration of the hurricane season. First of these to arrive was Mr. Gene Dunlap, who set up the darkroom equipment and established good practices; and he was ably followed by Messrs. Chuck McCullough and Randy Lyles. The competence of the men sent to Miami from the NESC and the spirit of cooperation between the two Centers has been outstanding. We wish also to thank Mr. Jerry Glover, Chief, NESC Satellite Operations Division, for reading the manuscript and making many valuable suggestions.

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