APPENDIX A

BASIC INFORMATION ON TIROS SATELLITES

The TIROS Satellites

Introduction

TIROS is the short name for Television and InfraRed Observation Satellite. TIROS I, launched April 1, 1960, by the National Aeronautics and Space Administration (NASA), carried television cameras only. TIROS II (launched November 23, 1960) and III (launched July 12, 1961) also carried equipment to sense solar and terrestrial radiation.

The primary instrumentation of TIROS III consists of two television cameras, both basically the same as the wide-angle cameras used in TIROS I and II, and scanning and nonscanning radiation detectors. The satellite instrumentation also includes tape recorders, transmitters, telemetry, and associated electronics for both the television camera and radiation systems, radio beacons, and a power supply of storage batteries and solar cells. There are auxiliary devices to control satellite attitude, wobble, and spin rate, and various switching, timing, and sequencing circuits to control the instrumentation. (See the section entitled "Other Equipment.") Miniaturization and weight-saving techniques compatible with maximum reliability and performance are used.

All the TIROS satellites are generally cylindrical in appearance. The vertical covering of this cylinder, which is 42 inches (107 cm) in diameter and 19 inches (48 cm) high, consists of 18 flat sections. The sides and top are covered with solar cells, the primary power source. The weight of TIROS III is approximately 287 pounds (130 kilograms).

TIROS III was launched in a northeasterly direction from Cape Canaveral, Fla., into a nearly circular orbit at a mean altitude of about 475 statute miles (760 kilometers). The period of revolution of the satellite around the earth is about 100 minutes, so that the satellite travels around the earth about 14.5 times every 24 hours. With plane of the orbit inclined about 48° to the equator, meteorologically useful data cannot be obtained poleward of approximately 55° latitude. The satellite is spin stabilized in space. Initially, its spin axis was normal to the earth at about 20.8° north latitude; this changes to some extent as discussed in the section entitled "Spin Axis Orientation." Both camera axes are parallel to the spin axis, and both cameras look in the same direction. The average orbital figures for TIROS I, II, and III are listed as follows:

	TIROS I	TIROS II	TIROS III
Period, min	99. 24	98. 26	100. 4
Average height, statute miles (km)	450(720)	420(676)	475(760)
Apogee, statute miles (km)	461. 3(740)	451. 5(726)	509. 8(820)
Perigee, statute miles (km)	436. 0(702)	387. 8(624)	457. 1(736)
Eccentricity	0. 00287	0. 00727	0. 00593
Inclination, deg	48. 392	48. 530	47. 898

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Photography

On Tiros III, the two television cameras designed to photograph the cloud cover of the earth under daylight conditions are the same in regard to the size of the earth area viewed and the resolution; both are the same in these respects as the wide-angle camera used on Tiros I and II. From an altitude of 475 miles (760 kilometers), these cameras are designed to view areas approximately 750 miles (1,200 kilometers) on a side when the cameras are pointed straight down (zero nadir angle); under these conditions, the cameras provide a resolution of the order of 1.5 to 2 miles (2.5 to 3 kilometers). When the cameras are looking at greater nadir angles, the extent of coverage is increased whereas the resolution decreases according to obvious goemetric factors. The narrow-angle camera used on Tiros I and II viewed areas approximately 75 miles (120 kilometers) on a side when the camera was pointed straight down. The best resolution was on the order of 0.2 to 0.5 mile (0.3 to 0.8 kilometer).

Some details about both cameras are given in the following table:

	Wide angle	Narrow angle
Field of view, deg	104	13
Area coverage from average height of satellite and zero nadir angle, sq miles (km)	750 (1,200)	75 (120)
Lens speed	f/1.5	f/1.8
Shutter speed, milliseconds	1.5	1.5
Lines per frame	500	500
Resolution per raster line pair, zero nadir angle, miles (km)	1.5 to 2 (2.5 to 3)	0.2 to 0.5 (0.3 to 0.8)

The decision to use two wide-angle cameras on Tiros III, rather than one wide-angle and one narrow-angle camera as on Tiros I and II, was based on several factors, most important of which is the provision for redundancy, or backup, in the event of a malfunction or failure of one of the cameras. Failure of the only wide-angle camera onboard either Tiros I or II would have made use of the narrow-angle camera data difficult or impossible. (Since camera No. 1 on Tiros *did* fail some 12 days after launch, the decision to use two wide-angle cameras has already proven to be fortunate). Furthermore, meteorologically significant cloud systems are most often apparent over the large areas shown in the wide-angle camera pictures. When both wide-angle cameras are operating, more extensive synoptic coverage than would be possible with one wide-angle camera and one narrow-angle camera can be obtained. Sufficient narrow-angle pictures are available to satisfy present research requirements until cameras providing similar resolution over wider areas become available in more advanced types of meteorological satellites.

Radiation sensors

The second series of meteorological sensors on Tiros III consists of three sets of radiation detectors. The first of these consists of a five-channel radiometer which uses the spin of the satellite to generate a scan. This radiometer is oriented with its optical axis at 45° to the spin axis of the satellite and scans the surface of the earth by means of a combination of the rotation of the satellite and its movement along the orbit. The spectral bands of these radiometers and the purpose of each are as follows:

Channel	Band	Purpose
1	6.0 to 6.5 microns	Radiation from water-vapor bands. This is designed to measure the temperature of the water-vapor layer at an average altitude somewhat below that of the tropopause. The altitude to which the measured temperature corresponds varies with the vertical distribution of water vapor.
2	8 to 12 microns	Radiation emitted through the atmospheric "window." The information expected from these measurements includes: (*a*) cloud-cover detection, especially at night and over areas where TV cameras are not operated; (*b*) measurement of cloud-top temperatures and, accordingly, a rough measure of cloud-top heights; (*c*) measurements of surface temperatures or temperature gradients over cloud-free areas.
3	0.25 to 6 microns	Albedo of the earth.
4	8 to 30 microns	Infrared radiation emitted by earth and atmosphere combined.
5	0.55 to 0.75 micron	Radiation in the red part of the visible spectrum. This channel is designed to provide gross visual radiation maps for comparison with the vidicon data and provides a gross visual spectrum reference in areas for which vidicon data are not obtained.

These radiation sensors provide a resolution of about 40 miles (about 65 kilometers) when looking straight down.

The second set of radiation sensors consists of a black and white body, each mounted in the apex of a cone. Each has a 450-mile (720 kilometer) diameter field of view which falls within the field of view of the vidicon cameras. These provide low-resolution data relative to the albedo of the earth and total emitted radiation for heat balance studies. These sensors are essentially the same on Tiros II and III.

The third set of radiation sensors is about the same as one of the experiments on the Explorer VII satellite. These sensors consist of four hemispheres, each about 1 inch (2.5 centimeters) in diameter, mounted on mirror surfaces on rods sufficiently extended from the base of the satellite so that, when in orbit, the hemispheres do not see any part of the spacecraft. One set of these hemispheres, a black body and a white body, is mounted on one side of the satellite with an identical pair exactly opposite it. The net effect of these four hemispheres is that of a white and black sphere of the same diameter isolated in space at the altitude of the satellite orbit. The black body absorbs most of the radiation incident upon it whereas the white body is sensitive mainly to radiation whose wave-length is longer than approximately 4 microns. When the direct solar radiation is subtracted, the data from these sensors can be used to infer the albedo of the earth and the total emitted radiation reaching the satellite. The field of view is from that part of the earth bounded by the horizon as seen from the altitude of the satellite.

Reduction and processing of the Tiros II and III radiation data from the five-channel radiometer are being undertaken as rapidly as possible; these data will be ready for general release in the near future. Studies of limited selected cases demonstrate that the data appear to be of significant meteorological value.

Other equipment

In addition to the two kinds of meteorological sensors previously described, the satellite carries a horizon sensor (to aid in determining spin axis attitude) and a series of sun sensors (for determining the north direction of the pictures, particularly when low nadir angles restrict the horizon visible on the pictures). There is also a magnetic coil for attitude control. (See the section entitled "Spin Axis Orientation.") Other equipment includes tape recorders for data storage, data transmitters, a command receiver, beacon transmitters for tracking and for telemetry of the performance of equipment, storage batteries, solar cells, and necessary associated electronics.

Operations

Tracking and orbit determination are being carried out by the minitrack network and the NASA Space Computer Center. The primary data acquisition stations for Tiros III are located at Wallops Island, Virginia, and Point

Mugu, California. The antennas for the latter station are located on San Nicolas Island, about 60 miles off the California coast. These stations program or command the satellite to perform such operations as:

- Transmission of cloud photographs from either camera while within telemetry range of the station (about 1,200 miles).
- Taking of one series of 32 sequential pictures *per camera* with either or both cameras at specific times in the future (normally when the satellite is remote from a station) and storage of them in the magnetic tape recorded.
- Read-out of the cloud pictures stored on magnetic tape in the satellite.
- Read-out of the radiation data stored in the satellite. This system is arranged to contain the radiation data from approximately the last full orbital pass.

Combinations of any or all of these operations may be performed during a single pass over a station, depending on the time within radio range. Attitude data are continuously transmitted through modulation of the tracking-beacon. The vidicon telemetry signals received at a data acquisition station are recorded on magnetic tape and simultaneously on film through photography of the monitor screen. The radiation data are recorded only on magnetic tape.

Decisions as to the regions of greatest meteorological interest for programing each satellite pass are made by the U.S. Weather Bureau based on consideration of locations suitably illuminated for photography, the attitude of the satellite, interpretation of data obtained on previous passes, and the stated plans of cooperating experimenters in the United States and abroad. These decisions are utilized by the NASA TIROS Technical Control Center in programing commands to the satellite unless changes are required by engineering or experimental considerations.

Spin axis orientation

In the case of TIROS I, interactions between the magnetic moment of the satellite and the magnetic field of the earth produced unexpected changes of the spin axis orientation (ref. 1). TIROS II and III are equipped with a magnetic attitude control coil through which, on command from ground stations, variable amounts of current are permitted to flow. This device makes it possible to exercise some control over the spin axis orientation. Although this cannot significantly change the orientation within a single orbit, it is possible to prolong the periods during which the satellite and its sensors are favorably oriented with respect to the sun and the earth. The maximum rate of change using this device is about 15° per day.

TIROS III: Programing Limitations and a Method for Determining Geographic Coverage

Based on the characteristics of a TIROS satellite, its orbit, and the solar illumination of the earth, it is possible to predict for each day of the orbital cycle of the satellite the approximate geographic area in which it is probable that satellite cloud-cover photographs will be taken. Although technical and programing factors introduce some uncertainty in predicting the areas to be photographed, these predictions can be useful for planning. More accurate photographic programing information was supplied over international meteorological communications networks 7 days in advance and then again 24 to 48 hours in advance. The following geographic limitations may be noted:

(*a*) The probability that photographic data will be obtained decreases poleward of the extreme orbital subpoints of the satellite; that is, no photographic data can be expected poleward of 55° north or 55° south latitude with the normal orbit which is inclined at 48° to the equator.

(*b*) Because of the location of the data acquisition stations, the amount of data obtained over the following countries and areas within 48° north and south latitudes will be severely limited: Afghanistan, southern Argentina, southern Chile and adjacent southeastern Pacific Ocean, Iran, Pakistan, India, and USSR.

The following sections describe the primary reasons for the limitations of the TIROS III coverage and a method for determining the areas of potential coverage for any given date. The material included has been based on the predicted (or nominal) orbit prior to launch. The actual orbit achieved does not vary substantially from the nominal. Any revisions are provided in the detailed programming data transmitted over meteorological communications circuits.

Latitude limitations

Because of the slight bulge of the earth at the equator, the plane of the orbit of the satellite precesses in right ascension at the rate of a few degrees per day. As a consequence of this rate of precession and the movement of the earth in its own orbit around the sun, a complete cycle of this precession of the plane of the orbit of the satellite relative to the sun is completed in about 9 weeks. This imposes latitude limits on the areas of photographic coverage because of the requirement for solar illumination.

In attempting to visualize these phenomena and their effects on the availability of observations over a given area, it is necessary to recall that for any single day the plane of the orbit remains nearly fixed in absolute space and relative to the sun, while the earth rotates independently within the orbit. Thus, on any single day, considering solar illumination only, the same latitudes at all longitudes could be observed by the cameras at various times during a 24-hour period. However, the locations of the read-out stations place an additional constraint on observable longitudes. (See next section.) The slow precession of the orbit plane causes the illuminated latitudes, as seen from the satellite, to change over a 9-week cycle in the manner described as follows.

The time of each launch is chosen so that initially the northern part of the orbit is on the side of the earth nearest the sun and the TV cameras can obtain data over latitudes from about the equator to 50° north latitude. (The satellite passes over the Southern Hemisphere only at night during these initial orbits.) Gradually, the latitude at which the orbit crosses the noon meridian moves slowly southward until, about 1 week after launch, the descending node (point where the orbit crosses the equator on the southbound leg) is on the same side of the earth as the sun. At this time, photographic observations will be made in the regions approximately between 35° north and 35° south latitude.

Precession of the orbit and southward movement of the illuminated areas under the orbit continue until about 4 weeks after launch; the southern part of the orbit is on the side of the earth nearest the sun and photographic data can be obtained over the area between 20° south and 50° south latitude but not in the Northern Hemisphere over which the satellite passes now only at night. From this point, the precession causes the illuminated portion of the orbit to move northward gradually; about 6 weeks after launch, the ascending node (point where the orbit crosses the equator on the northbound leg) is on the same side of the earth as the sun and again the observable latitudes are primarily in the tropics. Continued precession and northward movement of the illuminated area under the orbit reach the point, about 8 weeks after launch, where the northernmost portion is again over the side of the earth nearest the sun, and photographic observations again are possible between 28° north and 50° north latitude. Precession continues and southward movement of the illuminated area under the orbit begins again. The whole cycle repeats about every 9 weeks throughout the useful life of the satellite.

The consequences are graphically illustrated in figure A–1, on which the shaded area indicates, for each date on the abscissa, the illuminated latitudes. For use in determining the areas of photographic coverage, the data on this graph are displayed in two parts, figures A–2(a) and A–2(b). Figure A–2(a) shows the illuminated latitudes on the southbound portions of the orbits whereas figure A–2(b) shows these latitudes for the northbound portions.

Longitude limitations

Within the illuminated latitude zone there are also longitude limitations upon the areas from which data may be obtained. The locations of the readout stations (Virginia and California) determine the extent of these limitations for the following reasons:

(*a*) The data storage capability of the satellite is limited.

(*b*) The range at which each station can contact the satellite and usefully read-out data is limited to line of sight from the ground to the satellite.

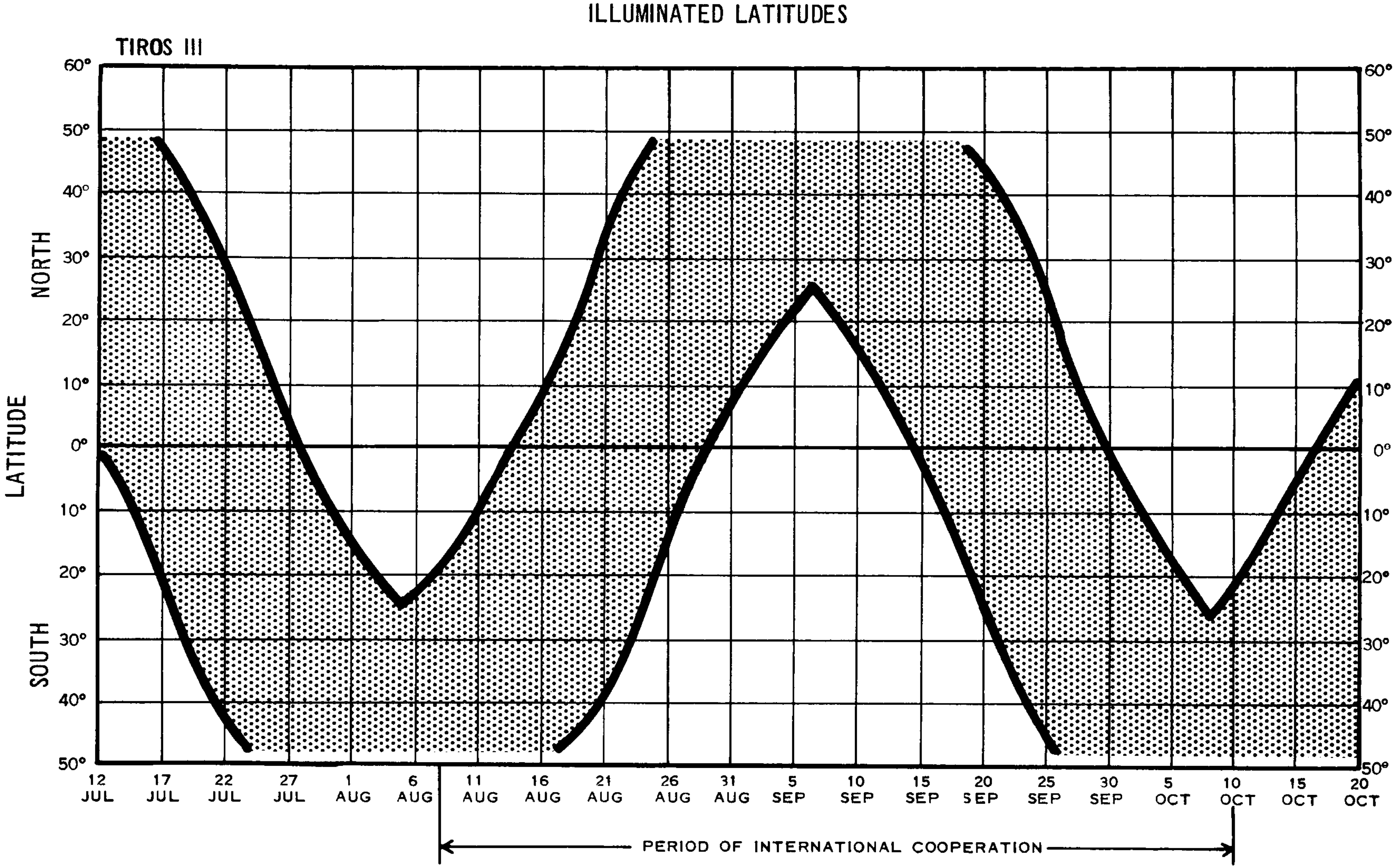

ILLUMINATED LATITUDES
TIROS III
LATITUDE
NORTH
SOUTH
60°
50°
40°
30°
20°
10°
0°
10°
20°
30°
40°
50°
12 JUL
17 JUL
22 JUL
27 JUL
1 AUG
6 AUG
11 AUG
16 AUG
21 AUG
26 AUG
31 AUG
5 SEP
10 SEP
15 SEP
20 SEP
25 SEP
30 SEP
5 OCT
10 OCT
15 OCT
20 OCT
PERIOD OF INTERNATIONAL COOPERATION

FIGURE A–1.

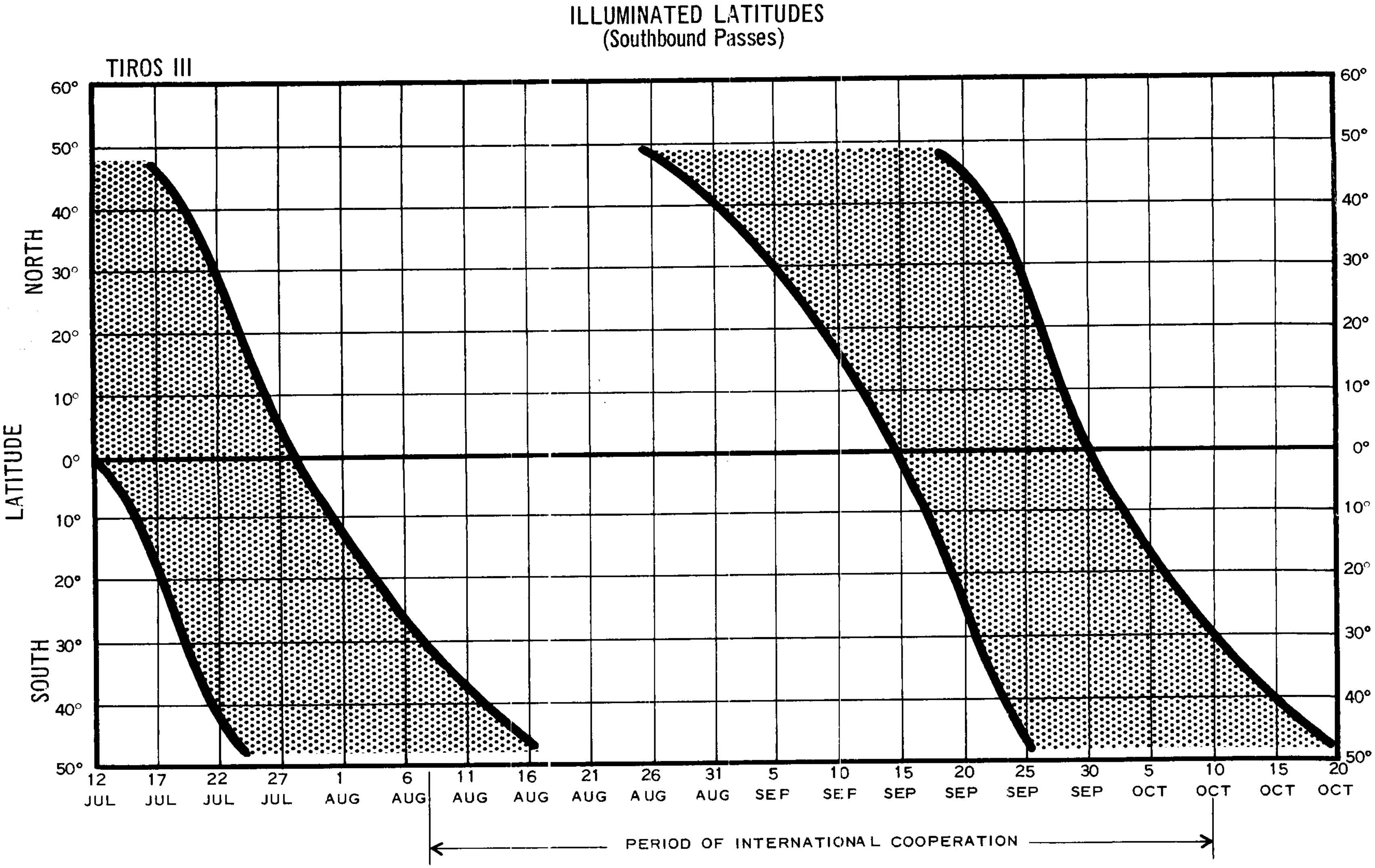

ILLUMINATED LATITUDES
(Southbound Passes)
TIROS III
LATITUDE
NORTH
SOUTH
60°
50°
40°
30°
20°
10°
0°
10°
20°
30°
40°
50°
12 JUL
17 JUL
22 JUL
27 JUL
1 AUG
6 AUG
11 AUG
16 AUG
21 AUG
26 AUG
31 AUG
5 SEP
10 SEP
15 SEP
20 SEP
25 SEP
30 SEP
5 OCT
10 OCT
15 OCT
20 OCT
PERIOD OF INTERNATIONAL COOPERATION

FIGURE A-2(a).

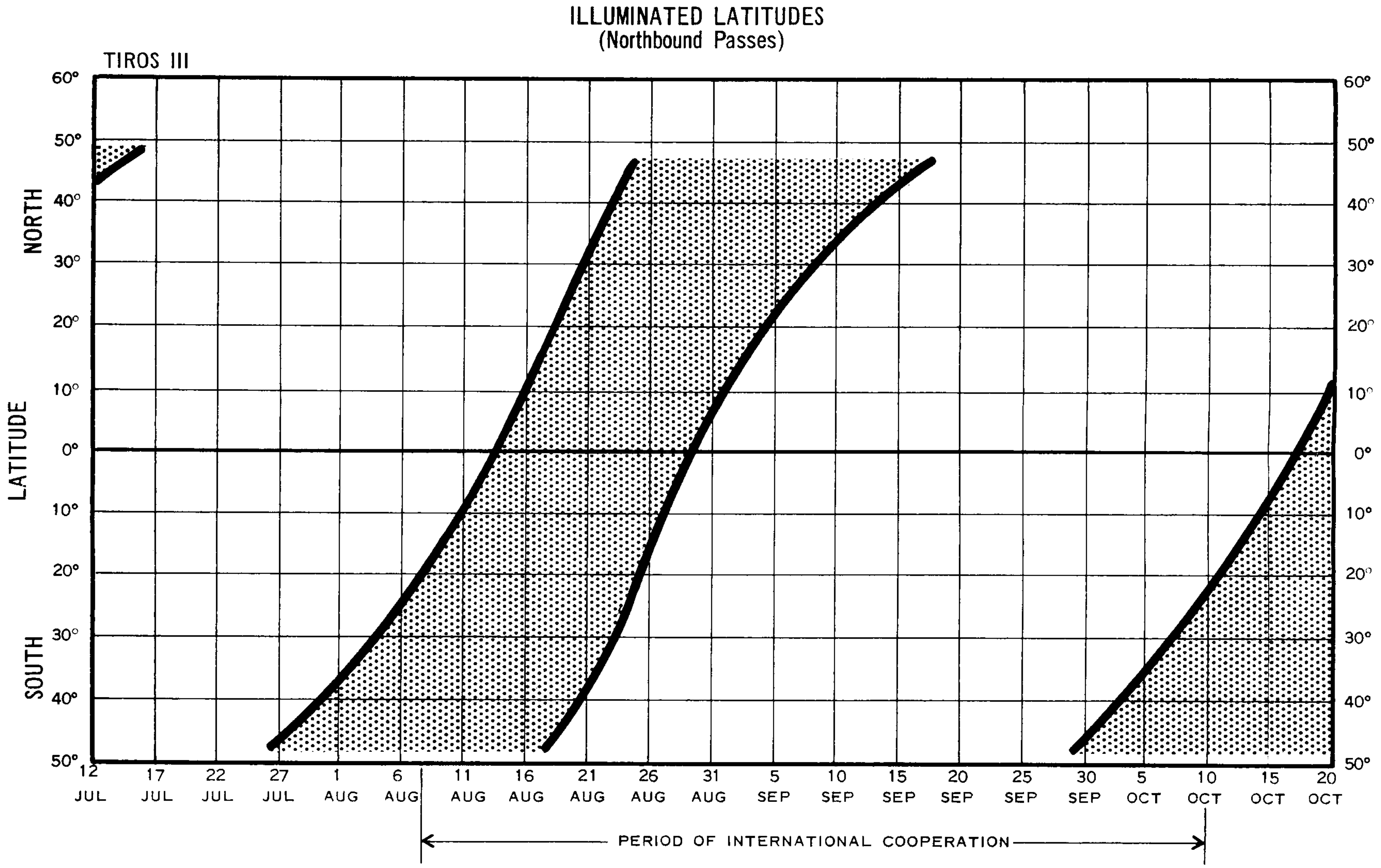

ILLUMINATED LATITUDES
(Northbound Passes)
TIROS III
LATITUDE
NORTH
SOUTH
60°
50°
40°
30°
20°
10°
0°
10°
20°
30°
40°
50°
12 JUL
17 JUL
22 JUL
27 JUL
1 AUG
6 AUG
11 AUG
16 AUG
21 AUG
26 AUG
31 AUG
5 SEP
10 SEP
15 SEP
20 SEP
25 SEP
30 SEP
5 OCT
10 OCT
15 OCT
20 OCT
PERIOD OF INTERNATIONAL COOPERATION

FIGURE A-2(b).

When plotted on a Mercator projection world map, the trace of the orbit subpoint describes a sine-shaped curve, centered on the equator, with a half-amplitude of just under 50° of latitude and a wavelength of approximately 335° of longitude. The 335° wavelength derives from the rotation of the earth under the satellite; the longitude of each ascending node being displaced approximately 25° west of that for the immediately preceding orbit. The range at which each data readout station can contact the satellite and usefully read-out data is a circle with a radius of about 20° of latitude.

Orbits with ascending nodes over the area of the Atlantic Ocean cannot be contacted by either data readout station; in fact, the first orbit following these that can be contacted has an ascending node of about 75° west longitude and can be reached by the Virginia station near the southeastern extremity of its range. (The following discussion relates to a 24-hour period starting with this orbit.) Following this orbit the next seven orbits can also each be contacted by either the Virginia or California stations (or both), the last one being that with an ascending node near 80° east, which is contacted by the California station near the southwestern extremity of its range shortly before its descending node near 115° west. During this 7½-orbit period, station locations impose no limit on the amount of data that can be obtained. The area covered during this 7½-orbit period is defined as Area I and is the most favorable area for photographic coverage.

During the approximately 6½ orbits between the last contact with the California station and the next contact with the Virginia station (about 24 hours after the first contact with the Virginia station, which started the period under consideration), we can obtain:

(a) One sequence of 32 pictures

(b) Solar and terrestrial radiation data for the last 100 minutes before the Virginia station contact

The areas covered during this 6½-orbit period include Areas II and III and are less favorable for photographic coverage.

Remote programing

An additional factor even further limits the data that can be obtained during this 6½-orbit period of time. The satellite clocks, which determine when remote picture sequences will start, can run for a maximum of only three orbits (5 hours) after being started before they initiate the picture-taking sequence. Under normal operating modes, this limits picture data following the last California contact to the area between this contact (just before the 115° west descending node) and 5 hours and 15 minutes later (shortly after the descending node at approximately 165° east longitude). The area covered during this three-orbit (5 hour) period following the last contact with California station is defined as Area II. From this point on, no pictures could be taken under normal operating modes until the first Virginia contact on the orbit with an ascending node between 75° west and 100° west.

To overcome this limitation, a supplemental mode of operation was tried for the first time during the TIROS III experiment. The clocks were set during the last California contact (just before the 115° west descending node) but, if not started then, they could be started by a special signal transmitted from the NASA minitrack station at Santiago, Chile. This experimental mode permitted pictures to be taken from the time an orbit came within range of Santiago (shortly before the ascending node near 30° west longitude) until the next contact with the Virginia station. This special mode was established primarily to increase the opportunities of obtaining tropical storm data over the tropical North Atlantic (it was successfully used to obtain pictures of hurricane Betsy), but can be more widely applied. The area over which pictures can be taken using this special mode (Santiago clock start) is defined as Area III. This special mode of operation can in no way increase the amount of picture data that can be obtained during the 6½-orbit time period (Areas II and III) following the last California contact; it only permits more flexibility in choosing the areas over which the one picture sequence is taken.

The areas (II and III) affected by this limitation of one series of pictures per day are approximately as follows:

(*a*) *On southbound portions of the orbits* (fig. A–3(a)): From a line running approximately from the southern tip of the Kamchatka Peninsula southeast to South Georgia Island (south Atlantic Ocean) westward to a line running from Hungary southeast to near the southern tip of New Zealand.

(*b*) *On northbound portions of the orbits* (fig. A–3(b)): From a line running from Sakhalin Island (north of Japan) southwest to about 50° south, 0° westward to a line running from the English Channel to about 50° south, 165° west.

It should be noted that most of these areas are also covered by orbits in the other phase which are contacted once per orbit by the Virginia or California stations. This is not true, however, for an area over central, southern, and southeastern Eurasia, and for another over the southeastern Pacific Ocean and southern Argentina and southern Chile; consequently, the amount of data that TIROS will be able to obtain over these latter areas will be severely limited.

Use of graphs and maps

To determine when pictures can be taken over any given area, first determine the latitudinal limits of the area. Then, using figure A–2(a), determine when those latitudes are illuminated for southbound passes. From figure A–2(b), make a similar determination for northbound passes. These are the approximate periods when it will be possible to take pictures over this area. Other limitations, discussed subsequently, preclude taking data over all areas at all times. The specific times within these possible areas when pictures were to be taken were more precisely identified by messages sent over international meteorological circuits 7 days and 24 to 48 hours in advance.

In many parts of the world, the period of southbound passes will be more favorable than that of northbound passes, or the reverse. To determine this, use figures A–3(a) and A–3(b). These maps show the geographical limits of Areas I, II, and III for southbound passes (fig. A–3(a)) and for northbound passes (fig. A–3(b)). Area I is the most favorable; next most favorable is Area II. Area III provides the least favorable probability of obtaining pictures from the satellite. It is roughly estimated that the probability of pictures being taken in Area I is about five times greater than in Areas II and III combined. Similarly, it is estimated that the probability in Area II is about twice as great as that in Area III.

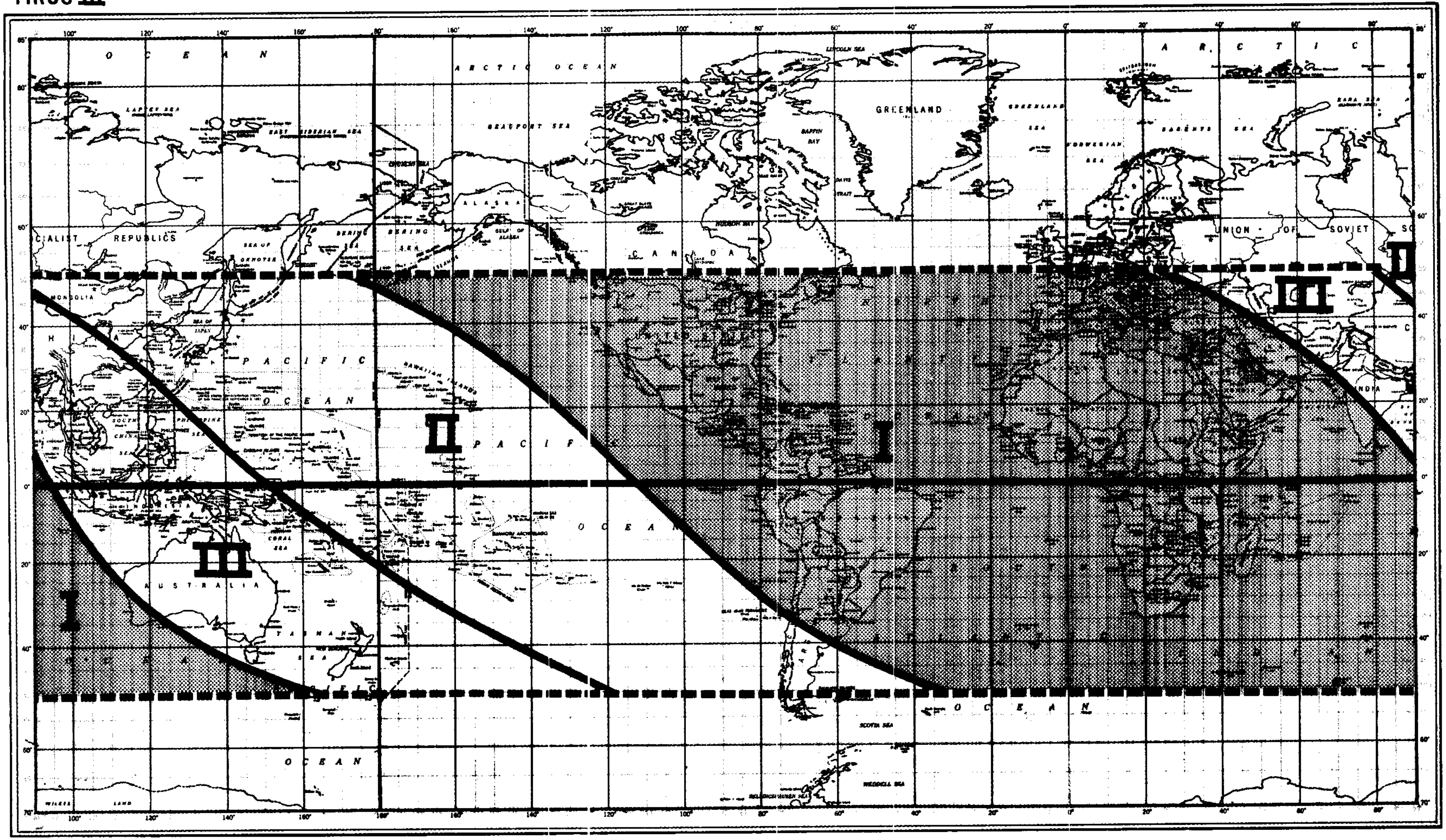
Example

Consider, as an example, the case of that part of Brazil between the Equator and 30° south latitude. On the southbound portions of the orbits, the northern part of the area is under an illuminated portion of the orbit from about September 15 to September 30; the southern part is under an illuminated portion from about September 21 to October 10. On the northbound portion of the orbits, the southern part of the area is under an illuminated portion of the orbit from about August 3 to August 23; the northern part is under an illuminated portion from about August 14 to August 28. However, Brazil is under Area I (most favorable condition) for southbound portions of the orbit while it is under Area III (least favorable conditions) for northbound portions. Accordingly, the most favorable period for TIROS pictures over Brazil would be during the period between about September 18 to October 3 when Brazil is under an illuminated southbound portion of the orbit. Perhaps a lesser effort might be set up for the period between about August 10 to 26; although illumination is satisfactory, Brazil is under those portions of the orbit that can be programmed only using the special Santiago clock-start mode. Consequently, there is much less chance of pictures being obtained over this area during August.

Derivation of maps and graphs

An overlay of the satellite track superimposed on a Mercator projection of the earth was used. The "high noon point" of the satellite orbit (that is, the point in any orbit at which the subsatellite point on the earth crosses the meridian of local high noon) is determined from the difference in right ascension (astronomical longitude) between the sun and the ascending node of the orbit. It is assumed that the minimum nadir angle (zero) occurs at this point—that is, the cameras are pointing straight down—and that the 30-minute illuminated area for a picture-taking sequence (one full 15-minute sequence per camera) will commence 15 minutes

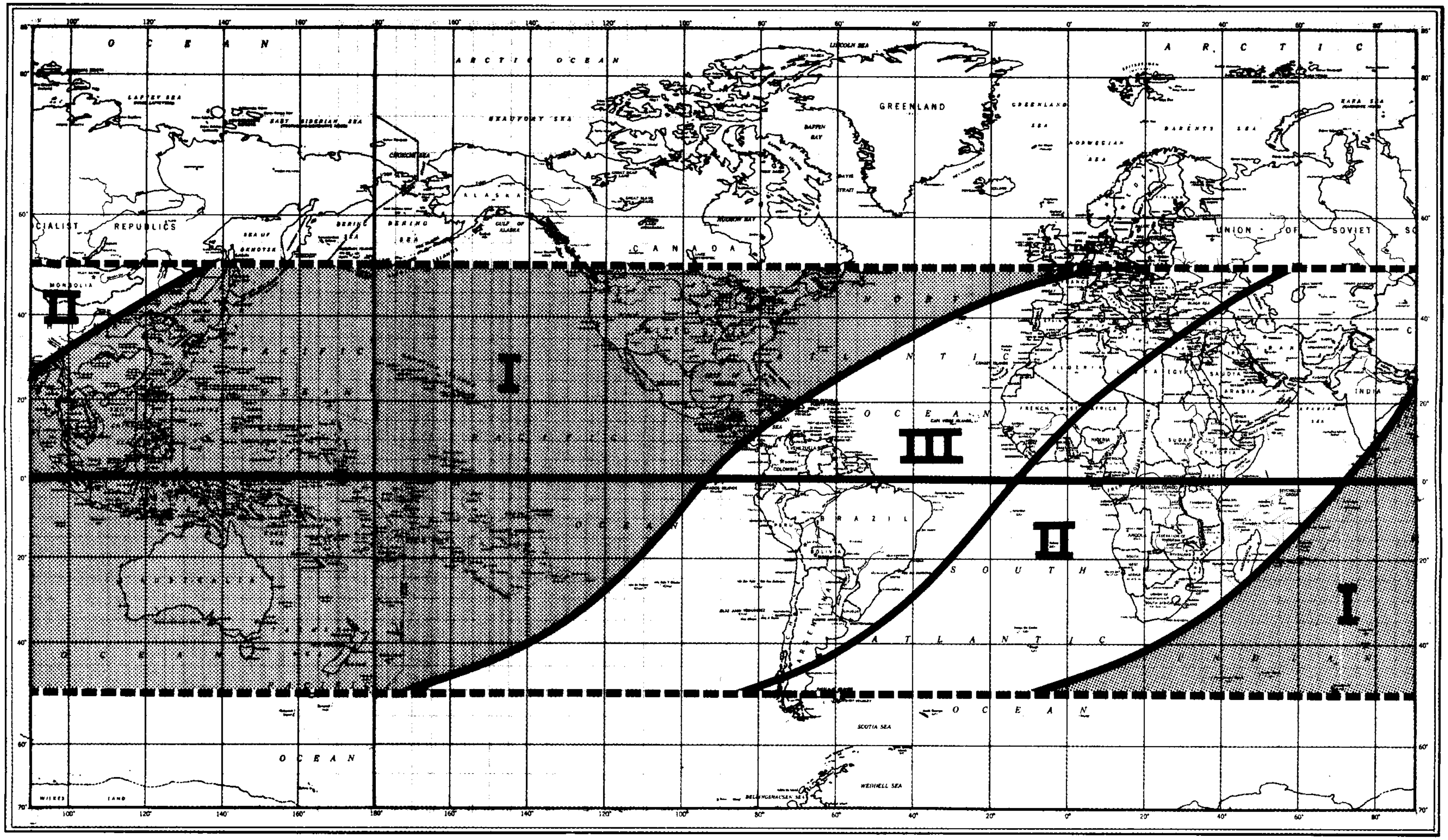
TIROS III



SOUTHBOUND PASSES

FIGURE A–3 (a).

TIROS III



NORTHBOUND PASSES

FIGURE A-3 (b).

before this point on the orbit and be completed 15 minutes after the high-noon point.

There are potential variations in the boundaries in the graphs and maps of 25° in longitude and 6° in latitude. The longitude may vary because of differences in the position of the first and the last orbits during which the satellite can be contacted by the two readout stations each 24-hour period. Both the longitude and latitude may vary, dependent upon camera attitude.

Assumptions

As mentioned previously, the assumption has been made that the minimum nadir angle (zero) occurs at high noon on the orbit and that the photographic sequence of the camera will evenly bracket high noon. In addition, it has been assumed that the satellite spin axis vector is in the orbital plane. In actual operation, the position of the minimum nadir angle will vary and the spin axis vector will generally be somewhat out of the orbital plane. A number of the picture sequences will be taken before or after high noon on the orbit in order to furnish a number of pictures with horizons to facilitate determination of attitude through photogrammetric techniques.

Thus, it will be possible under some conditions to obtain a limited number of pictures north of 48° north and south of 48° south, the extreme orbital subpoints. However, the probability of data being obtained decreases when proceeding poleward of these latitudes.

Other limitations

There follows a discussion of other factors which limit the data which can be obtained from Tiros III:

(*a*) Orbit inclination: Because the orbit of the satellite is inclined at an angle of slightly less than 50° to the equatorial plane, the satellite is unable to gather significant meteorologically useful data poleward of about 55° N. and S. latitude.

(*b*) Spin stabilization: For all practical purposes, the orientation of the spin axis of the spacecraft remains fixed in absolute space over any one orbit (the rate of change of the spin axis orientation due to use of the magnetic control coil cannot exceed about 15° per day). Accordingly, even under the most favorable circumstances with regard to the orientation of the spin axis and the position of the sun, the TV camera is pointed toward illuminated portions of the earth over only about one-third of each orbit. The interaction of the satellite with the magnetic field of the earth keeps the camera pointing approximately to the nadir near the high-noon point of the orbit, regardless of whether this occurs in the Northern or Southern Hemisphere.

(*c*) Magnetic tape storage capacity:

(1) Photographic data: During the period between the programing of the camera for remote (storage) picture operation and the reading out of the data from the tape recorder on the camera, only one set of 32 remote pictures, taken sequentially at 30-second intervals, can be obtained by a camera system. The overall length of the area observed during one sequential strip of 32 pictures is of the order of 6,000 miles (9,600 kilometers), at best. Accordingly, between successive contacts with the data acquisition stations, at best only one such set of 32 pictures can be taken by the camera system.

(2) Radiation data: Because these data are recorded on a continuously running endless loop magnetic tape which completes its cycle in about 100 minutes, data older than 100 minutes are erased as newer data are recorded. Thus, only data observed within 100 minutes before data read-out by a ground station can be obtained.

(*d*) Power: At times the rate of power provided by the solar cells is insufficient to permit the taking of as many TV pictures as would otherwise be available. The extent of this constraint varies with the precession of the orbit plane and the orientation of the satellite spin axis. In addition, available power gradually decreases as the nickel-cadmium storage batteries degrade with age and with repeated charge-discharge cycles.

Reference

1. Bandeen, William R., and Manger, Warren P.: *Angular Motion of the Spin Axis of the Tiros I Meteorological Satellite Due to Magnetic and Gravitational Torques.* Jour. of Geophys. Res. (Letter to ed.), vol. 69, no. 9, Sept. 1960, pp. 2992–2995.