BRAZILIAN STATION FOR TRACKING, RECEPTION AND PROCESSING FOR EARTH RESOURCES TECHNOLOGY SATELLITES (ERTS)

REPORT LAFE-188

April 1972

PR — National Research Council
Institute For Space Research (INPE)
São José dos Campos - SP - Brazil

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PRESIDÊNCIA DA REPÚBLICA
CONSELHO NACIONAL DE PESQUISAS
INSTITUTO DE PESQUISAS ESPACIAIS
São José dos Campos - Estado de S. Paulo - Brasil

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This document, whose publication was authorized by the undersigned, contains a detailed description of the specifications for the INPE station for ERTS program.

It is possible to able to record the MSS and RBV channels by late 1972 and have the automatic data processing system ready by March 1973.

This document is the result of team work on the subject, and the engineers Ronaldo V. Guimarães and Marne C. Serrano had a special participation in it.

Fernando de Mendonça
General Director

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CHAPTER 1

INTRODUCTION

1.1 - General Considerations

The purpose of this document is to present a study on a ground station to receive in Brazil the information transmitted by satellites of the ERTS series, the first of which will be launched by NASA in June 1972.

According to the final document submitted to NASA by General Electric (firm contracted by NASA to do the study of the ERTS program), the satellite and its recording system has a life span of one year and one thousand hours of operation, respectively. Taking into account that the data obtained by ERTS are of great usefulness for many countries, one might estimate that the one thousand hours of operation forecast for the wide-band tape recorder will be attained within approximately 6 months after the satellite lauching. So that the information destined to Brazil is not interrupted, it should receive it directly from the satellite through a ground station. As the station installed in the Brazilian territory could receive real time data covering many other South American countries, the Brazilian government with NASA concurrency may eventually contact the governments of those countries to verify if they are interested in participating in the program.

With such a station, Brazil could have at its disposal the necessary means to monitor in a repetitive way the resources of its territory. At any given day we could have information in image form and digital magnetic tapes from the most remote and farthest points of the national territory. These data could be provided to all the Brazilian agencies, private or not, which are linked to Carthography and Surveying and/or Exploration of natural resources.

Brazil's participation in the ERTS Program and in future programs on natural resource satellites would make it possible:

- To develop a map on the use of the Brazilian soil;
- To classify per areas the geological characteristics of the Brazilian soil;
- To develop an agricultural map for Brazil;
- To develop a map of the Brazilian forest reserves;
- To reduce losses in the agriculture through fast identification of plague infestation;
- To plan the distribution of the yearly production to the whole Brazil through estimating of the crops per area;
- To increase the production through the determination of soil characteristics and water reserve control;
- To plan in a better way the rural and urban development;
- To identify geological features, such as faults, folds, lithology, etc.;
- To monitor dynamic phenomena such as sedimentation,coastal changes, erosion, crop growing, water reserves, level, etc.;
- To evaluate the development at the constructing of big highways such as those under construction in the Amazon region;
- To collect data at fixed stations in remote points of the Brazilian territory, such as: level of the waters of lakes, reservoirs and dams; soil humidity, surface temperature; ocean salinity; ocean currents; atmospheric pollution; direction and velocity of the winds, etc.;
- To make an inventory of the water sources;
- To identify, monitor and evaluate the atmosphere and water pollution;
- To increase the fish production through the localization of the cold sea currents, of areas biologically rich and

of ideal temperature conditions for fishing;
- To plan in a better way sea voyages through sea conditions detected;
- To detect big navigation disasters;
- To make cartography surveying of the whole Brazilian territory;
- To make surveying of cloud coverages;
- To provide surveying of cloud coverages;
- To provide information with demographic inferences,etc.;
- To better plan the occupation of areas, such as Amazon region, and fiscalize such an occupation so as to make it rational, without major modification of its ecological equilibrium.

1.2 - The Brazilian Environment and the Imagery collected by Satellite

A way to take advantage of an immense region like the interior of Brazil, an area of 6 million square kilometers with a populational density of only 2 inhabitants per square kilometer, would be to develop in it activities compatible with its vastness and low population density. These activities could initially be restricted to points of limited areas where emphasis could be put on the exploration of local natural resources. The satellite capability to cover extensive areas of the Earth Surface in a short time and with relatively moderate expenses suits the necessity for ample initial surveying of these remote areas. This basic surveying, in its turn, will make possible the concentration of later surveys with airplane or conventional methods of surface in relatively small areas.

In relation to intermediary regions, between the central areas and the coast, also vast with about 2.5 million square kilometers but, in contrast, with a population density of 35 inhabitants per square kilometer, the use of sensors in airplanes, flying at high altitudes or on orbital platform, besides allowing the finding of new sources of natural resources or additional exploration of existing productive source, will certainly be useful in the economical exploration and control of the agriculture and forests on a regional level. The necessities of current information about the use of the earth and about the growing and condition of plants present an almost unlimited demand for data collected by remote sensing . Data collected from orbital altitudes have a special meaning for a country where extensive agriculture is predominant and the forests are in general huge. The data collected for specialists in agriculture and silviculture will probably be of equal importance for geographers and planners interested in ample regional developments.

On the other hand, there are at present in Brazil,organized efforts to solve the problems of economic development of immense regions with extremely different characteristics such as the humid Amazonic Basin and the dry Northeast.

An example of the application of data on soils, collected by satellite, would be that of help in the changing of existing conditions in the "campos cerrados", found in an area of about 1.5 million of square quilometers in Central Brazil and in above mentioned intermediary region. The research has shown that the problem is essentially of high acidity of the soil, what can be minimized through the addition of dolomitic calcareous and fertilizers. Along the extensive Brazilian Coast with more than 7 thousand kilometers, the data collected from orbital altitudes could delineate temperature contrasts which characterize the configurations of the Brazil current, on South and East Coast, and of Falklands currents (Malvinas) which reach the shores of extreme South during the Winter. Besides being important to the navigation, this information presents correlation to the movement to sea biological communities and therefore to commercial fishing.

1.3 - Systematic Survey of Natural Resources and the Images of Satellites

With surveys in 5 height levels as described later we could present a generic program which would permit to execute fast and economically:

- regional mapping, and
- selective mappings of more promising areas for the development of a determined region.

In this program, links of a dependency have been established, with increasing details, where it is presumed that a level of detection may serve as "truth" for the preceding higher level besides bringing a contribution of new information.

This approach results in a filtering system which besides making it possible to select more promising areas in each level of survey, would lead to a process for fast reduction of areas, where the evaluation or interpretation of data on larger areas would permit a rapid elimination of the parts of these areas that would show less potential.

In order to better locate the problem some information items on the collecting vehicle and the type and format of the data produced are then shown.

1.3.1 - Level for Orbital Survey (Highest Level)

1.3.1.1 - ERTS Satellites

The first Earth Resources Technology Satellite, known as ERTS-A, mentioned previously, will be launched by NASA in June 1972.Further information about it and its sensing and recording equipments will be presented in this report.

1.3.1.2 - SKYLAB

In addition to the satellites of the ERTS series, NASA will launch in 1973 an experimental space station, with a crew of three people, known as "SKYLAB WORKSHOP". This spacecraft will orbit at altitudes of 435 km (235 nautical miles), with an inclination of 50^0 and will rotate crews during three periods, the first of 28 days and the second and third of 56 days. In a total period of 8 months, 5 months will, practically,have manned operation.

Besides a great many scientific experiments, observations of the Earth are programmed for this project. As the Brazilian territory will be entirely covered by orbits of 50^0 of inclination in relation to the Equator, these observations will be particularly interesting to Brazil.

The sensing equipments of the Orbital station are described in the Appendix A.

Brazil, through INPE, proposed to NASA to participate in such program.

1.3.2 - Aircraft Survey Level at High Altitude

To give an example of this level we take the case of the Amazon Region where a CARAVELLE, of "LASA Engenharia e Prospecções S.A."; flying at a speed of 700 km/hour (380 knots) and at an altitude of 11.000 to 12.000 meters (36,000 to 40,000 feet) above the ground, is utilized for acquisition of radar imagery and photographic data. The Side Looking Radar (SLAR) utilizing synthetic aperture, type Good-Year model 102, presents spatial resolution better than 20 meters in all points of the images. It works in "X" band (3 cm of wavelength).

All the flights, controlled by a inertial navigation system, are performed along lines in the orientation N-S, making a lateral scanning of 37 km width, with adjacent scannings overlap of 30%. The presentation of the results is being performed in mosaics of 1^0 x 1.5^0, in the scale of 1:250.000.

The geographical linking of the lines of flight has been obtained through the use of SHORAN stations with determined geographic coordinates by observation of satellites with a Transit ground station operated by LASA and AEROSERVICES.

Besides the radar, a metric camera ZEISS is being utilized with a super-big-angular lens, provided with false-color infrared film.Its field of view permits overlapping with radar images.

The photos are being taken with 60% of longitudinal overlapping and small lateral overlapping and are presented in film format 23 x 23 cm (9 x 9 inches), in a scale of 1:130,000.

Simultaneously with the photos of the metric camera, multispectral photos in black and white have been obtained with a I^2S camera of four lenses. The scale is of 1:73,000 with four images displayed on every film frame of 23 cm. The coverage is therefore partial, almost 25% of the total.

1.3.3 - Aircraft Survey Level at Medium Altitude

In the third level, which would be an aerial reconnaissance on regional scale, performed at this time at medium altitudes, it would be sought to conciliate the employment of geophysical sensors, considered today as a basic requirement for the geological reconnaissance of great areas, such as multispectral aerial photographies, in scales of current use among the photo-interpreters interested in the additional disciplines.

The flight altitude in this survey, which might be qualified as a transition, would be between 9,000 to 11,000 feet above the ground (3,000 m nominal) with flight lines spaced 5 km, cut by transversal lines each 25 km.

To control flight lines and their geographic positioning, inertial or doppler navigation systems are used.

It is appropriate to say that the utilization of other sensors such as electromagnetometers, thermal imagers, spectrometers of gama or mercury radiation, due to the fact that their maximum altitudes of aerial use are very low and, therefore, are incompatible with that specified to this stage.

The two preceding stages, where we would seek to take advantage of sensors susceptible of being applied in large scale areas, would be complemented by the one just outlined, in which a survey of transition from regional to local is suggested. This survey, in acceptable conditions of performance, time and cost, would give data whose nature and degree of definition would permit more selective studies. The information obtained through these surveys would certainly make possible not only the basic mapping but also the choise of more promising areas which would be the targets of the conventional detailed surveys mentioned next.

This selection would be obviously facilitated by a study of existing information about the region and by the consideration of the data collected during the visual aerial reconnaissance, forecasted also for this stage.

The set of accumulated data in the third stage would serve as the "truth" for the preceding higher levels of reconnaissance.

1.3.4 - Aerial Detailing Level at Medium and Low Altitude

The services for detailed surveying of the areas selected as more promising in the preceding stage would require a specific planning for each case. However, certain steps seem to be indispensable. It is included, in this case, a preliminary measure which aims at eliminating the natural uncertainties of interpretative processes: a short trip for reconnaissance of the ground, to the areas, qualified as promising. Probably, the data of greater interest to be obtained in loco would be geochemical ones. Distances and difficulties to reach the areas would be factors considered in the priority classification of the areas considered as promising.

Initially, at this level the utilization of the following sensors in combined system would be considered.

- Imagers (thermal in the visible in the ultraviolet,etc.);
- Magnetometers;
- Electromagnetometers;
- Mercury Spectrometers;
- Gamma radiation Spectrometers.

All these sensors should be used in flights at low altitude. The plotting of the data collected would be in scale of photomosaics obtained by aerial photographic coverage in scales more convenient to cartographic needs of each target-area.

In the same way as in the third stage, the flights would continue to be utilized for visual observation. Once again this level would serve as "truth" for the preceding levels by a re-evaluation of the areas qualified as promising and would permit a final selection of those which would deserve the studies of the next stage.

1.3.5 - Ground

Although the surveys at this level are qualified as "ground truth", the work which would be done in it should also have an exploratory feature. The sites chosen should be considered as advanced bases for relatively prolonged operation and even as eventual poles of development of the area.

Considering these conditions, bigger investments in the development of the chosen areas would be justified. Such a development should include, for example, the building of landing fields and other material resources which, besides allowing a longer permanence of the personnel at the place, would permit the efficient execution of the field works.

In a more critical form than in the preceding stage, the research on the ground to be performed in these areas should be object of careful specific planning .

CHAPTER 2

ERTS SYSTEM

The control and conservation of the natural resources of the earth is vital to the future of mankind. An attempt for such control and conservation will be done through the ERTS Program (Earth Resources Technology Satellite), under NASA responsibility.

The ERTS-A will be the first of a serie of satellites aiming at providing the first data about the natural and cultural resources of the Earth collected by a systematic way and will be launched in June 1972. This satellite with a forecasted lifetime of one year, will have a quasi polar circular, sun-synchronous orbit, so that each point of the earth surface be repeated covered each 18 days always at the same time.

The ERTS satellite will carry a Multispectral Scanner System (MSS), Return Beam Vidicon (RBV), Wide Band Tape Recorders (WBTR), and a Data Collection System (DCS) for the acquisition of data from earth based Data Collection Platforms (DCP). The satellite's payload will include, in addition to the two sensing systems, equipment to transmit outputs from the sensor plus information about housekeeping and the status of the spacecraft. The satellite will transmit synchronization and calibration signals along with the video signals.

The data originated by the MSS and RBV, the DCS signals, the tracking signals and the information on the operating status of the system will be transmitted to ground in the S-band frequency range. On the ground such data will be received, recorded and transformed later in photographic images and digital tapes for direct access to the computer (CCT - Computer Compatible Tapes).

The ERTS Program is the precursor of the EROS Program which comprises satellites for observation of Earth Resources (EOS) and which should be implemented by NASA in the second half of the this decade.

2.1 - Sensors

The spectral band covered by the two types of sensors (RBV and MSS) has been chosen with great care and with the help of several user agencies of the ERTS Program.

The television cameras (RBV) have been designed for the following spectral bands:

0.475 - 0.575 microns (blue-green);

0.580 - 0.680 microns (orange-red);

0.690 - 0.830 microns (red).

The lower band, 0.475 - 0.575 microns, will allow the study, for example, of areas where the water predominates. The upper band, 0.690 - 0.830 microns, centered more or less in 0.750 microns (peak of radiation for chlorophyll) will allow the study of areas covered by green vegetation. The upper limit of 0.830 microns represents the limit response of the television system. The information of the infrared is located above this limit, also required by the users of ERTS; to provide this information and to also cover the same band of the television system, the multispectral scanner (MSS) was especified. The MSS provides information in the following bands:

0.500 - 0.600 microns (green to orange);
0.600 - 0.700 microns (orange to red);
0.700 - 0.800 microns (red to near infrared);
0.900 - 1.100 microns (near infrared).

The three first bands are in the visible spectrum and the last one in the near infrared. In each band there are six photo-detectors. A simple scanning of the mirror of the multispectral scanner will provide information about a strip of 100 nautical miles for all the 24 photodetectors. Table 2.1 shows the main characteristics of the two sensors (RBV and MSS) and of wide band tape recorder (WBVTR) of the satellite.

The resolution or definition of the resulting multispectral images of the two types of sensors are from 60 to 130 meters, but it has been forecasted that some objects of smaller dimensions can be discovered and recognized. The images will have scale of about 1:1.000.000 and may be transformed, on the ground, in black and white photographs for each sensor spectral band. Thus, for each area of 100 x 100 nautical miles there will be seven images. The several images may be composed so as to provide color or false color images.

The second Earth Resources Technology Satellite, ERTS-B, will have essentially the same specifications of the ERTS-A, except for the addition of an extra spectral band in the multispectral scanner (10.4 to 12.6 microns - thermal infrared).

Table 2.1 - Multispectral Sensors (RBV and MSS) and Recorder (WBVTR) Characteristics.

RBV Camera Subsystem

Characteristic	Camera No. 1	Camera No. 2	Camera No. 3
Spectral Bandwidth (nanometers)	475-575	580-680	690-830
Resolution (at maximum scene highlight contrast)	4500 TVL	4500 TVL	3400 TVL
Edge Resolution (percentage of center)	80	80	80
Signal-to-Noise Ratio (at 10 TVL)	33 dB	33 dB	25 dB
Dynamic Range	50:1	50:1	50:1
Gray Scale ($\sqrt{2}$ transmission steps)	10	10	8
Horizontal Scan Rate (lines/sec)	1250	1250	1250
Number of Scan Lines	4200	4200	4200
Readout Time (seconds)	3.5	3.5	3.5
Video Bandwidth (MHz)	3.5	3.5	3.5
Time Between Picture Sets (seconds)	25	25	25
Exposure Time (milliseconds)	8, 12 or 16	8, 12 or 16	8, 12 or 16
Image Distortion (maximum)	1%	1%	1%
Deflection Skew (maximum)	+0.5%	+0.5%	+0.5%
Size and Centering Shift (maximum)	± 2%	± 2%	± 2%

Multispectral Scanner Subsystem

Spectral Bandwidth (microns)	Channel 1	0.5 to 0.6
	Channel 2	0.6 to 0.7
	Channel 3	0.7 to 0.8
	Channel 4	0.8 to 1.1
	Channel 5	10.4 to 12.6 (ERTS B only)
Scanning	Object Plane	
Scan Rate	13.6 Hz	
Scan Efficiency	50%	
Detectors/Band/Scan (Channels 1 thru 4)	6	
Instantaneous Field of View	260 ft x 260 ft	
Multiplexer Output	15 Mbps PCM	

Wideband Video Tape Recorder/Reproducer

Scanning Principle	Transverse Scan
Video Processing Technique	FM
Tape Width	2 in.
Tape Length	2000 ft
Record Time	30 minutes
Rewind Speed	4 times record speed
High Speed Forward	4 times record speed
Bandwidth	DC to 3.5 MHz (-6 dB), DC to 6 MHz
Signal-to-Noise Ratio	42 dB p-p/rms @ 2.5 MHz, BW
Transient Response	Approx 5% peak (overshoot)
Linearity	± 3%
Drift	± 5% input to output
Switching Transients	Below peak-to-peak noise
Head Wheel Start Power	Approx 250 watts peak decreasing to average power in 4 seconds

2.2 - The Orbit

The satellite orbit is circular, quasi polar, sun synchronous and keeps a constant inclination of 99.088 degrees. Whith this orbit, the satellite sensors will always scan the same area with the same solar illumination, making it simpler to detect changes in vegetation and levels of water. The satellite will cover 100 nautical mile wide strip, returning to scan the same area at the same local time, each 18 days. The equipment controlling the attitude of the satellite detect position errors so that the satellite can be positioned correctly with errors inferior to 0.7 degrees in relation to the three axes of position.

The orbital parameters of the ERTS are adjusted so that the adjacent strips have sidelap of 10% on each side in the absence of any attitude error.

The ERTS orbit has a semi-major axis of 7,300 km and an approximate period of 103 minutes. The geographical longitude of subsequent passages of the ERTS under the Equator shifts by 25.8167 degrees towards West. Coverage of adjacent bands occur each 14 revolutions and are separated in longitude of 1.4338 degrees, i.e, 160 km at the Equator. At the end of 18 days or conclusion of 251 revolutions the period of coverage is completed.

Table 2.2 shows some nominal orbital parameters.

Table 2.2 - Nominal Orbital Parameters

Orbital Parameters	Nominal Orbit
Altitude	492.35 mn (912 km)
Inclination	99.088 degrees
Period	6196.015 sec (103 min)
Eccentricity	0.0001
Local time when the satellite crosses the Equator descending	09:30 h
Duration of the cycle of coverage	18 days (251 revolutions)
Distance between adjacent ground tracks at Equator	86.028 mn (160 km)

CHAPTER 3

ERTS LINKS

The frequency assignments and bandwidths for the ERTS-A and B are as follows:

Link 1: USB - Uplink for command

RF carrier: 2106.4 MHz
Bandwidth: 3.6 MHz
Modulation: PCM/FSK - FM/PM

Link 2: MSS - Downlink (MSS Data)

RF carrier: 2229.5 MHz
RF bandwidth: 20 MHz
Modulation: PCM/FSK
Bit rate: 15 mb/sec

Link 3: RBV - Downlink (RBV Data)

RF carrier: 2265.5 MHz
Video bandwidth: 3.5 MHz
RF bandwidth: 20 MHz
Modulation: Video/FM

Link 4: USB - Downlink (narrowband data)

RF carrier: 2287.5 MHz
Bandwidth: 5 MHz
Modulation: PM

Link 5: VHF - Downlink (telemetry data)

RF carrier: 137.86 MHz
Bandwidth: 90 KHz emergency; 30 KHz normal
Modulation: PCM/PM

Link 6: DCS - Data collection uplink

RF carrier: 401.9 MHz
Bandwidth: 100 KHz
Modulation: PCM/FSK

Link 7: VHF - Uplink for command

RF carrier: 154.2 MHz
Bandwidth: 30 KHz
Modulation: PCM/FSK - AM/AM

For the reception and processing of ERTS imagery only links 2,3, and 4 are relevant. Link 5 provides a back-up for telemetry data also transmitted by link 4. Brazil's station may eventually receive these data also via link 5. Link 6 is used to transmit data from ground platforms to the satellite (DCS system). Links 1 and 7 are required to command and control the satellite and sensor interrogation; the Brazilian station will not need equipments for these links since NASA could program the satellite for Brazilian coverage.

3.1 - Wideband links (RBV and MSS)

The main characteristics of these two links are summarized in table 3.1.

Table 3.1 - Wideband Links

	MSS	RBV
Center frequency	2229.5 MHz	2265.5 MHz
RF bandwidth	20 MHz	20 MHz
Transmitter power	20* watts	20* watts
Modulation	PCM/FSK	Video/FM

* Commutable power of 10 or 20 watts

3.2 - USB downlink

This link is capable of transmitting all narrowband data plus PRN signal.

The general specifications are the following:

Carrier frequency: 2287.5 MHz ± 0.0015%, non coherent mode.
240/221 times USB uplink carrier frequency, coherent mode.
Modulation: Phase modulation
RF bandwidth: 5 MHz

It is necessary to transmit simultaneously the following signals on the USB downlink carrier:

1 - DCS signal
2 - Real time PCM telemetry
3 - Stored PCM telemetry

The stored PCM telemetry signal normally transmitted is the one recorded by the satellite narrowband tape recorder (NBTR). In case these tape recorders fail, the signal to be transmitted is the one recorded on the auxiliary channels of the wideband tape recorders (WBVTR). A description of the main characteristics of each signal follows.

DCS signal

Signal description: frequency modulated sine wave
Bandwidth: 100 KHz centered in the frequency of 1024 KHz

Real time PCM telemetry

Signal description: PCM split-phase
Bit rate: 1 kilobit/sec.
Detection error probability: less than 10^{-6}

Stored PCM telemetry signal

Sinal description: PCM split-phase
Bit rate: 24 kilobit/sec when the signal is recorded in the NBTR, or
1 kilobit/sec. when the signal is recorded in the WBVTR.
Detection error probability: less than 10^{-6}

In order to transmit the three signals simultaneously on the USB downlink carrier it is necessary to use several subcarriers. The subcarriers used are the following:

Subcarrier	Subcarrier modulation type
1024 KHz	PCM/FSK/PM
768 KHz	PCM/PSK/PM
597 KHz	PCM/PSK/FM

3.3 - VHF downlink

This link is used to transmit either the real time PCM telemetry signal or the stored PCM telemetry signal. This link provides a back-up for the USB downlink.

The general characteristics of this link are the following:

- Center frequency of transmission: 137.86 MHz
- Channel bandwidth: 30 KHz, in real time
  90 KHz, stored

The description of each signal follows:

Real time PCM telemetry signal

Signal description: PCM split-phase
Bit rate: 1 kilobit/sec.
Detection error probability: less than 10^{-6}

Stored PCM telemetry signal

Signal description: PCM split-phase
Bit rate: 24 kilobit/sec. or 1 kilobit/sec.

3.4 - USB uplink

In this link the following signals are transmitted:

- Pseudo randon-noise (PRN) ranging signals
- Command signal

The general characteristics are the following:

- Carrier frequency 2106.4 MHz
- Carrier modulation: phase
- Information bandwidth: 1.5 MHz
- Command subcarrier frequency: 70 KHz

3.5 - VHF uplink

In this link the same signals of command of the USB uplink are transmitted. The general characteristics are the following:

- Carrier frequency: 154. 2 MHz
- Modulation: PCM/FSK - AM/AM
- Carrier modulation index: 80% AM (peak)
- Command subcarriers: 8.0 KHz to 8.6 KHz
- Command bit rate: 128 bps

- Probability of error in command detection: less than 10^{-6}
- Bandwidth: 30 KHz

CHAPTER 4

LINK CALCULATIONS

4.1 - RBV Link (Return Beam Vidicon)

The three "Return Beam Vidicon" cameras will operate simultaneously and will generate a video signal covering the frequencies from DC to 3.5 MHz. The output signal of the cameras may enter the input terminals of the wide band transmitter for transmission in real time or enter one of the wide band tape recorders (WBVTR 1 or 2) for recording and later play-back for transmission. At the ground receiving station, a wide band discriminator processes the signal received above the threshold together with the noise, recovering the video signal with an increase in the signal/noise (S/N) ratio after the detection.

For the RBV link the frequency of 2265,5 MHz was specified. The RF bandwidth of 20 MHz is also considered as the noise bandwidth. Using a power of 20 or 10 watt transmitter in the satellite for an angle of elevation of the antenna of the receiving station of 5^0, we conclude that:

- The gain of the satellite antenna for an elevation angle of 5^0 for the ground antenna is better than 4.0 db. This value includes the polarization losses;
- The transmission losses were calculated at 1.35 db. These losses include the losses between the ouput terminals of the power amplifier and the input of the antenna terminals, including losses in the filters, connectors, cables, circulators, etc. The atmospheric losses are considered for 5^0 of elevation and estimated at 0.7 db.
- The losses of the free space are calculated from the formula:

$$L_{FS} = 20 \log \frac{\lambda}{4\pi d}$$

where,

$$d = (R_e + h) \frac{\text{sen } \delta}{\text{sen}(90^0+\alpha)} \text{, and}$$

$$\delta = \cos^{-1} \left(\frac{R_e}{R_e + h} \right) - \alpha$$

Using the altitude h = 492 nautical miles (910 Km), elevation angle $\alpha = 5^0$ and radius of the Earth R_e = 6380 Km, we find

$$\delta = 24.3 \text{ degrees}$$

$$d = 1620\text{nm} \quad (3000\text{km})$$

$$L_{FS} = 169.1 \text{ db}$$

- The thermal noise power in a 20 MHz equivalent band is calculated from N = KTB, where

$$K = 1.38.10^{-23} \text{ Joule}/{}^0\text{K}$$

$N = 10 \log_{10} 1,38.10^{-23}$ dbw by ^{0}K by Hz, what leads to,

$N = -228.6$ dbw by ^{0}K by Hz.

4.1.1 - Selection of FM parameters

The signal to noise ratio $(S/N)_o$ in the discriminator output terminals is given by

$$(1) \quad (S/N)_o = \frac{3}{2} \left(\frac{\Delta f}{f_m}\right)^2 \frac{B_{RF}}{f_m} \; (C/N)$$

Where:

Δf is the peak deviation from center frequency of the RF signal

f_m is the modulating frequency

B_{RF} is the RF bandwidth, and

C/N is the carrier - to - noise ratio at

the input terminals of the discriminator

Using

$f_m = 3.5$ MHz

$B_{RF} = 20$ MHz

The modulation index (ρ) was calculated through the analysing of Bessel's functions so that the energy out of the lateral bands be no greater than 1 % of the total energy.

With $\beta = 1.6$ the energy outside the band of 20 MHz is approximately 1,1 %.

The Modulation Improvement Factor (MIF) is computed from

$$\mathrm{MIF} = \frac{3}{2} \left(\frac{f}{f_m}\right)^2 \frac{B_{RF}}{f_m}$$

With the index $\rho = 1{,}6$ results a value of

MIF = 22 or 13,4 db.

The equation (1) is valid for a sine modulating signal; when the video signal is applied, the following consideration must be taken into account:

- The information signal is 80 % of the video signal peak to peak. The signal to noise ratio S/N at the detector output will then be $(0.8)^2$ times the signal to noise ratio of peak, corresponding to a reduction of 2 db.

- The video signal which produces the same peak to peak FM deviation of a sine signal has a power 8 times bigger than the average power of sine signal. The signal to noise ratio will have then an increase of 9 db.

We should consider an increase in the carrier to noise ratio of 13.4 due to MIF, a reduction of 2db due to the first consideration above and an increase of 9 db due to the second consideration. That is an increase of 20.4 db.

Two types of stations with the corresponding specifications, gain of antennas, antenna noise temperature and receivers with a margin of 6 db are considered. The two types of stations are presented next.

Receiver station with parabolic antenna of 9 meters diameter

For the RBV link a power of transmission of 20 or 10 watts can be used.

- Spacecraft transmitter power.

  $P_T = 43$ dbm for 20 watts

  $P_T = 40$ dbm for 1o watts

- Spacecraft antenna gain: 4.0 dB includes the polarization losses.
- Transmission losses:-1,35 dB.
- Space losses:-169,8 dB.

  Free space loss: -169,1 dB.
  Atmospheric loss: - 0,7 dB
  -169,8 dB

- Receiver antenna gain: The gain is computed from the formula:

$$G = \eta \frac{(\pi D)^2}{\lambda}$$

for $\eta = 55$ % and D = 30 feet G = 44 dB

- System temperature: $T_s = 125^0K$
- Noise power in the band of 20 MHz: -104,6 dBm

N = KTB

$K = 1,38\ 10^{-23}$ Joule/^0K
$T = 125^0K$
B = 20 MHz

N = 104,6 dbm.

- System margin: - 6 dB
- Received power: - 86,15 dbm

4 + 43 + 44 = 91 db
169,8 + 6 + 1,35 = -177,15
- 177,15 + 91 = -86,15 dbm

- Carrier to noise ratio: + 18,45 db
  - 86,15 - (-104,6) = + 18,45
- FM improvement: 13,4 db

  for $\beta = 1,6$
- Detected signal to noise ratio S/N

  S/N = 18,45 + 13,4 - 2+9 = 38,85 db

Receiver station with parabolic antenna of 6 meters diameter

- Spacecraft transmitter power

  43 dbm for 20 watts
  40 dbm for 10 watts
- Spacecraft antenna gain: 4.0 db
- Receiver antenna gain:
  for η = 55 %
  D = 20 feet we get G = 40.5 db
- System temperature: $T_s = 125^0K$ or 75^0K
- Noise power (20 MHz):

$N = KTB \quad T_s = 125^{0}K \rightarrow N = -104{,}6$ dbm

$T_s = 75^{0}K \rightarrow N = -106{,}85$ dbm

- System margin: - 6 db
- Carrier to noise ratio

For $T_s = 125^{0}K \rightarrow 15{,}45$ db

For $T_s = 75^{0}K \rightarrow 17{,}70$ db

- Signal to noise ratio

For $T_s = 125^{0}K \quad \frac{S}{N} = 35{,}85$ db

For $T_s = 75^{0}K \quad \frac{S}{N} = 38{,}1$ db

The results for an elevation angle of 5^{0} and for a transmitter power of 20 watts are shown in table 4.1

Table 4.1 - RBV Link Calculation

Parameters	5 Degree Elevation		
	30 Ft. Dish	20 Ft. Dish	
Spacecraft transm. pow.	43 dbm	43dbm	43 dbm
Spacecraft antenna gain	4.0 db	4.0 db	4.0 db
Transmission Loss	- 1.35 db	- 1.35 db	- 1.35 db
Space loss	- 169.8 db	- 169.8 db	- 169.8 db
Receiver antenna gain	44,0 db	40.5 db	40.5 db
System temperature	125°K	125°K	75°K
Noise power	-104.6 dbm	- 104.6 dbm	- 106.85 dbm
System margin	- 6 db	- 6 db	- 6 db
Received power	- 86.15 dbm	- 89.15 dbm	- 89.15 dbm
Carrier-to-noise ratio	+ 18.45 db	+ 15.45 db	+ 17.70 db
FM improvement (β = 1.6)	+ 13.4 db	+ 13.4 db	+ 13.4 db
Detected signal-to-noise ratio (peak to peak)	+ 38.85 db	35.85 db	38.1 db

4.1.2 - Signal Degradation

The sensor output signal to noise ratios are given as 33,33 and 25 dB for I, II and III cameras respectively.

We consider the complete link and examine the degradation suffered by the signal transmitted in real time.

The signal to noise ratio at the output terminals of the receiver of the ground station is given by,

$$(S/N)_o = \left[\frac{1}{(S/N)_S} + \frac{1}{(S/N)_{TL}} \right]^{-1} \qquad \text{where}$$

$(S/N)_S$ - signal to noise ratio of the cameras

$(S/N)_T$: - signal to noise ratio of the transmission link

Considering camera I,

$(S/N)_S = 33$ db $\qquad (S/N)_{TL} = 38,85$

$33 \text{ db} \longrightarrow 2,10^3$

$38,85 \text{ db} \quad 7,7.10^3$

$$(S/N)_o = \left[\frac{1}{2.10^3} + \frac{1}{7,7.10^3} \right]^{-1} \longrightarrow 32,1 \text{ dB}$$

i.e, a degradation of $\simeq$ 0,9 dB

Figure 4.1 shows that if the degradation is to be maintained equal to or smaller than 1 dB, the $(S/N)_{TL}$ has to be in excess of 38.7 dB. We can then calculate the degradation for three considered ~~considered~~ conditions of operation:

Operation	power	$(\frac{S}{N})_{TL}$	degradation
Antenna 30 Ft $T_s = 125^oK$	20W	+38.85 db	-0.9 db
Antenna 20 Ft $T_s = 125^oK$	20W	+35.85 db	-1.8 db
Antenna 20 Ft $T_s = 75^oK$	20W	+38.1 db	-1.0 db

These results show a more convenient operation with an antenna of 30 Ft. Observe that the system temperature ($T_s = 125^oK$) considered for illustration of the calculations is attained in systems utilizing a cooled parametric amplifier; in systems utilizing uncooled parametric amplifier the system temperature will be bigger than 200^oK.

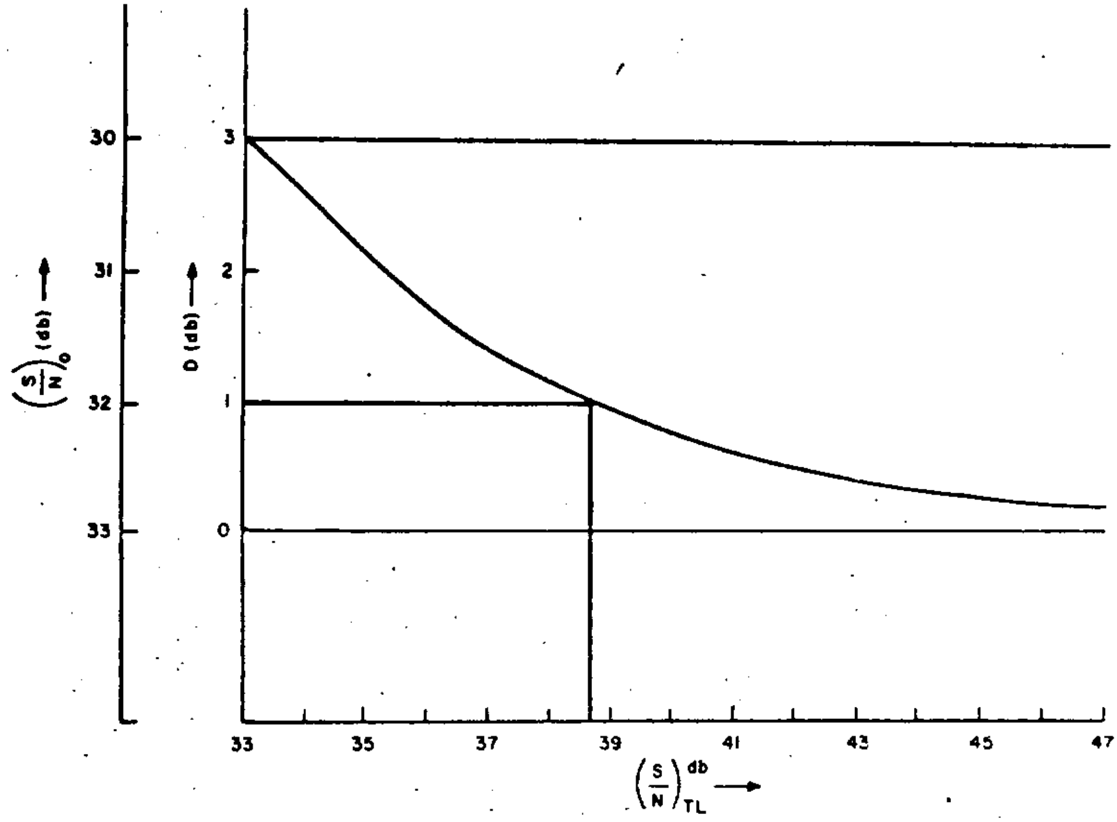


Fig. 4.1 - Signal Degradation (RBV).$(\frac{S}{N})_S$ = 33 db

4.2 - MSS Link

The wideband MSS link occupies a band of 20 MHz with PCM/FSK modulation and center frequency of 2229,5 MHz.

Theoretical and experimental investigation show that the carrier energy to noise density ratio influences the probability of error at the detection; for a probability of error, $P_e = 10^{-5}$, a relation of 14.0 db with detection discriminator is obtained. With an optimum coherent receiver C/N = 13,0 db for $P_e = 10^{-5}$ is obtained. Experimental results indicate 13,5 db. Table 4.2 shows the link calculations:

Table 4.2 - MSS Link Calculations

5 Degree Elevation			
Parameters	30 Ft	20 Ft	20 Ft
Spacecraft transm. power	43 dbm	43 dbm	43 dbm
Spacecraft antena gain	4.0 db	4.0 db	4.0 db
Transmission loss	-1.35 db	-1.35 db	-1.35 db
Space loss	-169.66 db	-169.66 db	-169.66 db
Receiver antenna gain	44.0 db	40.5 db	40.5 db
Temp. System	125° K	125°K	75°K
Noise power	-105.8 dbm	-105.8 dbm	-108.05 dbm
System margin	-6 db	-6 db	-6 db
Received power	-86.01 dbm	-89.01 dbm	-89.01 dbm
Carrier-to-noise ratio	+19.79 db	+16.78 dbm	+19.04 db

Taking the more pessimistic value of C/N = 14.0 db for a probability of error $P_e = 10^{-5}$, we will have extra margin of 5.79 db, 2.78 db or 5.04 db. Each of these numbers must be reduced 1.5 db to take into account the degradation due to the distortion of delay time. Table 4.3 is then obtained.

Table 4.3 - Extra margin for the MSS link

Operation	Power	Margin
Antenna 30 Ft $T_s = 125^oK$	20W (10W)	4.29 db (1.29 db)
Antenna 20 Ft $T_s = 125^oK$	20W (10W)	1.28 db (-1.72 db)
Antenna 20 Ft $T_s = 75^oK$	20W (10W)	3.54 db (0.54 db)

The MSS link parameters are essentially the same calculated for the RBV link with the following exceptions:

- The central frequency for the MSS link is 2229.5 MHz,which results in a reduction of 0.14 in the loss of free space.
- The predetection of the MSS link is limited to the bit rate (15 MHz between the 3 db points).

The same observation made for the RBV link with relation to the system temperature ($T_s = 125^oK$) utilized to illustrate the calculations is valid.

4.3 - UBS downlink

The USB down signal S (t) has the following form:

$$S(t) = \sqrt{2C} \cos \left[w_c t + \sum_{i=1}^{n} \theta_i \cos(w_{si} t + \phi_i (t)) + \theta_{n+1} U(t) + n(t) \right] \qquad (2)$$

where:

c = received total power
w_c = carrier frequency
θ_i = peak phase deviation of carrier due to ith subcarrier
θ_{n+1} = peak phase deviation of carrier due to ranging signal
w_{Si} = i-th subcarrier frequency
$\phi_i(t)$ = information which is angle - modulation on i-th subcarrier
$U(t)$ = two level ($\pm$ 1) square wave ranging signal
$n(t)$ = Gaussian band limited noise (density N_0)

Figure 4.2 shows a typical demodulation system of the USB signal, without the PRN signal.

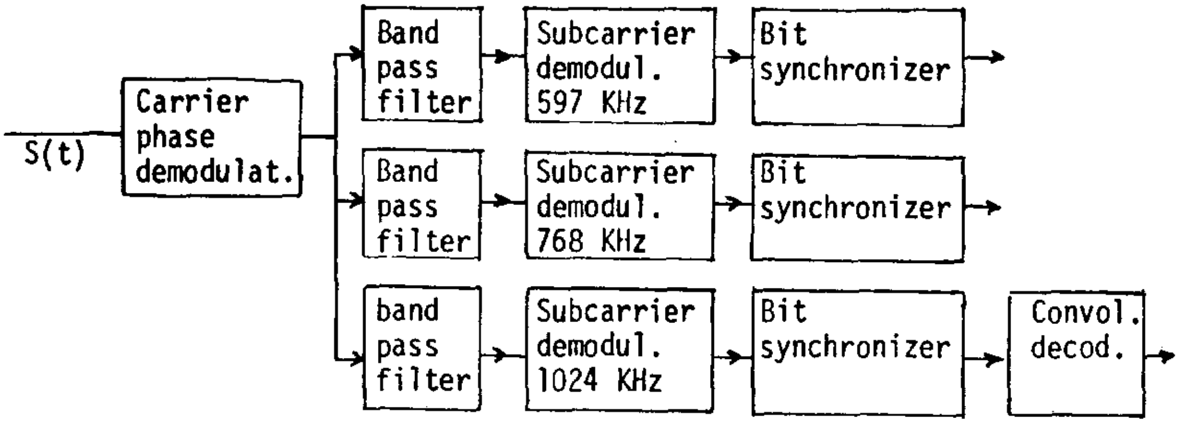


Fig. 4.2 - USB signal demodulation.

Table 4.4 shows the IF bandwidth for each subcarrier.

Table 4.4 - IF bandwidth for each subcarrier

SUBCARRIER	IF BANDWIDTH
1024 KHz	6 KHz, 150 KHz, 600 KHz
768 KHz	20 KHz, 35 KHz
597 KHz	sufficient for at least 24 Kbs.

4.3.1 - Required S/N_0 for each subcarrier channel

597 KHz Channel

The stored PCM telemetry signal modulates a subcarrier of 597 KHz.

A perfect detector for PCM/FSK needs an energy by bit to noise power density ratio (E/N_0) at the detector input according to Fig. 4.3 in function of the probability of error, P_e.

For a probability of error smaller than 10^{-6}, E/N_0,should be bigger than 10.5 db for a perfect detector. Adding 2.5 db for a real detector, E/N_0 must be bigger than 13.0 db to get a probability of error smaller than 10^{-6}.

$$\frac{E}{N_0} = \frac{ST}{N_0}$$

S - average power at the subcarrier

T - period by bit = $\frac{1}{\text{bit rate}}$

$\frac{1}{T}$ = 24 Kbit/sec.

$$\frac{S}{N_0} = \frac{1}{T}\left(\frac{E}{N_0}\right) = 13.0 \text{ db} + 10 \log_{10} 2.4.10^4$$

$$= 13.0 + 43.8 = 56,8 \text{ db Hz}$$

$$\left(\frac{S}{N_0}\right)_1 = 56.8 \text{ db hz}$$

where $(S/N_0)_1$ is the signal to noise ratio required for the 597 KHz subcarrier.

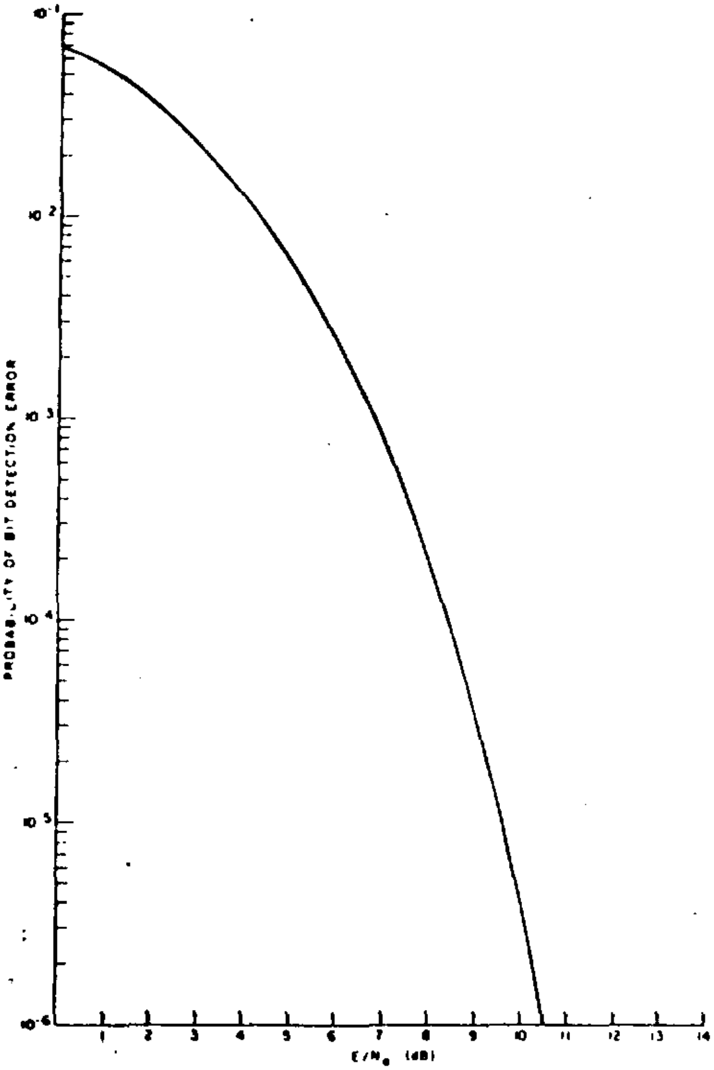


Fig. 4.3 - Relation between P_e and E/N_0 for an ideal coherent PCM/PSK

1024 KHz Channel

The 1024 KHz channel is used to receive the DCS signals. This signal consists of a sinusoid of center frequency 1024 KHz, which is frequency modulated by the information and noise. More noise is added to the information signal in the downlink. The total signal to noise ratio $(S/N)_{total}$ at the input of the processer at the receiving station should be zero db in a bandwidth of 100 KHz centered in 1024 KHz.

The calculation of the signal to noise ratio for this channel provides $(S/N_0)_2 = 66.0$ db Hz.

768 KHz Channel

This channel is used to transmit the real time PCM telemetry signal. This signal modulates a subcarrier of 768 KHz.

Fig. 4.4 shows the block diagram of the detector for the signal of the channel of 768 KHz.

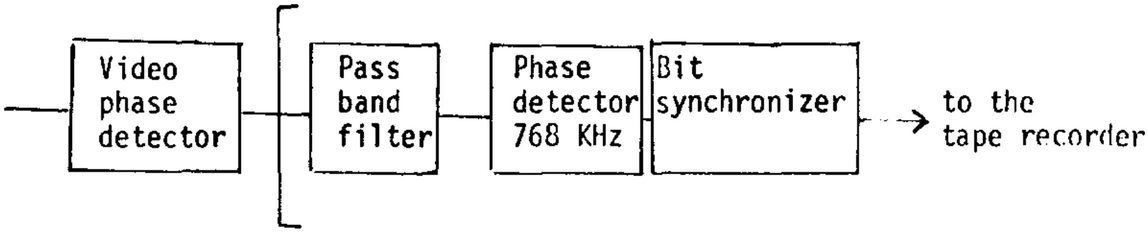


Fig. 4.4 - Detection of the channel of 768 KHz.

The value of S/N_0 calculated for the channel of 768 is $(S/N_0)_3 = 44.0$ db-Hz for $P_e = 10^{-6}$.

Table 4.5 shows the calculation of USB link for antennas of 9 and 6 m.

Table 4.4 USB Dowlink Calculation

Parameter		9 m	6 m
Transmitter power	dbm	30.0	30.0
Transmitting circuit less	db	-2.0	-2.0
Transmitting Antenna Gain (includes polarization loss)	db	-1.0	-1.0
Free space loss	db	-169.3	-169.3
Transmitter frequency	MHz	2287.5	2287.5
Receiving antenna gain (includes circuit less)	db	43.4	39.9
System margin	db	-6.0	-6.0
Received total power	dbm	-104.9	-108.4
Receiver noise Power density	dbm/Hz	-174.5	-178.0
System Temperature	^{o}K	250	110
Received $\frac{c}{N_o}$	db/Hz	69.6	69.6
Required $\frac{c}{N_o}$	db/Hz	48.5	48.5
Extra margin	db	21.1	21.1

4.4 - USB Uplink

This link is necessary to transmit the Pseudo Random Noise PRN ranging signal and command data subcarrier (70 KHz).

Table 4.6 shows the link calculation for an antenna of 9m and 6 m.

Table 4.6 - USB Uplink Calculation

Parameters	9 m	6 m	
Transmitted power	70.0	70.0	dbm
Transmitting circuit loss	0.0	0.0	db
Transmitting antenna gain	43.0	39.5	db
Space loss	-169.9	-169.9	db
Atmospheric attenuation	-0.7	-0.7	db
Carrier frequency	2106,4	2106.4	MHz
Receiving antenna gain (includes polarization loss)	+4.0	+4.0	db
Receiving circuit loss	-1.5	5.0	db
Pointing loss of the receiving antenna	-5.0	5.0	db
System margin	-6.0	6.0	db
Received total power	-66.1	-66.1	dbm
Modulation loss	0.0	0.0	db
Available carrier power	-66.1	-66.1	dbm
Necessary carrier power	-109.0	109.0	dbm
Extra margin	42.9	42.9	db

CHAPTER 5

RECEIVING AND TRACKING STATION MODEL

INPE intends to install a station to track the satellite, receiving and recording the information transmitted by it.

Fig. 5.1 shows a block diagram for a possible tracking and receiving station including the recording system.

The uplink is not necessary for Brazil because the satellite commands are recorded in redundant memories of high reliabity, in case the memories fail the satellite would become non-operational.

Figure 5.1 shows the equipment used to receive the data transmitted in MSS, RBV and USB links and the recording system used to record these data.

The receiving equipment to receive the data transmitted by the Data Collection System (DCS) does not appear in the figure because in an initial phase the station would not receive this signal. It intends to study the possibility to receive these data in the future.

5.1 - Equipment Specifications

5.1.1 - Antenna

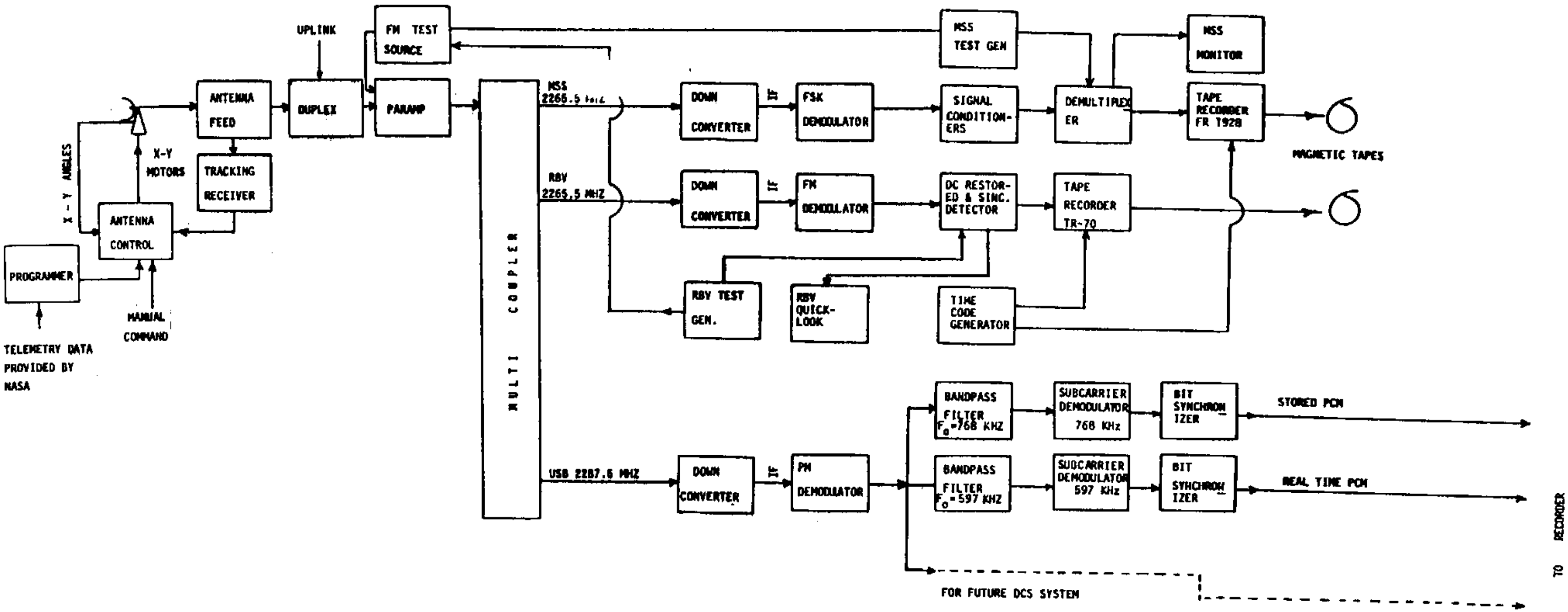
The system will use a 9 m diameter parabolic antenna with a noise temperature of nearly 65^{o}K.

If the system noise temperature is 125^{o}K (utilized in the illustration of the calculations) the safety margin will be 6 db. If the system temperature is greater than 125^{o}K the safety margin will be smaller than 6 db. See table 4.1 and paragraph 4.1.2 for the RBV link which is more critical.

The antenna and the pedestal must operate in normal conditions with wind of up to 60 km/h.

The antenna must be solid with surface roughness sufficient

F I G . 5.1 - E R T S T R A C K I N G A N D R E C E I V I N G S T A T I O N B L O C K D I A G R A M



to operate on the band 8025-8400 MHz. This consideration is important because the service of exploration of the Earth Resources by means of satellites, in the future, will utilize this band in accordance with the resolution of the ITU at the meeting WARC-ST/71 held in Geneva in June 1971.

5.1.2 - Antenna Feed

It must have capacity to provide all the necessary signals for the tracking.

These signals will generate the signals differences, ΔE and Δa, for the tracking receiver and the sun signal, $\sum$, for the parametric amplifier.

5.1.3 - Tracking System

The station will probably have two tracking systems; one using the autotrack system and the other using the programmed tracking with the aid of a computer. It could have as an option, the manual tracking for initial positioning of the antenna.

The autotrack system uses an antenna feed with capacity to generate the azimuth and elevation error signals.

The antenna must be initially positioned either by the operator or by using the programmed tracking.

5.1.4 - Parametric Amplifier

The parametric amplifier must have a bandwidth greater than 72 MHz. In the future satellites for exploration of the Earth Resources, when the frequencies are allocated to the band from 8025 to 8400 MHz, in accordance with the WARC-ST/71, of the ITU, this amplifier will probably have a broad bandwidth.

Calculations made show that an uncooled parametric amplifier with noise temperature of $100^{o}K$ would be sufficient with an 9 m diameter antenna, with a lower margin to 6 db for the RBV link, which is the most critical.

5.1.5 - MSS Equipment

5.1.5.1 - Down Converter

The noise temperature of the down converter must be such that the noise system temperature was equal to $125^{o}K$(9 m antenna with a lower margin to 6 db for the RBV link).

5.1.5.2 - FSK demodulator

This device must demodulate the PCM/FSK signal of the MSS link.

5.1.5.3 - Signal Conditioner

This unit synchronizes the 15 Megabits for second (Mbs), providing also time information for a later demultiplexation and/or recording.

5.1.5.4 - Demultiplexer/test Generator/Monitor

This unit will be utilized to demultiplex the MSS signal reproduced by a series type tape recorder (for example the TR 70 - CVR-3F modified) or to demultiplex the signal to be recorded in a parallel type tape recorder (for example the AMPEX FR-1928). A monitor will be used to visualize in analog form the MSS data. The test generator provides the test MSS signal which modulates a FM source to verify the correct operation of the whole system.

5.1.5.5 - MSS Tape Recorder

The recording system must be completely compatible with that used by NASA in the United States.

This tape recorder may be a FR-1900 modified (parallel type tape recorder) to record 28 tracks (model FR-1928) or some other series type tape recorder in which the demultiplexer would not be necessary for the recording.

A parallel type tape recorder records, at a speed of 60 inches/s, 25 tracks of digital data, one channel of time information, one of PCM telemetry signal, and one channel of capstan servo and a voice channel. The tape recorder tracks may be used as follows:

Channel 1 - capstan servo reference frequency
Channels - 2, 4, 6, 8, 10, 12 - Group 1
Channels - 14, 16, 18, 20, 22, 24 - Group 2
Channels - 3, 5, 7, 9, 11, 13 - Group 3
Channels - 15, 17, 19, 21, 23, 25 - Group 4
Channel 26 - Group 5 (ERTS-B only)
Channel 27 - time information
Channel 28 - PCM telemetry Signal

The tapes used must be 1 inch width in $10^{1}/2$ or 14 inches diameter reels.

5.1.6 - RBV Equipment

5.1.6.1 - Down Converter

See paragraph 5.1.5.1

5.1.6.2 - FM Demodulator

This demodulator must demodulate the video/FM signal (RBV data).

5.1.6.3 - Video Processor and Synchronism Separator (VPASS)

This unit must process the RBV video signal to permit the recording and display (quick-look) of images.

5.1.6.4 - RBV Tape Recorder

This tape recorder must be completely compatible with that used by NASA.

The tape recorder to be used will be the RCA TR 70-CVR-3E (or equivalent) which is a modification of the commercial tape recorder TR-70.

This tape recorder may use tapes 3M 500 that come in reel lengths of 1,200-2,400-3,600-4,800 or 5,600 feet; in term of recording time the lengths are equivalent to 738 - 1,476-2,214-2,952 - or 3,444 seconds.

The tapes used must be 2 inches wide in 14 inch diameter reels.

5.1.7 - USB Equipment

5.1.7.1 - Down Converter

See paragraph 5.1.5.1

5.1.7.2 - PM Demodulator

This demodulator must demodulate the information at the USB carrier.

5.1.7.3 - Band Pass Filters

The filter for the stored PCM telemetry signal must have a central frequency f_0 = 597 KHz and sufficient bandwidth for at least 24 kbps. The filter for the real time PCM telemetry signal must have a central frequency f_0 = 768 KHz and a 35 KHz bandwidth.

5.1.7.4 - Subcarrier Demodulators

These discriminators must demodulate the two sub-carriers f_s = 768 KHz and f_s = 597 KHz.

5.1.7.5 - Bit Synchronizer

These units (2) provide the synchronization of the 24 kbps and 1 kbps data of the 597 and 768 KHz channels respectively,for later recording.

5.1.7.6 - Recording System for the Signals of the USB Link

These signals are recorded in the auxiliary channels of the tape recorders AMPEX FR-1928 (or equivalents) and RCA TR-70 (or equivalents) or can be recorded separately in any other digital tape recorder (it may be the AMPEX FR-1900 already existent at INPE).

For recording of the DCS signals in a later phase this digital tape recorder (FR-1900) would certainly be necessary.

5.1.8 - Test Generators: TPG (RBV) and RSE (MSS)

The function of these equipments are the following:

- To generate the test signals for simulation of the MSS and RBV signals;
- To generate and simulate the noise spectrum which can be combined with the test signals to simulate the receiving of the satellite signals.

5.1.9 - Quick-look Monitor (QLM) to Visualize the RBV Signals

This device permits a quick visualization of the three RBV cameras. It also accepts the signals provided by the TPG unit; these signals are first sent to the VPASS unit.

The QLM permits the visualization in a cathode ray tube of the RBV data and of the test signal of the TPG for evaluation of characteristics of the system. It is equipped with a Polaroid camera whic photographs continuously the images of the three RBV cameras.

5.1.10 - Timing System

The timing station consists of a group of equipment which include:

- Time code generator
- Frequency synthetizer
- Synchronizer
- Oscilloscope

5.1.11 - FM Signal Source for Test

This is a generator for precision signals in the band of 2200 to 2300 MHz.

The output may be continuous or modulated by the signal provided by the TPG test generator of the RBV or by the MSS test signal generated in the RSE.

The TPG generator provides the video test signal (0 to 3.5 MHz) for control of the receiving and recording equipment of the RBV signal.

The MSS-RSE test generator provides the 15 Mbps signal for control of the receiving and recording equipment of the MSS signal.

These signals of the TPG and MSS-RSE modulate the FM signal of test; this modulated signal is injected at the test input of the parametric amplifier and later on in the receiving and recording circuits to evaluate the conditions of operation of the complete system.

CHAPTER 6

IMAGE PROCESSING STATION

The image processing station has the following main functions:

- To transform the RBV data received in films through the control of IAT tapes (Image Annotation Tape) in which these are annotated. The information for correction is obtained from telemetry data contained in the USB downlink and from "fixed error" tapes. The films obtained correspond in quality to the preliminary processing (bulk process). Manual measurements are made with these films from the position of objects whose coordinates are previously known, so that a group of coefficients for correction is obtained and applied to the original video tape of the RBV, and images of quality corresponding to the precision process are obtained.
- To transform MSS data into films of preliminary quality and later into precise quality.
- To transform the MSS data in digital tapes for direct access to the computer (CCT).

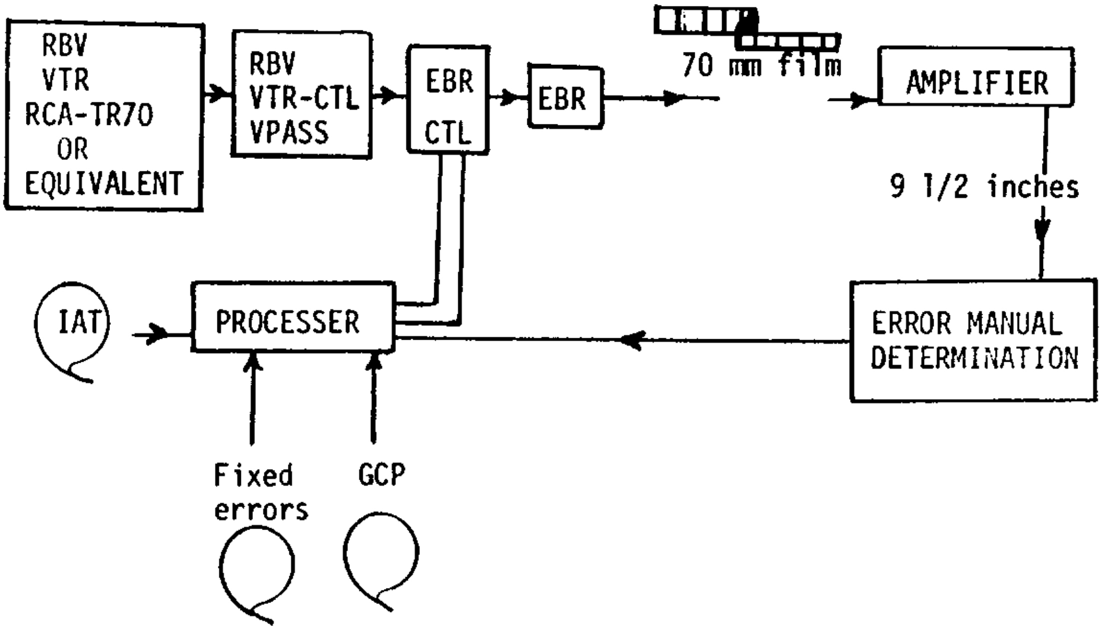
6.1 - Image Annotation Tape (IAT)

To produce these tapes use for error systematic correction, tapes with ephemeris data to be provided by NASA and the data with the satellite characteristics contained in the USB down link are necessary. With these two tapes it is possible to produce the IAT tape.

Geometrical corrections are made through the determination of the satellite angles in relation to reference position and the deviation of the nominal height of the satellite. The satellite angles are determined from PCM telemetry data. The ephemeris data permit calculation of the deviation of the nominal height.

6.2 - Transformation of RBV Data

The RBV data recorded are reproduced and sent to VPASS and next to a Electron Beam Recorder (EBR-CTL) and immediately after to a Electron Beam Recorder (EBR).



Initially corrections are made through the control of the IAT tape and "fixed error" tape; this first step produces images of preliminary quality; after developing the 70 mm film some images are chosen, these images can be enlarged to 9 1/2 inches.

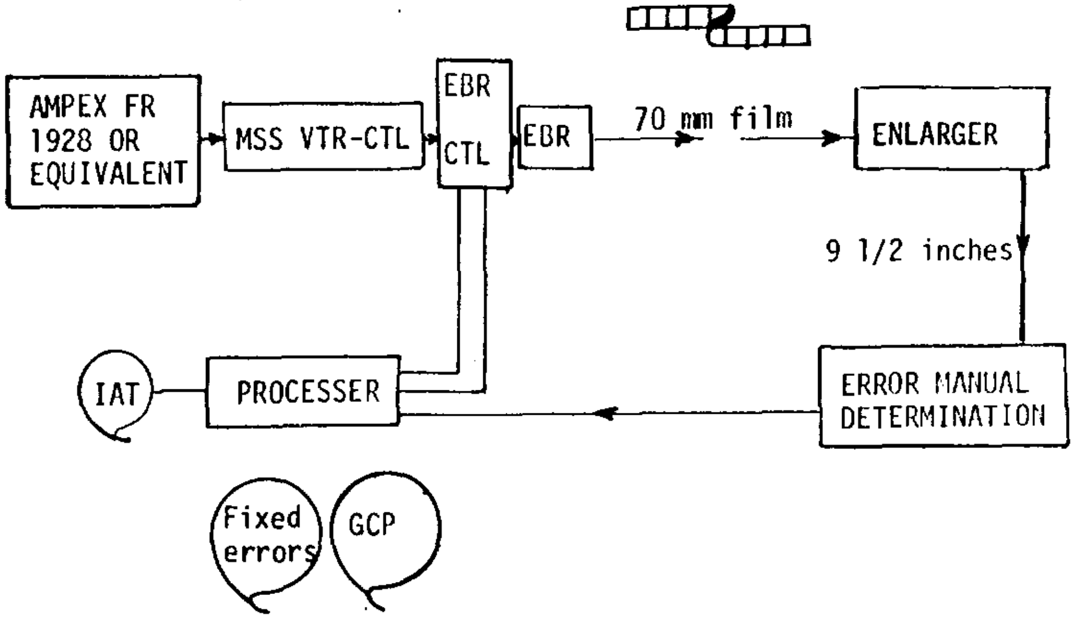
Some images are selected for further corrections; to determine these corrections, manual measurements are made from the exact localization of some points and knowledge of the distortions of the lenses. These measurements are put in the processor to obtain correction coefficients. These coefficients are applied to the Electron Beam Recorder Control.

Using again the original video tapes of the RBV and applying the correction coefficients during the second step, the images are produced again after the enlarging with precision quality.

6.3 - MSS Data Transformation

The MSS recorded data are converted into films through the control of the IAT tape and fixed error tape. This first passage produces images of preliminary quality.

With manual measurements the correction coefficients are obtained to produce the precision images through a second passage of the original MSS tape.



The MSS data are converted into tapes compatible with the computer through two magnetic tape units(HP MTU).

CHAPTER 7

LOCATION AND COVERAGE

7.1 - Location

As it was considered previously, the system presented in this document must be constituted of 2 subsystems, the tracking and receiving station and the Image Processing Station. Considering that they are complementary, the ideal situation would be that in which both were located at the same point or at near point. The proximity criterion is however, flexible in the sense that it is the function of several factors. For example, the access facility to each of the stations and the means of transportation which will interconnect them.

As an example and as basis for calculation of the amount of data to be received, we next present studies which put the location of the tracking and receiving station near the city of São José dos Campos (23^oS and 46^oW).

7.2 - Coverage

The coverage was calculated taking into consideration the elevation angles of 2^o and 5^o above the horizon.

The geometry utilized for the calculation is presented in Fig. 7.1.

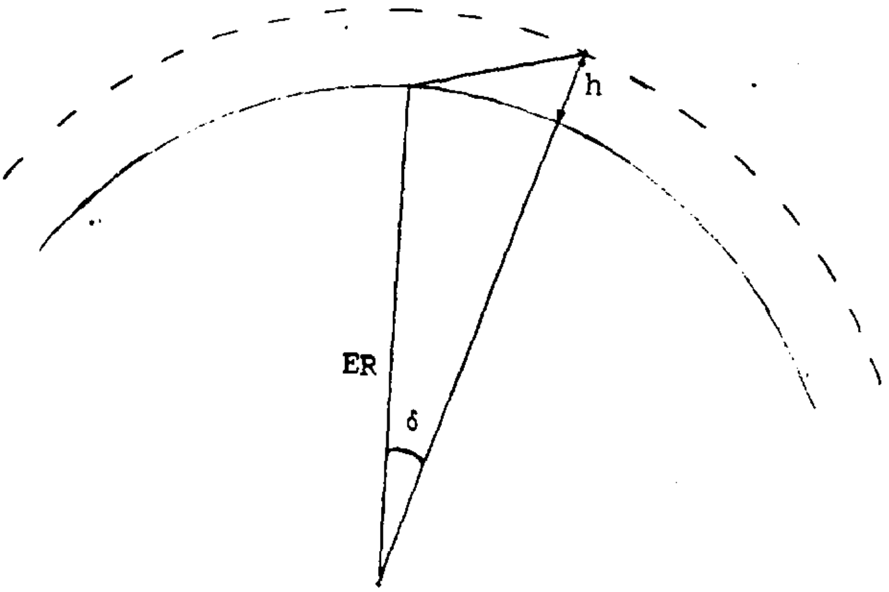


Fig. 7.1 - Geometry for the calculation of the central angle.

The calculation of the central angle (δ) for various elevation angles is included in table 7.1.

From this table the following values are obtained:

Central Angle (δ)	Height (h)	Elevation (a)
24.3^{o}	910 km	5^{o}
27.0^{o}	910 km	2^{o}

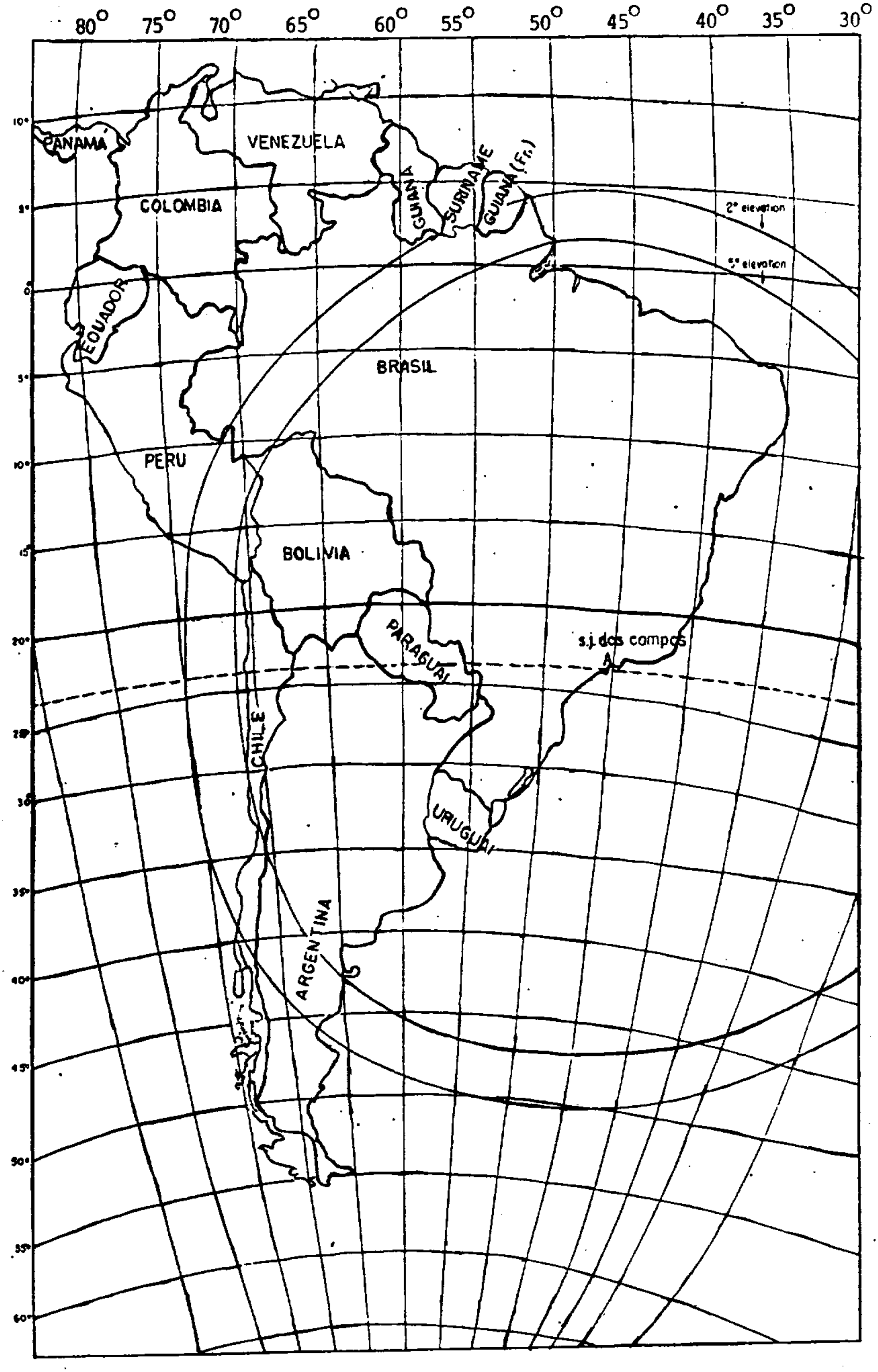
With the values of central angles one may trace the coverage of Fig. 7.2 for elevation 2^{o} and 5^{o}.

Fig. 7.2. shows that almost the whole of Brazil would be covered and the following countries as well:

Total Coverage	Partial Coverage
Bolivia	Argentina
Paraguay	Chile
Uruguay	Peru
	French Guiana

Table 7.1 - Central angle calculation
Angles measured in Degrees
Height: 910 Km

Central Angle	Elevation
1	82.03
2	74.31
3	67.03
4	60.33
5	54.25
6	48.80
7	43.93
8	39.60
9	35.73
10	32.27
11	29.17
12	26.36
13	23.80
14	21.47
15	19.33
16	17.35
17	15.52
18	13.80
19	12.20
20	10.69
21	9.26
22	7.91
23	6.62
24	5.39
25	4.22
26	3.09
27	2.00
28	.95



7.2 - COVERAGE OF THE STATION LOCATED IN SÃO JOSÉ DOS CAMPOS

CHAPTER 8

AMOUNT OF DATA RECEIVED BY THE STATION

The location of the station under study would permit gathering data for Brazil and other South American Countries.

The amounts of data available for recording at this station will be calculated considering that the satellite elevation angle considered in São José dos Campos is greater than 5°. The elevation angle is limited by this value owing to problems of atmospheric scintillations and refraction effects. The elevation angle of 5° is a pessimistic estimate. With a good tracking system and favorable conditions it would be possible to increase the amount of data received.

8.1 - Orbital Parameters

The Orbital Parameters used for the calculation of the amount of data are the following:

Point of insertion	130° W long, 0° lat.
Altitude:	910 Km (492.35 min)
Inclination:	99.088 degrees
Period:	103 min
Eccentricity	0.0001
Coverage cycle duration	18 days (251 rev.)
Distance between adjacent trajectories	160 Km (1.4338 degrees)
Separation in longitude between consecutive trajectories	25.8167 degrees

8.2 - Graphical method to determine the time spent by the satellite to cover the area of observation from the São José dos Campos station.

The graphical method used to determine this time is the following: on the first day the orbits 10 and 11 separated by 25.8167 degrees longitude are forecasted in the coverage area of the station;on the second day the orbits 24 and 25 are forecasted and so on. A certain number of orbits is forecasted for each day as shown in Fig. 8.1. The length of the trajectories was transformed in time used by the satellite, to describe these trajectories.

The calculation was done only for the continental coverage, either for Brazil or for other countries as well, within the coverage range of the station. For the calculation, it was assumed that the trajectories within the coverage area of the station are parallel.

The solar illumination angle depends on the latitude and on the seasons; this is shown in Fig. 8.2. It is convenient to keep in mind that within the area covered by the receiving station from São José dos Campos, the solar angle is always greater than 17 degrees. For our purposes this angle should be considered satisfactory.

For an elevation of 5^0, thirty-three (33) orbits cut the coverage area of the station. Twenty-two (22) of these orbits cut the continental part.

The time spent by the satellite in each day and the corresponding 22 passages are shown in Table 8.1.

The longest time spent by the satellite, within the continental coverage, is about 694 seconds.

In the first day (see Table 8.1) the satellite describes the trajectories 10 and 11 but only the orbit 11 cuts the continental part. On the 6th day, for example, the satellite describes the orbits 80 and 81 and similarly for each one of the 18 days of the cycle. Table 8.1 shows the time spent to cover each country.

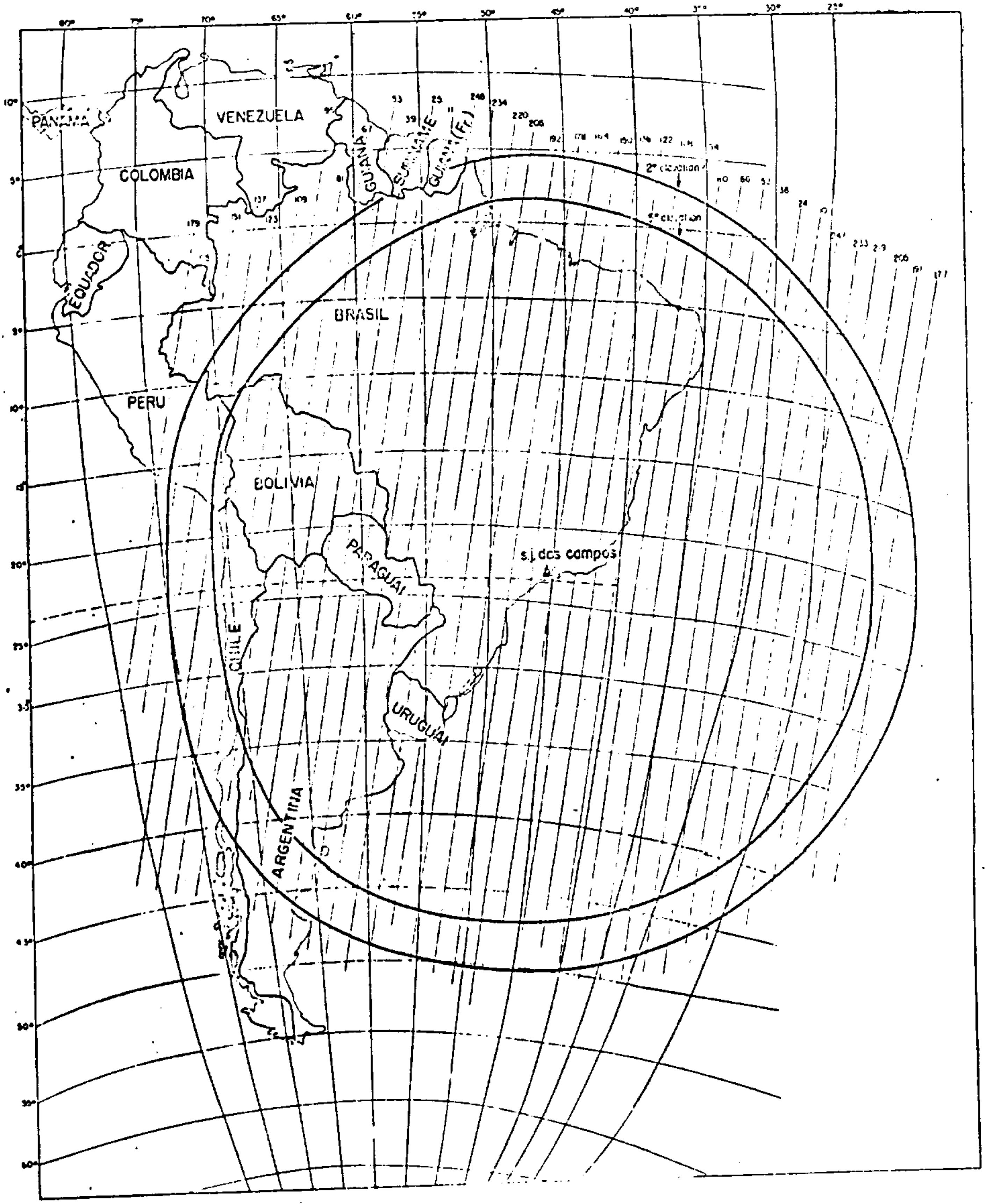


Fig. 8.1 - Coverage of the station located in São José dos Campos

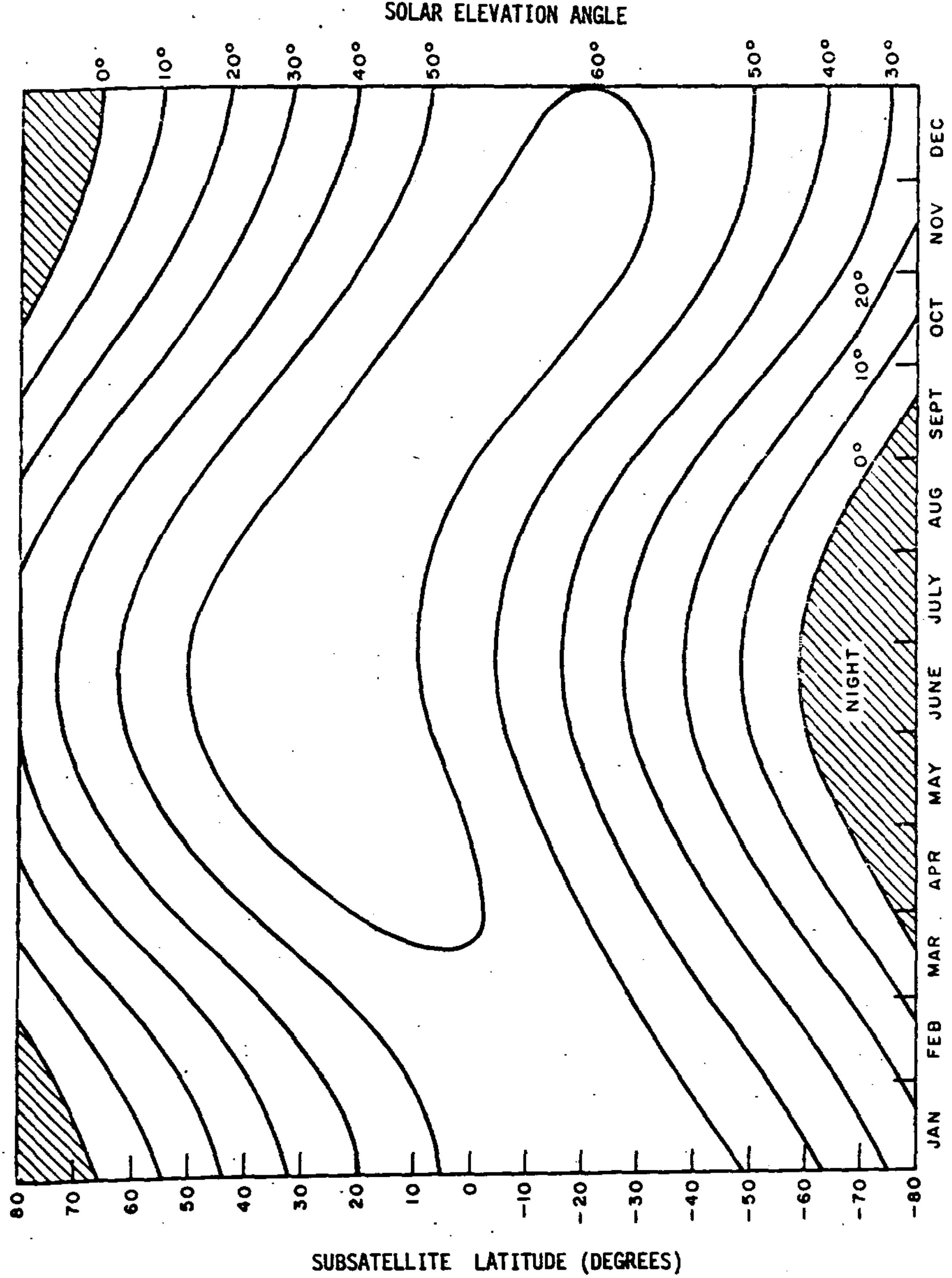


Fig. 8.2

SOLAR ANGLE ELEVATION

Table 8.1 - Time Spent on Continental Coverage

			TIME SPENT (SECONDS)													
DAY	PASSAGE NUMBER		BRAZIL		BOLIVIA		ARGENTINA		CHILE		PARAGUAY		URUGUAY		TOTAL	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1	10	11	-	380	-	-	-	243	-	-	-	49	-	-	-	672
2	24	25	-	281	-	39	-	288	-	-	-	86	-	-	-	694
3	38	39	-	259	-	52	-	310	-	-	-	69	-	-	-	690
4	52	53	-	190	-	120	-	300	-	-	-	43	-	-	-	653
5	66	67	-	172	-	87	-	350	-	-	-	-	-	-	-	609
6	80	81	86	138	-	163	-	243	-	-	-	-	-	-	86	544
7	94	95	121	95	-	181	-	157	-	35	-	-	-	-	121	468
8	108	109	281	35	-	173	-	-	-	190	-	-	-	-	281	398
9	122	123	348	9	-	121	-	-	-	111	-	-	-	-	348	241
10	136	137	348	-	-	-	-	-	-	-	-	-	-	-	348	-
11	150	151	348	-	-	-	-	-	-	-	-	-	-	-	348	-
12	164	165	430	-	-	-	-	-	-	-	-	-	-	-	430	-
13	178	179	465	-	-	-	-	-	-	-	-	-	-	-	465	-
14	192	193	520	-	-	-	-	-	-	-	-	-	-	-	520	-
15	206	207	550	-	-	-	-	-	--	-	-	-	19	-	569	-
16	216	217	516	-	--	-	-	-	-	-	8	-	78	-	602	-
17	234	235	465	-	-	-	35	-	-	-	35	-	85	-	620	-
18	248	249	396	-	-	-	202	-	-	-	56	-	-	-	654	-
			4874	1559											5392	4969

8.3 - Magnetic Tape Requirements

The magnetic tapes for the tape recorder AMPEX FR 1928 are provided in 9,200 feet reels (280 m) or, in terms of recording time, 1.840 seconds.

The magnetic tapes for the tape recorder RCA TR 70-CVR-3E are provided in reels of 1,200, 2,400, 3,600, 4,800 or 5,600 feet lengths or, in terms of recording time, 738, 1,476, 2,214, 2,952, 3,444 seconds at a speed of 19.5 inch p.s.

The calculation of the number of tapes was made considering the recording in only one reel of the largest number of consecutive passages possible.

This method is illustrated in Table 8.2 for the AMPEX FR 1928 or equivalent. The recording time for passage 11 on the first day and 25 on second day are added. The total time of recording for continental coverage of these 2 passages is of 1,366 seconds, with 474 seconds of tape unused.

Table 8.3 shows the number of tapes necessary for the tape recorder RCA TR 70-CVR-3E or equivalent in a period of 18 days.The method used for calculation of tapes for the RCA TR 70-CVR-3E or equivalent is the same used in the calculation of number of tapes for the AMPEX FR 1928 or equivalent, with the later condition that the amount of unused tape be at a minimum. If for example:

(day, passages)	Recording time	Whole reel time	Non used time
(1,11) + (2,25) + (3,39)	2056 sec	2214 sec	158 sec
(1,11) + (2,25) + (3,39) + + (4,53) + (5,67)	3318 sec	3444 sec	126 sec

Using a 3,600 foot reel (2214 sec.) one can record 3 passages; the non used time of the tape corresponds to 158 sec. Using a 5,600 foot reel (3444 sec.) one can record 5 passages; the non used time of the tape corresponds to 126 sec. The method used of minimum time of non used tape chooses the 3444 sec. reel.

Table 8.2 and 8.3 show the total number of non used tapes in seconds/reel.

Table 8.4 shows the number of reels for the two tape recorders for the cycle of 18 days. Table 8.5 shows the cost of magnetic tapes for the period of 18 days.

The total coverage cost (continental sea) will be approximately the double of the cost shown in Table 8.5.

8.4 - Estimate of the quantity of photographs

The data recorded in the recording system of the tracking and receiving station will be processed and transformed in photographs later.

We will give an estimate of the final quantity of photographs that the system will provide.

Based on the data of table 8.1, the number of scenes (185 Km x 185 Km), which the station will receive per cycle (18 days) were calculated for the continental coverage of Brazil and total continental coverage (Brazil and other South American countries). It was considered that 30% of the images would not be utilized due to the excessive coverage of clouds. From the 70% left 10 preliminary copies will be prepared (we consider 10 users) in black and white paper and transparency. From these images it was considered that 20% would be composed of colors.From the preliminary images (bulk), it was considered that 30% will be transformed in precision images and copied for 10 users. It was considered that all precision images will be composed of colors. Tables 8.6, 8.7, and 8.8 illustrate these considerations and calculations.

With the estimate mentioned above the total amount of photographs provided to the users per day is shown in Table 8.9.

Tables 8.10 and 8.11 show the photographic processing costs per day for Brazil and for total continental coverage.

Table 8.12 shows the total annual cost for the indicated coverages.

The Brazilian User will demand annually 75% of preliminary images and 25% of precision ones; the color images, preliminary and precision, represent 9% of the image total.

Table 8.2 - Requirement for Magnetic Tape - Recording Time AMPEX FR 1928

TOTAL LAND COVERAGE		
(DAY; PASS Nº)	RECORDING TIME SEC.	UNUSED TAPE SECS/REEL
(1,11) + (2,25)	1366	474
(3,39) + (4,53)	1343	497
(5,67) + (6,80) + (6,81)+ + (7,94) + (7,95)	1828	12
(8,108) + (8,109) + (9,122)+ + (9,123) +(10,136)	1616	224
(11,150) + (12,164) + + (13,178) + (14,192)	1763	77
(15,206) + (16,216) + + (17, 234)	1791	49
(18, 248)	654	1186
TOTAL:	10361	2519

BRAZIL ONLY		
(DAY, PASS Nº)	RECORDING TIME SEC.	UNUSED TAPE SECS/REEL
(1,11) + (2,25)+ +(3,39)+ (4,53)+ +(5,67)+(6,80)+ +(6,81)+(7,94)+ +(7,95)	1722	118
(8,108)+(8,109) +(9,122)+(9,123) +(10,136)+ +(11,150)+ +(12, 164)	1799	41
(13,178)+(14,192)+ +(15,206)	1535	305
(16,216)+(17,234)+ +(18,248)	1377	463
	6433	927

Table 8.3 - Requirement for Magnetic Tape - Recording Time
RCA TR 70-CVR-3E

TOTAL LAND COVERAGE				BRAZIL ONLY			
(DAY, PASS Nº)	RECORDING TIME SECS.	REEL LENGTH SECS.	UNUSED TAPE SECS/REEL	(DAY, PASS Nº)	RECORDING TIME SECS.	REEL LENGTH SECS.	UNUSED TAPE SECS/REEL
(1,11) + (2,25) +(3,39) + +(4,53) + (5,67)	3318	3444	126	(1,11) + (2,25)	661	738	77
(6,80) + (6,81) + (7,94) + +(7,95) + (8,108) +(8,109)+ +(9,122)+(9,123)+(10,136)	2835	2952	117	(3,39) + (4,53) + (5,67) + + (6,80)	707	738	31
				(6,81) + (7,94) + (7,95) + + (8,108) + (8,109)	670	738	68
(11,150)+(12,164)+(13,178)+ +(14,192)+(15,206)+(16,216)	2934	2952	18	(9,122) + (9,123) +(10,136)	705	738	33
(17,234) + (18,248)	1274	1476	202	(11,150)+(12,164)+(13,178)+ +(14,192)+(15,206)+(16,216)+ +(17,234)	3294	3444	150
				(18,248)	396	738	342
TOTAL	10361		463		6433		701

Table 8.4 - Tape Reel Requirements

	TAPE REEL REQUIREMENTS	
	AMPEX FR 1928	RCA TR-70
TOTAL LAND COVERAGE	7 reels of 9200 feet	1 reel 2400 feet 2 reels 4800 feet 1 reel 5600 feet
BRAZIL ONLY	4 reels of 9200 feet	5 reels of 1200 feet 1 reel 4800 feet

Table 8.5 - Magnetic Tape Cost

	AMPEX	RCA	TOTAL US$ (18 days)	ANNUAL COST* US$
TOTAL LAND COVERAGE	7 reels of 9200 feet US$ 2200	1 reel (2400 feet):US$ 110 2 reels (4800 feet):US$ 440 1 reel (5600 feet):US$ 256 US$ 806	US$ 3006	US$ 61000
BRAZIL ONLY	4 reels of 9200 feet US$ 1250	5 reel (1200 feet):US$ 275 1 reel (4800 feet):US$ 220 US$ 495	US$ 1745	US$ 36000

* Is assumed that all the available data is recorded and preserved

Table 8.6 - Amount of Images Received in the Station

	BRAZIL		TOTAL CONTINENTAL COVERAGE	
	RBV	MSS	RBV	MSS
Time/days	6433	6433	10,361	10.361
Scenes/18 days	257	257	414	414
Scenes/day	14	14	23	23
Images/day	42(3x14)	56(4x14)	69(3x23)	92(4x23)
Scenes without excessive cloud cover/day (70 % of the total)	10	10	16	16
Images without excessive cloud cover/day (70 % of the total)	30(3x10)	40(4x10)	48(3x16)	64(4x16)

Table 8.7 - Photo Copies of the Preliminary Images ("BULK")

	BRAZIL		TOTAL CONTINENTAL COVERAGE	
	RBV	MSS	RBV	MSS
Black and White prints	300 (30x10)	400 (40x10)	480 (48x10)	640
Black and White transparencies	300 (30x10)	400 (40x10)	480 (48x10)	640
Color prints (20 % of the total)	20 (20% of 10x10)	20 (20% of 10x10)	40 (20% of 16x10)	40
Color transparencies (20 % of the total)	20 (20 % of 10x10)	20 (20 % of 10x10)	40 (20 % of 16x10)	40
TOTAL	640	840	1040	1360

Table 8.8 - Photo Copies of the Precision Images

	BRAZIL		TOTAL CONTINENTAL COVERAGE	
	RBV	MSS	RBV	MSS
Black and white prints	90 (30% de 300)	120 (30% of 400)	150	200
Black and white transparencies	90 (30% de 300)	120 (30% of 400)	150	200
Color prints (100 % of the total)	30	30	50	50
Color transparencies (100 % of the total)	30	30	50	50
TOTAL	240	300	400	500

Table 8.9 - Total Photos Produced per day

	BRAZIL	TOTAL CONTINENTAL COVERAGE
Preliminary (bulk) photos	1.480	2.400
Precision Photos	540	900
TOTAL	2.020	3.300

Table 8.10 - Photo Processing Cost Per day for Brazil

Preliminary (bulk) Processing	US$
Film of 70 mm	5.0
Processing of 98 images/day	13.0
700 black and white prints copies	150.0
700 black and white transparencies copies	150.0
40 color print copies	14.0
40 color transparencies copies	14.0
TOTAL/DAY	346.0

Precision Processing	US$
Film of 70 mm	2.0
Processing of 21 images/day	3.0
210 black and white print copies	45.0
210 black and white transparencies copies	45.0
60 color print copies	21.0
60 color transparency copies	21.0
TOTAL/DAY	137.0

Table 8.11 - Photo Processing Cost Per day for Continental Coverage

Preliminary (bulk) Processing	US$
Film of 70 mm	9.0
Processing of 161 images/day	20.0
1120 black and white print copies	242.0
1120 black and white transparency copies	242.0
80 color print copies	28.0
80 color transparency	28.0
TOTAL/DAY	569.0
Precision Processing	
Film 70 mm	3.0
Processing of 35 images/day	4.0
350 black and white print copies	54.0
350 black and white transparency copies	54.0
100 color print copies	35.0
100 color transparency copies	35.0
TOTAL/DAY	185.0

Table 8.12 - Photo Processing Annual Cost

	BRAZIL	TOTAL CONTINENTAL COVERAGE
Preliminary (bulk) Processing	US$ 126,290	US$ 207,685
Precision processing	US$ 50,005	US$ 67,525
TOTAL	US$ 176,295	US$ 275,205

CHAPTER 9

GROUND STATION COST

We will analyze the cost for the implantation of an ground station to receive and process the information transmitted by ERTS satellite. The implantation could be done in parts, starting with the Tracking and Receiving Station and later with the first part of the station (Tracking and Receiving) it would be possible to track the satellite, receive information, and record it in magnetic tapes. These tapes would then be sent to NASA, where they would be processed at NDPF (NASA Data Processing Facility) and would be later returned to Brazil.

To avoid the necessity of sending the magnetic tapes to the United States, we would have to buy, simultaneously with the tracking and receiving station, the second part of the ground station, which refers to the image processing; this would make the treatment of the magnetic tapes previously recorded at the Tracking and Receiving Station possible here in Brazil.

We will present separately the cost of the Tracking and Receiving Station and the Image Processing Station with the respective operational costs.

9.1 - Tracking and Receiving Station

The Tracking and Receiving Station is a station where we would receive RBV information, MSS and the real time PCM telemetry, recorded in magnetic tapes. The cost of the basic components of this station would be approximately those shown in table 9.1.

Table 9.1 - Cost of the Components of the Tracking and Receiving Station

COMPONENTS	PRICE (US$)
1. Pedestal, 30 feet parabolic reflector, feeder, base extension, tracking receiver, tracking programmer, servo amplifiers, power amplifier, tracking converter, scan code generator, cables, multicoupler, down converter, RF patch-panel, antenna control.	250.000
2. Parametric amplifier (uncooled)	15.000
3. Receivers for MSS and RBV	20.000
4. Receiver for USB and PM subcarrier demodulator	18.000
5. Signal conditioner and MSS demultiplexer	100.000
6. Video processer and synchronism separator (VPASS)	100.000
7. Test equipment	40.000
8. Timing station	5.000
9. Tape recorder AMPEX FR 1928	70.000
10. Tape recorder RCA TR 70-CVR-3E	200.000
11. Quick-look monitor for RBV	90.000
12. Bit synchronizer for PCM telemetry	60.000
13. Building (300 m^2)	50.000
TOTAL	1.000.000

Table 9.2 - Annual cost of operation and maintenance of the Tracking and Receiving Station

COMPONENTS	PRICE (US$)
1. Magnetic tapes (in the assumption that all recorded tapes are kept at INPE)	60.000
2. Personnel	
1 electronic engineer	
2 electronic technicians for maintenance	
4 operators	30.000
3. Replacement material	50.000
TOTAL	140.000

Table 9.2 shows the operational and maintenance cost of the Tracking and Receiving Station.

The total price of this station could be reduced to approximately US$ 100.000 if we change the "Quick-look monitor" (item 11) for a simple oscilloscope and eliminate the purchase of test equipament (item 7).

If we changed the tape recorder of parallel recording, AMPEX-FR-1928, for a tape recorder of series recording, for example the TR70-CVR-3E modified, the price of the station would increase by approximately US$ 50.000.

So that the system could become completely reliable, it would be interesting to purchase some reserve units.

There is the possibility that this station would expand by the purchase of equipment for receiving other signals transmitted in the USB channel. These other signals would be the DCS (Data Collection System) and the stored PCM telemetry. This expansion could possibly be in the purchase of a digital tape recorder for example the AMPEX FR-2000. The accomplischment of this expansion would increase the price of the station in approximately US$ 150.000 irrespective of the price of the DCS (Data Collection Platforms) and sensors correlate to these platforms.

There is also the possibility that the expansion could be to receive meteorological satellites in the band S, such as Tiros N and SMS/GOES. For this, three receivers are enough.

9.2 - Image Processing Station

This processing station permits the complete processing of RBV, MSS and USB signals (telemetry PCM and DCS) in Brazil; they have capacity to generate the preliminary and precision images for RBV and MSS and the CCT (computer Compatible Tapes) for MSS besides performing multispectral analyses.

Figure 9.1 shows the configuration of this complete processing station; it is noteworthy that the processing for precision images is obtained with manual determination of local errors in all photographs, one by one; it is also noteworthy that in this figure the DCS processing, the generator of CCT tapes and the multispectral analyses are not shown.

The proposed station may be schematically separated in terms of cost,as table 9.3 shows.

Table 9.3 - Cost of image processing station

ITEMS	PRICE (US$)
1. Electron Beam Recorder (with controls)	200.000
2. RBV and MSS preliminary processing (bulk)....	1.200.000
3. RBV and MSS precision processing	800.000
4. CCT tapes for MSS	100.000
5. DCS processing	200.000
6. Multispectral analysis	250.000
total	2.750.000

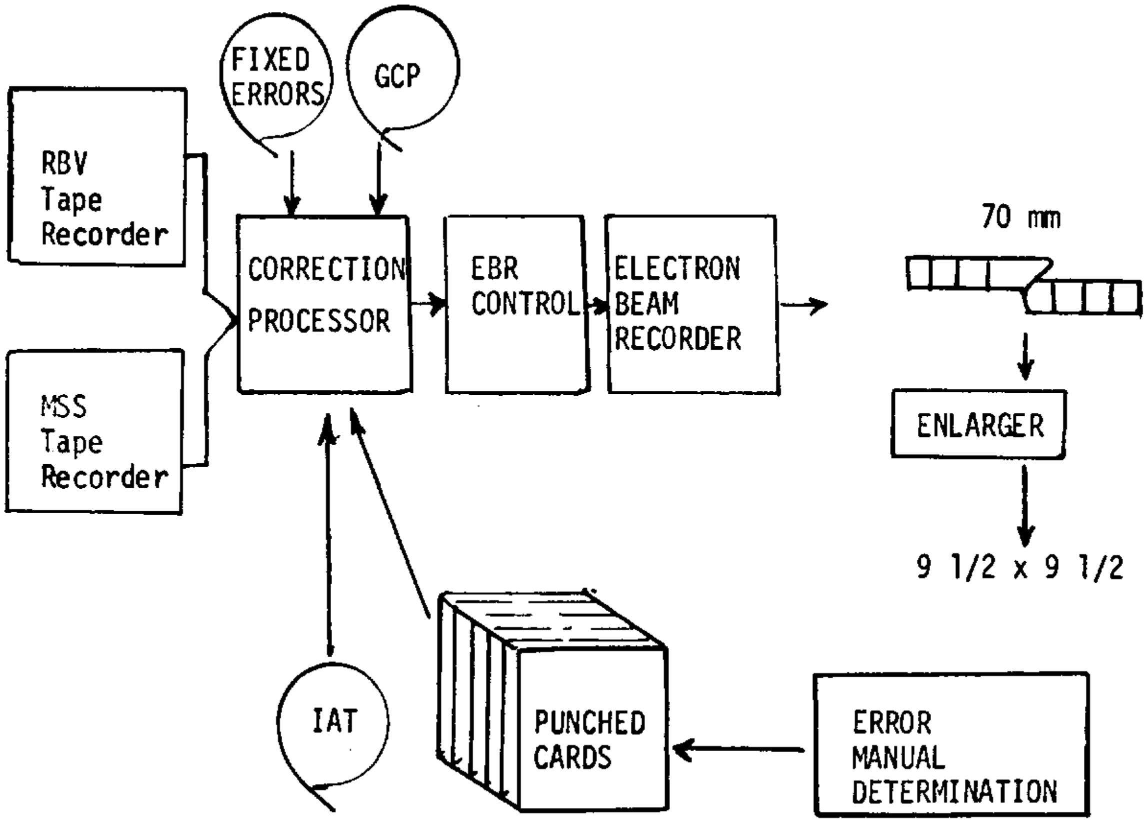


Fig. 9.1 - Image Processing Station

It should be noted that the processor is included in the item concerning the preliminary processing; it should be also noted that in this item the price for generation of IAT tapes (Image Annotation Tape) and "Fixed Errors" tapes is not included in this item because it was considered that NASA will provide Brazil with these tapes for preliminary corrections and annotations.

The generation of these two tapes is already included in item 3; i.e., to go from the preliminary processing to precision processing with generation of IAT and "Fixed Error" tapes, there would be an increase of approximately US$ 800.000.

The sophistication grades of the system may be considered as:

SPECIFICATIONS	PRICE (US$)
1º) Images without corrections and annotations ..	200.000
2º) Preliminary images annotated, with IAT and "Fixed Error" tapes provided by NASA.........	1.400.000
3º) Preliminary and precision images annotated, with IAT and "Fixed Errors" tapes generated at INPE	2.200.000
4º) Item 3º) more generation of CCT tapes for MSS	2.300.000
5º) Item 4º) more DCS processing	2.500.000
6º) Item 5º) more multispectral analyses	2.750.000

It should be noted that the tape recorders utilized to reproduce the tapes recorded in the Tracking and Receiving Station for subsequent processing are not estimated here, since the tracking and processing stations are considered to be in the same place. If this is not possible, the cost of the processing station would increase by the price of the tape recorders (US$ 270.000).

Table 9.3 shows the annual cost of operation and maintenance of the Image Processing Station, including the photographic processing.

Table 9.4 - Annual cost of operation and maintenance of Image Proces$ing Station

DISCRIMINATION	PRICE US$
1. Computer compatible tapes	20.000
2. Personnel	
-3 engineers	
-2 maintenance technicians	
-8 operators	60.000
3. Replacement material	100.000
4. Photographic processing	176.000
TOTAL	356.000

9.3 - Summary of the Station Total Cost

The cost of the Tracking and Receiving Station Shown in Table 9.1 (US$ 1.000.000) would be increased by US$ 150.000 (to make possible the receiving of DCS signals and storing of PCM telemetry not estimated in Table 9.1) and another US$ 50.000 for the acquisition of some reserve units which be almost indispensable. Then the cost of the Tracking and Receiving Station would be US$ 1.200.000. The operational cost for a year would be US$ 140.00, as shown in Table 9.2.

The cost of the investment for the acquisition of the Image Processing Station would be increesed by US $ 270.000, correponding to additional tape recorders; this would result in a total of US$ 3.020.000. The operational cost for a year would be US$ 356.000, as shown in table 9.4.

Summarizing, we would then have the total cost of the investment and operation for a year:

PURCHASE INVESTMENT	PRICE (US$)
1. Tracking and Receiving Station	1.200.000
2. Image Processing Station	3.020.000
	4.220.000

ANNUAL OPERATION	
1. Tracking and Receiving Station	140.000
2. Image Processing Station	356.000
	496.000

Then, the investment in the purchase of the equipment in Cruzeiros, considering the presente rate of exchange for the dollar ... (Cr$ 5.845) will be Cr$ 24.665.900,00.

The disbursement of this amount of money occurs in accordance with the Chronogram of Fig. 9.2; it allows for 25% of the total at the signing of the contract with the firms; 15% of the total at the end of the second, third and fourth months after the signing of the contract; 20% of the total at the shipping of the equipment; 10% of the total at the end of the installation.

It is convenient to remember that the firms proposing to sell the equipment for the station are interested in trying to get international financing.

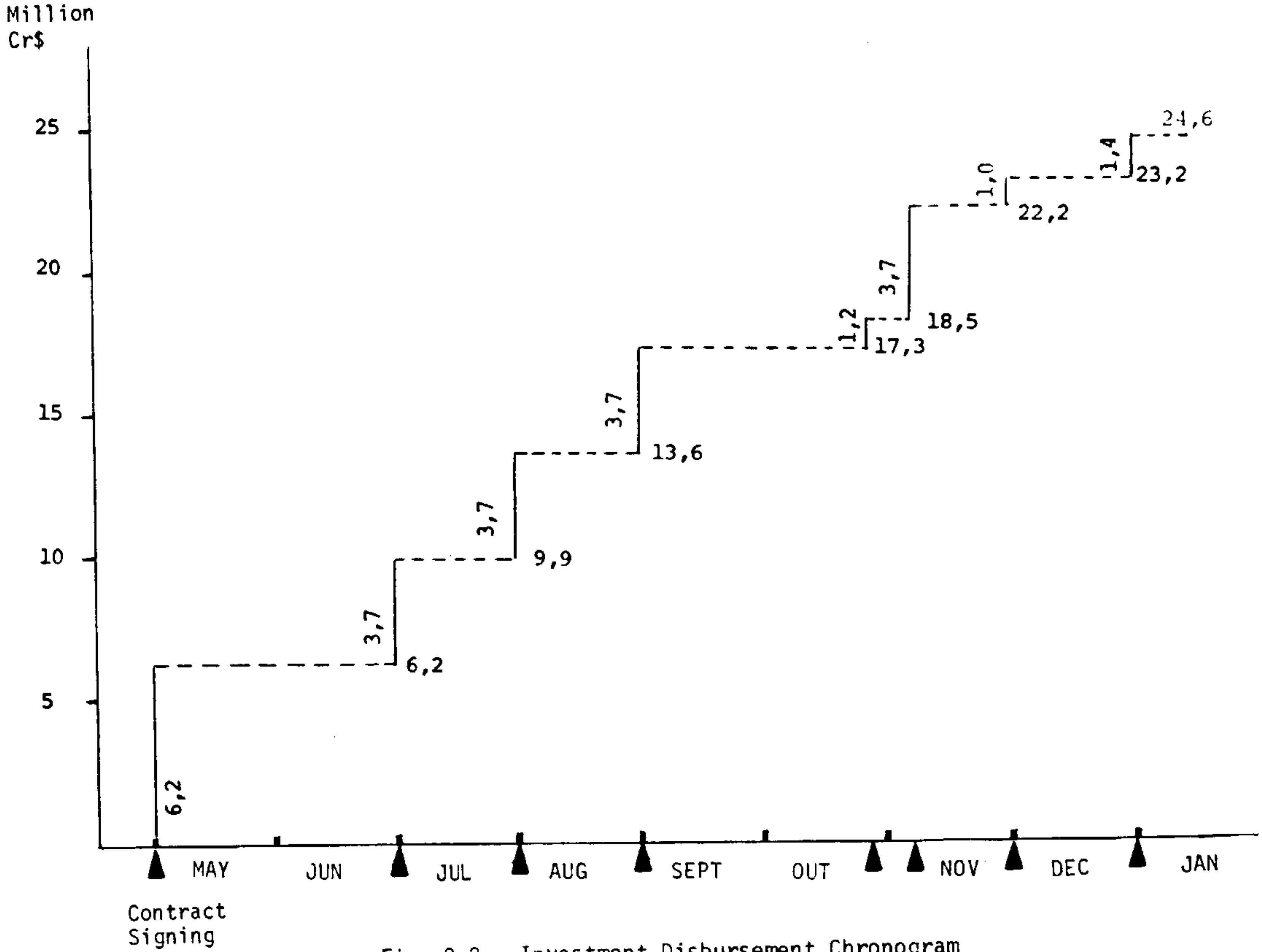


Fig. 9.2 - Investment Disbursement Chronogram

CHAPTER 10

STATION IMPLANTATION

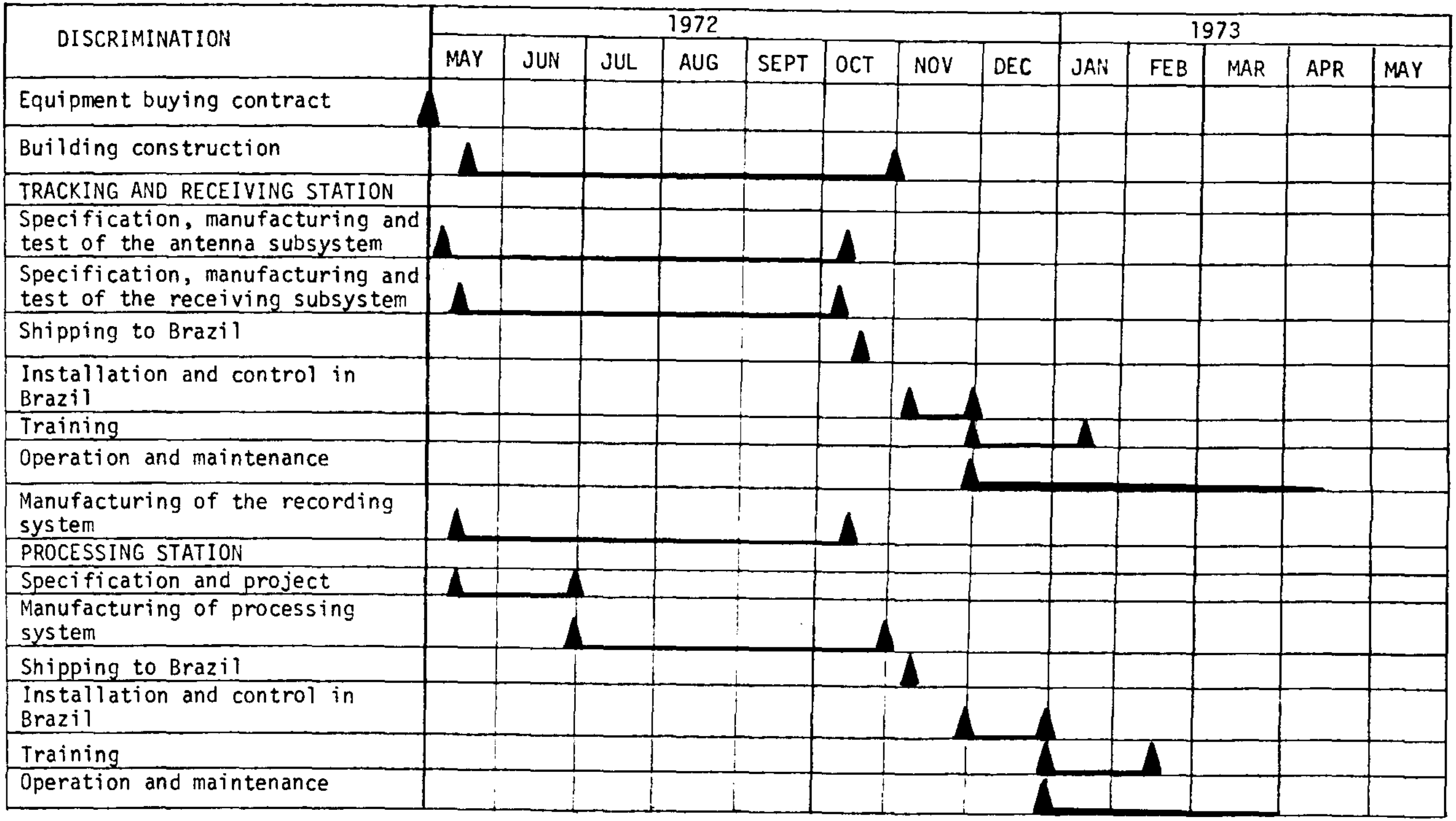
CHRONOGRAM

The launching of the satellite ERTS-A is forecasted to take place in the week of June 22,1972. If the order is made in May, the receiving and recording part will go into operation in November 1972, and the image processing part two months later.

Satellites for exploration of the Earth resources such as the EOS and possibly other ERTS will secure continuity of the program.

Table 10.1 shows the chronogram for the implantation of the stations; this table shows that the building where the station will be installed must be concluded by early November 1972.

Table 10.1 - Station Implantation Chronogram



CHAPTER 11

CONCLUSION

It is hoped that the previous chapters have made it clear that the installation of the mentioned station in Brazil will represent a priceless technique in the surveying and preservation of the resources of the country.

INPE's effort to provide Brazil with such a station is of relevant importance mainly in the part concerning the solution of fundamental problems of the country, such as those enumerated in Chapter 1.

The INPE proposed station in its complete version will permit Brazil to receive data from all the national territory and transform them in a group of seven photographs in the spectral bandwidth of the visible and near infrared; these photos could be distributed to all Brazilian entities interested; this group of 7 images (3 provided by the television system and 4 by the scanner system) is renewed every 18 days, due to the repetitive coverage of the satellite. This station in its more complete version would cost Cr$ 24.650.000,00.

Brazil's participation in the ERTS program and consecutively in the future program of exploration and surveying of Earth resources, using orbital platforms, will result in enormous benefits to the country by relatively low costs as compared to other methods of surveying.

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APPENDIX A

SENSING EQUIPMENT OF THE AMERICAN ORBITAL STATION

(SKYLAB)

Some of the sensing equipment to be used in the experiments for observation of the Earth include:

i) Multispectral photographic equipment (S-190)

This experiment uses six 70 mm high precision cameras with matching between the distortion and lenses of focal distance of 15.2 cm (21.2^0 field of view through planes) giving an area coverage of 163 x 163 km (88 x 88 nautical miles) and a photo scale of 1:2,800,00 . The lenses are aligned and mounted in a panel of simple lenses with its parallel optical axes less than a minute of arc. Images will be registered within 5 mirrors of error. The cameras are equipped with synchronous obturators, offset for the movement of the spacecraft. It is expected that the system reaches a resolution (film-lens) of more than 100 lines per milimeter, in color. The effective ground resolution may be approximately 30 meters. The system is designed for the following spectral combination of wave/film length:

0.5 to 0.6 microns - Pan X black and white film
0.6 to 0.7 microns - Pan X black and white film
0.7 to 0.8 microns - Black and white infrared film
0.8 to 0.9 microns - Black and white infrared film
0.5 to 0.88 microns - Color infrared
0.4 to 0.7 microns - Color Hi-Res

The spectral band covered by mission S-190 in general corresponds to the spectrum coverage designed for multispectral scanners and "Return Beam Vidicon" (RBV) of the ERTS. Similar sensors will be used in airplanes to permit the correlation of simultaneous observations of the "SKYLAB", ERTS, aerial and terrestrial.

ii) Multispectral Scanner (S-192)

This sensor will provide radiation values in several spectral bands through scanners with angle of 10^o to produce strips of 78 km. Each strip will have an instantaneous field of view of 80 m^2. The spectral bands are approximately:

1) 0.410 to 0.460 microns
2) 0.460 to 0.510 microns
3) 0.520 to 0.556 microns
4) 0.565 to 0.609 microns
5) 0.620 to 0.670 microns
6) 0.680 to 0.762 microns
7) 0.783 to 0.888 microns
8) 0.980 to 1.080 microns
9) 1.090 to 1.190 microns
10)1.200 to 1.300 microns
11) 1.550 to 1.750 microns
12) 12.100 to 2.350 microns
13) 10.200 to 12.500 microns

iii) The set of cameras considered for the "SKYLAB" consists of a modified camera Hycon KA-74. This equipment has a lens with focal distance of 18 miles long and produces images of 4.1/2 x 4.1/2 inches in film rolls of 5 inches width. The equipment was qualified for use in manned satellites but, although it might be used for vertical and oblique photos, it is not a mapping camera.

The equipment being considered for the possible future flights of the "SKYLAB" II or III includes a camera for ground mapping with a focal length of 12 inches, with film format of 9 x 14.1/2 inches, for which lenses giving adequate aperture may be obtained: a camera of stellar altitude with focal length of 6 inches using 70 mm film, a laser altimeter and a camera of focal lenght of 12 inches with film format of 9 x 18 inches. A panoramic camera of the lunar program may be used, too. This camera has lenses focal length of 24 inches, 108^0 for scanning, casement of 4.1/2 x 45 inches, aperture F3.5 and is capable of producing 1.650 exposures. It is considered that photos from this camera would give details of mapping in the scale of 1:50.000 and 1:25.000. Copiers of rectification and transformation which duplicate essentially the geometry of the adopted system are being developed.

ESTAÇÃO DE RASTREIO, RECEPÇÃO E PROCESSAMENTO PARA SATÉLITES DE RECURSOS TERRESTRES (ERTS)

RELATÓRIO LAFE-188

Março 1972

PR — Conselho Nacional de Pesquisas
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São José dos Campos — S P — Brasil

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PRESIDÊNCIA DA REPÚBLICA
CONSELHO NACIONAL DE PESQUISAS
INSTITUTO DE PESQUISAS ESPACIAIS
São José dos Campos - Estado de S. Paulo - Brasil

ESTAÇÃO DE RASTREIO - RECEPÇÃO E PROCESSAMENTO PARA SATÉLITES DE RECURSOS TERRESTRES

O presente documento, cuja publicação foi autorizada pelo abaixo assinado, envolve, conforme determinação da Comissão Brasileira de Atividades Espaciais, uma fundamentação detalhada das solicitações contidas no nosso Ofício nº 144 (Vide Apêndice B), encaminhado ao Presidente do Conselho Nacional de Pesquisas que posteriormente o apresentou à apreciação daquela Comissão.

Este documento é o resultado do trabalho de uma equipe ligada ao assunto sendo que os Engenheiros Ronaldo V. Guimarães e Marne C. Serrano tiveram uma especial participação.

F de Mendonça
Fernando de Mendonça
Diretor Geral

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CAPÍTULO 1

INTRODUÇÃO

1.1 - Considerações Gerais

A finalidade deste documento é apresentar o estudo de uma estação terrestre destinada a receber no Brasil as informações transmitidas pelos satélites da série ERTS, sendo que o primeiro deles será lançado pela NASA, (agência espacial dos EEUU), em junho de 1972.

Conforme o documento final apresentado à NASA pela General Electric, (firma contratada pela NASA para fazer o estudo do programa ERTS), o satélite e o sistema de gravação do mesmo tem vida útil prevista para um ano e mil horas de operação respectivamente. Levando em conta que os dados obtidos pelo ERTS são de grande utilidade para um número elevado de países, pode-se estimar que as mil horas de operação previstas para o gravador serão atingidas em aproximadamente 6 meses após o lançamento do satélite. Para que as informações destinadas ao Brasil não sejam interrompidas, o mesmo deverá recebê-las diretamente do satélite mediante uma estação de terra. Como uma estação instalada em território brasileiro cobrirá também outros países sulamericanos, o Governo Federal poderá eventualmente entrar em contato com os governos destes outros países, para sondar o interesse dos mesmos no programa.

Com tal estação, o Brasil terá meios de monitorar continuamente as riquezas de todo o território brasileiro. Num mesmo dia teremos informações em forma de imagens e fitas magnéticas digitais, dos mais remotos e longínquos pontos do território nacional. Estes dados poderão ser fornecidos a todas as agências brasileiras, privadas ou não, que estejam ligadas à Cartografia e ao Levantamento e/ou Exploração de Recursos Naturais.

A participação do Brasil no programa ERTS e nos futuros programas de satélites de recursos naturais, tornaria possível:

- Desenvolver um mapa de uso das terras de todo o território brasileiro;
- Classificar por áreas as características geológicas e do solo de todo o Brasil;
- Desenvolver um mapa agricultural para o Brasil;
- Desenvolver um mapa das reservas florestais brasileiras;
- Reduzir perdas na agricultura através da identificação rápida de infestações de pragas;
- Planejar a distribuição para todo o Brasil da produção anual, através da estimativa das colheitas por áreas;
- Aumentar a produção através da determinação das características do solo e controle das reservas de água;
- Planejar melhor o desenvolvimento rural e urbano;
- Identificar feições geológicas tais como falhas, estruturas, dobras;
- Monitorar fenômenos dinâmicos tais como sedimentação, mudanças litorâneas, erosão, crescimento das colheitas, nível das reservas de água, etc.;
- Avaliar o desenvolvimento na abertura de grandes estradas tais como as em construção na região amazônica;
- Coletar dados de estações fixas em pontos remotos do território brasileiro, tais como: nível das águas dos lagos, dos reservatórios e das represas; umidade de solo; temperatura das superfícies; salinidade do oceano; correntes oceânicas; poluição atmosférica; direção e velocidade dos ventos, etc.;
- Fazer um inventário das nascentes de águas;
- Identificar, monitorar e avaliar a poluição da atmosfera e das águas;
- Aumentar a produção da pesca através da localização das correntes marítimas frias, das áreas biologicamente ricas e das condi-

ções de temperaturas ideais para a pesca;

- Planejar melhor as viagens marítimas através das condições de mar detetadas;
- Detetar grandes desastres de navegação;
- Fazer levantamento cartográfico de todo o território brasileiro
- Fazer levantamento das coberturas de nuvens;
- Prover informações com inferências demográficas, etc.;
- Melhor planejar a ocupação de áreas como a Amazônia, bem como fiscalizar tal ocupação de tal maneira que ela seja feita racionalmente, sem rompimento do equilíbrio ecológico.

1.2 - O Meio Ambiente Brasileiro e as Imagens Coletadas por Satélite

Uma das maneiras de tirar proveito de uma imensa região como o interior do Brasil, uma área de 6 milhões de quilômetros quadrados com uma densidade populacional de apenas 2 habitantes por quilômetro quadrado, seria desenvolver no mesmo atividades compatíveis com a sua vastidão e baixo índice de povoamento. Essas atividades poderiam inicialmente se restringir a pontos, ou áreas limitadas onde a ênfase deveria ser colocada na exploração dos recursos naturais locais. A capabilidade do satélite para cobrir extensas áreas da superfície da terra em curto espaço de tempo e com despesas relativamente moderadas se casa perfeitamente com a necessidade de um amplo levantamento inicial dessas remotas áreas. Esse levantamento básico por sua vez possibilitará a concentração de posteriores levantamentos com aeronave ou métodos convencionais de superfície em áreas relativamente pequenas.

Com relação às regiões intermediárias, entre as áreas centrais e a costa, também vasta, com cerca de 2,5 milhões de quilômetros quadrados porém, em contraste, com uma densidade populacional da ordem de 35 hab. por km^2, uso de sensores em aviões, voando a grandes altitudes ou em plataformas orbitais, além de permitir a descoberta de novas fontes de recursos naturais ou adicional exploração de fontes produtivas já existentes, será certamente muito útil na exploração económi ca e no controle da agricultura e das florestas num nível regional. As necessidades de informações correntes sobre o uso da terra e sobre o crescimento e condição das culturas apresentam uma quase ilimitada demanda dos dados coletados por sensoriamento remoto. Dados colhidos de alturas orbitais têm um especial significado para um país onde a agricultura extensiva é predominante e as florestas são, em geral, gigantescas. Os dados coletados para os especialistas em agricultura e silvicultura serão provavelmente de igual importância para geógrafos e planejadores interessados em amplos desenvolvimentos regionais. Há, por outro lado, atualmente no Brasil, esforços organizados no sentido de solucionar os problemas de desenvolvimento econômico de imensas regiões com características extremamente diferentes como a úmida Bacia Amazônica e o seco Nordeste.

Um exemplo de aplicação de dados sobre solos, colhidos por satélite, seria o da ajuda na mudança das condições existentes nos "campos cerrados", encontrados numa área de cerca de 1,5 milhões de quilômetros quadrados no Brasil Central e na região intermediária supra-citada. Pesquisas têm mostrado que o problema é essencialmente de alta acidez do solo, que pode ser minimizada através da adição de calcáreo dolomítico e de fertilizantes.

Ao longo da extensa costa brasileira com mais de 7 mil quilômetros, dados colhidos de altitudes orbitais poderiam delinear os contrastes de temperatura que caracterizam os contornos da corrente do Brasil, nas costas Sul e Leste, e das correntes de Falklands (Malvinas) que chegam às praias do extremo sul durante o inverno. Além de serem importantes para a navegação, estas informações apresentam correlação com o movimento das comunidades biológicas marinhas, e consequentemente com a pesca comercial.

1.3 - Levantamento Sistemático de Recursos Naturais e as Imagens de Satélites

Com o levantamento, em 5 etapas, a seguir mostrado, procurou-se apresentar, a título de ilustração, um programa genérico que

LEVANTAMENTO SISTEMÁTICO

NÍVEL DO LEVANTAMENTO ESCALA DAS IMAGENS	SENSORES E COBERTURA	SÍTIOS NO SOLO
1- NÍVEL ORBITAL MINI-ESCALAS	IMAGEADOR MULTI-ESPECTRAL CAMARAS DE TELEVISÃO E FOTOGRÁFICAS (COBERTURA GLOBAL E REPETITIVA)	PONTOS DE CONTROLE
2- NÍVEL DE RECONHECIMENTO A GRANDE ALTURA MINI A PEQUENAS-ESCALAS (VERDADE DO NÍVEL 1)	RADAR DE VISADA LATERAL E CÂMARA MÉTRICA (TOTAL), CÂMARA MULTI-ESPECTRAL (PARCIAL)	PONTOS DE CONTROLE
3-NÍVEL DE RECONHECIMENTO A MÉDIA ALTURA ESCALAS MÉDIAS (VERDADE DO NÍVEL 2)	MAGNETÔMETRO (TOTAL) E CÂMARA MULTI-ESPECTRAL (PARCIAL) OBSERVAÇÃO AÉREA VISUAL	PONTOS DE CONTROLE E ESTAÇÕES MAGNETOMÉTRICAS
4-NÍVEL DE DETALHAMENTO A MÉDIA E BAIXA ALTURA ESCALAS MÉDIAS A MAXI (VERDADE DO NÍVEL 3)	CÂMARA MÉTRICA, SENSORES GEOFÍSICOS, IMAGEADOR MULTI-ESPECTRAL (ÁREAS ALVO) OBSERVAÇÃO AÉREA VISUAL	VIAGENS DE CAMPO ÀS ÁREAS ALVOS
5- TERRENO (VERDADE NO SOLO)	GEOQUÍMICA, GEOFÍSICA, ESPECTROMETRIA, HIDROMETRIA, ETC	BASES AVANÇADAS DE EXPLORAÇÃO

Mini-escalas: 1:1.000.000 ou menores

Pequenas escalas: 1:30.000 ou menores

Escalas médias: 1:25.000 a 1:12.000

Grandes escalas: em torno de 1:5.000

Maxi-escalas: 1:2.000 ou maiores.

permitiria executar a partir de imagens de satélites rápida e economicamente:

- mapeamentos regionais;
- mapeamentos seletivos das áreas mais promissoras para o desenvolvimento de uma determinada região.

Nesse programa estabeleceu-se elos de uma cadeia de dependência, com detalhamento crescente, onde presume-se que um nível de detalhamento possa servir como "verdade" para o nível que lhe anteceda, além de trazer uma contribuição de novas informações, o que dele usualmente se espera.

Com isso visar-se-ia obter um sistema de filtragem que possibilitando seleção de áreas mais promissoras em cada nível de levantamento conduzisse a um processo de rápida redução de áreas, onde a avaliação ou interpretação de dados sobre áreas maiores permitisse a rápida eliminação das partes dessas áreas que mostrassem menos potencial.

A fim de melhor situar o problema aparecem a seguir algumas informações sobre o veículo de coleta e o tipo e formato dos dados produzidos.

1.3.1 - Nível de Levantamento Orbital

1.3.1.1 - Satélites ERTS

O primeiro Satélite de Tecnologia para Recursos Naturais, conhecido como ERTS-A, como já dissemos anteriormente, será lançado pela NASA em junho de 1972. Maiores informações sobre o mesmo e seus equipamentos sensores e de gravação, serão apresentados ao longo deste trabalho.

1.3.1.2 - Laboratório Espacial (SKYLAB)

Além dos satélites da série ERTS, a NASA lançará em 1973, uma estação espacial experimental, com três tripulantes, conhecida como

"SKYLAB WORKSHOP". Essa espaçonave orbitará em altitudes de 435 Km (235 milhas náuticas), numa inclinação de 50^{o} e receberá tripulação durante três períodos, o primeiro de 28 dias e os segundos e terceiros de 56 dias. Num período total de 8 meses, ter-se-á, praticamente, 5 meses de operação tripulada.

Além de um grande número de experimentos científicos, estão programadas para esse projeto, observações da Terra. Como o território nacional ficará inteiramente coberto por órbitas de 50^{o} de inclinação em relação ao Equador, essas observações serão de particular interesse para o Brasil.

No Apêndice A está apresentado uma descrição dos equipamentos sensores da Estação Orbital.

O Brasil, por intermédio do INPE, fêz proposta à NASA para também participar deste programa.

1.3.2 - Nível de Reconhecimento Aéreo a Grande Altura

Para exemplificar este nível tomamos o caso do levantamento da Região Amazônica, onde está sendo utilizado, para aquisição de dados de radar e fotográficos, um CARAVELLE, da LASA Engenharia e Prospeções S.A., voando a uma velocidade de 700 Km/hora (380 nós) e a uma altitude de 11 a 12.000 metros (36 a 40.000 pés) acima do terreno. O radar de visada lateral (SLAR) utilizado, do tipo abertura sintética Goodyear modelo 102, apresenta uma resolução espacial melhor do que 20 metros em todos os pontos da imagem. Funciona na faixa "X" (3 cm de comprimento de onda).

Todos os vôos, controlados por sistema de navegação inercial, são executados ao longo de linhas na orientação N-S, fazendo uma varredura lateral de 37 Km de largura, com as varreduras ajacentes superpostas de 20%. A apresentação dos resultados está sendo feita em mosaicos, de 1º x $1,5^{o}$, na escala de 1:250.000.

A amarração geográfica das linhas de vôo vem sendo obtida pelo emprego de estações SHORAN, com coordenadas geográficas determinadas por observação de satélites TRANSIT (operadas pela LASA e AEROSERVICES).

Além do radar, está sendo utilizado uma câmara métrica ZEISS, com lente super-grande-angular, provida com filme infravermelho falsa-cor. O seu campo de visão permite superposição com as imagens do radar.

As fotos estão sendo tiradas com 60% de superposição longitudinal e pequena superposição lateral e são apresentadas no formato do filme, 23 x 23 cm (9 x 9 pol.), numa escala de 1:130.000.

Simultaneamente com as fotos da câmara métrica vêm sendo obtidas fotos multi-espectrais, em branco e preto, por meio de uma câmara de quatro lentes I^2S. A escala é de 1:73.000, com quatro imagens dispostas em quadrado num único filme de 23 cm. A cobertura, é portanto, parcial, quase 25% do total.

1.3.3 - Nível de Reconhecimento Aéreo à Média Altura

No terceiro nível, que seria de reconhecimento aéreo em escala regional, desta feita executado em alturas médias, procurar-se-ia conciliar o emprego de um sensor geofísico, o magnetômetro, hoje considerado como requisito básico para o reconhecimento geológico de grandes áreas, como o de fotografias aéreas multi-espectrais, em escalas de uso corrente entre os foto-intérpretes interessados nas demais disciplinas.

A altura de vôo neste levantamento, que poderá ser qualificada como de transição, seria entre 9.000 e 11.000 pés acima do terreno (3.000 m nominais) com linhas de vôo espaçados de 5 km, cortadas por transversais cada 25 km.

No que se refere às medidas obtidas com o magnetômetro, seria possível a sua apresentação em mapas, com o campo geomagnético principal removido, mostrando contornos a intervalos de 25 gamas, numa escala de 1:1.000.000. Os dados magnéticos seriam registrados em forma digital, o que permitiria o uso extensivo de computadores na compilação dos mapas.

Para obtenção dos dados fotográficos seriam utilizadas, ou câmaras multi-lentes dotadas de lentes e filtros adequados e de um único filme, ou então conjuntos de câmaras, cada uma provida da desejada combinação de filme-filtro. Em ambos os casos as distâncias focais das lentes empregadas deveriam permitir a tomada de fotos em escalas da ordem 1:20.000.

Para o controle das linhas de vôo, e sua amarração geográfica, seriam empregados sistemas de navegação inerciais ou "doppler".

Cabe observar que não foi prevista a utilização de outros sensores, tais como eletromagnetômetros, imageadores térmicos, espectrômetros de radiação gama ou de mercúrio, por serem as suas altitudes máximas de emprego aéreo muito pequenas e, portanto, incompatíveis com a especificada para esta etapa.

As duas etapas precedentes, onde procurar-se-ia tirar partido de sensores suscetíveis de aplicação em larga escala, seriam complementadas pela que acaba de ser esboçada, na qual sugere-se um levantamento de transição do regional para o local. Este levantamento, em condições aceitáveis de desempenho, tempo e custo, forneceria dados que por sua natureza e grau de definição permitiriam estudos mais seletivos. As informações, obtidas por intermédio desses levantamentos, certamente possibilitariam, não só mapeamento básico, como a escolha das áreas mais promissoras que seriam os alvos dos levantamentos detalhados convencionais mencionados a seguir.

Essa seleção seria, evidentemente, facilitada por um estudo das informações existentes sobre a região e pela consideração dos dados colhidos durante a observação aérea visual, também prevista para esta etapa.

O conjunto dos dados acumulados na terceira etapa serviriam como a "verdade" para os níveis de reconhecimento precedentes.

1.3.4 - Nível de Detalhamento Aéreo à Média e à Baixa Altura

Os serviços de levantamento detalhado das áreas selecionadas como mais promissoras na etapa anterior, exigiriam um planejamento específico para cada caso. Certas providências parecem, no entretanto, imprescindíveis. Esta nesse caso, uma medida preliminar que visa eliminar as naturais incertezas dos processos interpreparativos: uma curta viagem, de reconhecimento no terreno, às áreas qualificadas como promissoras. Provavelmente, os dados de maior interesse a serem obtidos in loco seriam geoquímicos. As distâncias e as dificuldades de acesso seriam fatores considerados na classificação prioritária das áreas promissoras.

Em princípio, nesse nível, seria considerada a utilização certamente em sistemas combinados, dos seguintes sensores:

- Imageadores (térmicos, no visível, no ultravioleta, etc);
- Magnetômetros;
- Eletromagnetômetros;
- Espectrômetros de mercúrio;
- Espectrômetros de radiação gama.

Todos esses sensores deveriam ser utilizados em vôos a baixa altura. A plotagem dos dados coletados seria na escala dos fotomosaicos obtidos por cobertura fotográfica aérea nas escalas mais convenientes às necessidades cartográficas de cada área-alvo.

Da mesma forma que na 3a. etapa, os vôos continuariam a ser aproveitados para observação visual. Este nível serviria como "verdade" para os níveis precedentes e, mediante uma reavaliação das áreas nele qualificadas como promissoras, permitiria uma seleção final daquelas que mereceriam os estudos da etapa seguinte.

1.3.5 - Terreno

Embora os levantamentos neste nível estejam qualificados como da "verdade no solo", os trabalhos que seriam nele realizados deveriam, também, ter um caráter exploratório. Os sítios escolhidos deveriam ser considerados como bases avançadas de operação relativamente prolongada e, mesmo como eventuais polos de desenvolvimento da área.

Nestas condições estariam justificados maiores investimen tos no desenvolvimento das áreas escolhidas. Desenvolvimento que deveria, por exemplo, incluir a construção de campos de pouso e outros recursos materiais que, permitindo permanência mais demorada de pessoal no local, possibilitassem uma execução eficiente dos trabalhos de campo.

De forma mais crítica que na etapa anterior, as pesquisas no terreno a serem executadas nessas áreas deveriam ser objeto de cuidadosos planejamentos específicos.

CAPÍTULO 2

O SISTEMA ERTS

O controle e a conservação das reservas naturais da terra é vital para o futuro da humanidade. Uma tentativa para este controle e conservação será feita através do Programa ERTS (Earth Resources Technology Satellite), sob a responsabilidade da NASA.

O ERTS-A será o primeiro de uma série de satélites, devendo ser lançado em junho de 1972, com vistas a prover os primeiros dados sobre os recursos naturais e culturais da Terra colhidos de uma maneira sistemática. Este satélite com uma vida útil prevista para um ano, terá uma órbita circular quase polar, síncrona com o sol, de modo que cada ponto da superfície da terra será sensoriado repetitivamente a cada 18 dias sempre na mesma hora. O satélite transportará um imageador multispectral (MSS - Multispectral Scanner -), um conjunto de três câmaras vidicons (RBV - Return Beam Vidicon -), dois gravadores de banda larga (WBTR - Wide Band Tape Recorder -) e um sistema de coleção de dados (DCS - Data Collection System -); este último para a aquisição de dados transmitidos por plataformas de coleta de dados (DCP - Data Collection Platforms -) sediadas em pontos estratégicos da superfície da Terra. O satélite terá também, complementando os dois sistemas sensores (imageador e vidicons), equipamentos para transmitir para estações receptoras de terra os dados coletados pelos sensores e informações relativas ao funcionamento dos mesmos e do satélite em si. O satélite transmitirá também sinais de sincronização e calibração juntamente com as informações captadas pelos sensores.

Os dados provenientes do MSS e RBV, os sinais do DCS, os sinais de rastreio e as informações sobre a operação do sistema serão transmitidos para a terra na faixa de frequência de microondas (banda S). Em terra tais dados serão recebidos, gravados, e posteriormente convertidos em imagens fotográficas e fitas digitais de acesso direto ao computador.

O programa ERTS, é o precursor do programa EROS, que consta de satélites de observação dos recursos terrestres (EOS) e que deverá ser implementado pela NASA na segunda metade da década de 70.

2.1 - Os sensores

A banda espectral coberta pelos dois tipos de sensores (RBV e MSS) foi escolhida com grande cuidado e com a ajuda das várias agências usuárias do programa ERTS. As câmaras de televisão (RBV) foram projetadas para as seguintes faixas espectrais:

0,475 - 0,575 microns (azul - verde)
0,580 - 0,680 microns (laranja - vermelho)
0,690 - 0,830 microns (vermelho).

A banda inferior, 0,475 - 0,575 microns permitirá o estudo, por exemplo, de áreas onde predomina água. A faixa superior, 0,690-0,830 microns, centrada mais ou menos em 0,750 microns (pico de radiação para a clorofila), permitirá o estudo de áreas cobertas por vegetação verde. O limite superior de 0,830 microns representa a resposta limite do sistema de televisão. Acima deste limite situam-se as informações do infravermelho, também requerida pelos usuários do ERTS; para fornecer estas informações e também cobrindo a mesma faixa do sistema de televisão, foi especificado o imageador multispectral (MSS). O MSS fornece informações nas seguintes bandas:

0,500 - 0,600 microns (verde a laranja)
0,600 - 0,700 microns (laranja a vermelho)
0,700 - 0,800 microns (vermelho a infravermelho próximo)
0,900 - 1,100 microns (infravermelho próximo).

As três primeiras na parte do visível do espectro e a última no infravermelho próximo. Em cada banda existem seis fotodetetores. Uma simples varredura do espelho do imageador multiespectral fornecerá informações sobre uma faixa de 100 milhas náuticas para todos os 24 fotodetetores. A tabela 2.1 mostra as características principais dos dois sensores (RBV e MSS) e do gravador de banda larga (WBVTR) do satélite.

A resolução ou definição das imagens multiespectrais resultantes dos dois tipos de sensores são da ordem de 60 a 130 metros, mas foi previsto que alguns objetos de dimensões menores podem ser descobertos e reconhecidos. As imagens terão escala de cerca de 1:1.000.000, e poderão ser transformadas, em terra, em fotos branco e preto para cada banda espectral de cada sensor. Assim, para cada área de 100 x 100 milhas náuticas existirão sete imagens. Ainda, em terra, as várias imagens poderão ser compostas de maneira a fornecer imagens coloridas ou em falsa cor.

O segundo satélite de tecnologia para recursos da terra, ERTS-B, terá essencialmente as mesmas especificações do ERTS-A, exceto pela adição de uma faixa espectral extra no imageador multi-espectral (10,4 a 12,6 microns - infravermelho térmico).

TABELA 2.1 - CARACTERÍSTICAS DOS SENSORES RBV-MSS E DOS GRAVADORES DE BANDA LARGA DO SATÉLITE

CÂMARAS RBV			
CARACTERÍSTICAS	Câmara nº 1	Câmara nº 2	Câmara nº 3
Faixas Espectrais (nanômetros)	475-575	580-680	690-830
Resolução (centro)	4500 TVL	4500 TVL	3400 TVL
Resolução nas extremidades (% do centro)	80%	80%	80%
Relação sinal-ruído	33 dB	33 dB	25 dB
Faixa Dinâmica	50:1	50:1	50:1
Escala cinza	10	10	8
Razão de varredura horizontal (linhas/seg)	1250	1250	1250
Número de linhas varridas	4200	4200	4200
Tempo de Leitura (seg)	3,5	3,5	3,5
Largura da faixa de video (MHz)	3,5	3,5	3,5
Tempo entre tomadas consecutivas (seg)	25	25	25
Tempo de exposição (milisegundos)	8, 12 ou 16	8, 12 ou 16	8, 12 ou 16
Distorção da Imagem (máxima)	1%	1%	1%
Imageador Multiespectral MSS			
Faixas espectrais (microns)	canal 1	0,5 a 0,6	
	canal 2	0,6 a 0,7	
	canal 3	0,7 a 0,8	
	canal 4	0,8 a 1,1	
	canal 5	10,4 a 12,6 (ERTS B apenas)	
Frequência de varredura	13,6 Hz		
Eficiência de varredura	50%		
Detetores/banda/varredura (canais 1,2, 3 e 4)	6		
Campo de visão instantânea (IFOV)	260 ft x 260 ft		
Saída Multiplexada	15 Mbps PCM		
Gravador de Banda Larga - WBVTR			
Princípio de Gravação	Varredura Transversa		
Técnica de Processamento de video	FM		
Largura da Fita	2 in.		
Comprimento da Fita	2000 ft		
Tempo de Gravação	30 minutos		
Largura de Faixa	DC a 3,5 MHz (-6 dB), DC a 6 MHz		
Relação Sinal-ruído	42 dB p-p/rms a 2,5 MHz		
Resposta Transiente	Aprox. 5% pico		
Linearidade	± 3%		

2.2 - A Órbita

A órbita do satélite é circular, quase polar, sol-síncrona, e mantém uma inclinação constante de 99,088 graus. Com esta órbita, os sensores do satélite imagearão uma mesma área sempre com a mesma iluminação solar, sendo assim mais simples detetar diferenças na vegetação e nos níveis de água. O satélite irá cobrir uma faixa contínua de 100 milhas náuticas (185 km) de largura e retornará para imagear uma mesma área, na mesma hora local, cada 18 dias. Os equipamentos controladores da altitude do satélite detetam erros de posição de modo que o satélite seja posicionado corretamente com erros inferiores a 0,7 graus com relação aos três eixos de posição.

Os parâmetros orbitais do ERTS são ajustados de modo que faixas adjacentes tenham uma superposição de 10% em cada lado, na ausência de erro de atitude.

A órbita do ERTS tem o semi-eixo maior igual a 7.300 Km e um período aproximado de 103 minutos. A longitude geográfica de passagens subsequentes do ERTS sob o equador se desloca de 25,8167 graus para o oeste. Coberturas de faixas adjacentes ocorrem a cada 14 revoluções e estão separadas em longitude de 1,4338 graus, ou seja, 160 km no equador. No fim de 18 dias, ou da conclusão de 251 revoluções, o período de cobertura é completado. A tabela 2.2 mostra alguns parâmetros orbitais nominais.

TABELA 2.2 - PARÂMETROS ORBITAIS NOMINAIS

PARÂMETROS ORBITAIS	ÓRBITA NOMINAL
Altitude	492,35 mn (910 km)
Inclinação	99,088 graus
Período	6196,015 seg (103 min.)
Excentricidade	0,0001
Hora local na qual o satélite cruza o equador na descida	09:30 h
Duração do ciclo de cobertura	18 dias (251 revs)
Distância entre trajetórias adjacentes no equador	86,028 mn (160 km)

CAPÍTULO 3

ENLACES DO ERTS

A alocação das frequências e as faixas ocupadas previstas para o ERTS-A e B são as seguintes:

Enlace 1: USB - enlace de subida para comando

Portadora de RF: 2106,4 MHz
Banda ocupada: 3,6 MHz
Modulação: PCM/FSK - FM/PM

Enlace 2: MSS - enlace de descida (dados do MSS)

Portadora de RF: 2229,5 MHz
Banda ocupada de RF: 20 MHz
Modulação: PCM/FSK
Velocidade de informação: 15 Mb/seg

Enlace 3: RBV - enlace de descida (dados do RBV)

Portadora de RF: 2265,5 MHz
Banda ocupada de video: 3,5 MHz
Banda ocupada de RF: 20 MHz
Modulação: video/FM

Enlace 4: USB - enlace de descida (dados de faixa estreita)

Portadora de RF: 2287,5 MHz
Banda ocupada: 5 MHz
Modulação: PM

Enlace 5: VHF - enlace de descida (dados de telemetria)

Portadora de RF: 137,86 MHz
Banda ocupada: 90 KHz emergência; 30 KHz normal
Modulação: PCM/PM

Enlace 6: DCS - enlace de subida para coleta de dados

Portadora de RF: 401,9 MHz
Banda ocupada: 100 KHz
Modulação: PCM/FSK

Enlace 7: VHF - enlace de subida para comando

Portadora de RF: 154,2 MHz
Banda ocupada: 30 KHz
Modulação: PCM/FSK - AM/AM

Para recepção e processamento das imagens somente os enlaces 2,3 e 4 são importantes. O enlace 5 é um enlace de reserva para os dados de telemetria que são transmitidos também no enlace 4. A estação do Brasil poderá eventualmente receber estes dados também no enlace 5. O enlace 6 é usado para transmitir os dados das plataformas (sistema DCS)de terra para o satélite. Os enlaces 1 e 7 são destinados ao comando e controle do satélite e a interrogação dos sensores; a estação brasileira não necessitará de equipamentos para esses enlaces já que a NASA programará as memórias internas do satélite para que o mesmo seja comandado quando estiver dentro de seu raio de cobertura.

3.1 - Enlaces de banda larga (RBV e MSS)

As características principais destes dois enlaces são apresentadas na tabela 3.1

TABELA 3.1 - ENLACES DE BANDA LARGA

	MSS	RBV
Frequência central	2229,5 MHz	2265,5 MHz
Banda ocupada de RF	20 MHz	20 MHz
Potência do transmissor	20*watts	20 * watts
Modulação	PCM/FSK	vídeo/FM

* Potência de 10 ou 20 watts comutável.

3.2 - Enlace de descida USB

Este enlace tem capacidade para transmitir todos os dados de banda estreita mais o sinal PRN.

As especificações gerais são as seguintes:

Frequência da portadora: 2287,5 MHz ± 0,0015%, no modo não coerente. 240/221 vezes a frequência portadora do enlace USB de subida, no modo coerente.

Modulação: modulação de fase

Banda ocupada de RF: 5 MHz

É necessário transmitir simultaneamente no enlace de descida USB os seguintes sinais:

1 - Sinal DCS
2 - Sinal PCM de telemetria em tempo real
3 - Sinal PCM de telemetria armazenado

O sinal PCM de telemetria armazenado normalmente transmitido é o gravado nos gravadores de faixa estreita do satélite (NBTR). No caso de falha desses gravadores o sinal a ser transmitido é o gravado nos canais auxiliares dos gravadores de faixa larga (WBVTR). Portanto, durante a reprodução dos gravadores, três sinais devem ser transmitidos no enlace de descida USB. Segue uma descrição das características principais de cada sinal.

Sinal DCS

Descrição do sinal: onda senoidal modulada em frequência
Banda ocupada: 100 KHz centrada na frequência de 1024 KHz

Sinal PCM de telemetria em tempo real

Descrição do sinal: sinal PCM split-phase
Velocidade de informação: 1 kilobit/seg
Probabilidade de erro na deteção: menor que 10^{-6}

Sinal PCM de telemetria armazenado

Descrição do sinal: sinal PCM split-phase
Velocidade de informação: 24 kilobit/seg quando o sinal estiver gravado no NBTR, ou 1 kilobit/seg quando o sinal estiver gravado no WBVTR
Probabilidade de erro na deteção: menor que 10^{-6}

Para transmitir todos os três sinais simultaneamente na portadora do enlace de descida USB é necessário empregar várias subportadoras. As subportadoras usadas são as seguintes:

Subportadora	Tipo de modulação da subportadora
1024 KHz	PCM/FSK/PM
768 KHz	PCM/PSK/PM
597 KHz	PCM/PSK/FM

3.3 - Enlace de descida VHF

Este enlace é usado para transmitir ou o sinal PCM de telemetria em tempo real ou o sinal PCM de telemetria armazenado.Este enlace é considerado como reserva para o enlace de descida USB.

As características gerais deste enlace são as seguintes:

- Frequência central de transmissão: 137,86 MHz
- Banda ocupada pelo canal: 30 KHz, em tempo real
  90 KHz, armazenado

Segue a descrição de cada sinal:

Sinal PCM de Telemetria em tempo real

Descrição do sinal: PCM split - phase
Velocidade de informação: 1 kilobit/seg
Probabilidade de erro na deteção: menor que 10^{-6}

Sinal de telemetria armazenado

Descrição do sinal: PCM split - phase
Velocidade de informação: 24 kilobit/seg ou 1 kilobit/seg

3.4 - Enlace de subida USB

Neste enlace são transmitidos os seguintes sinais:

- "Pseudo random-noise (PRN) ranging signal"
- Sinais de comando

As características dos sinais são as seguintes:

- Frequência da portadora recebida: 2106,4 MHz
- Modulação da portadora: fase
- Banda ocupada pela informação: 1,5 MHz
- Frequência da subportadora de comando: 70 KHz

3.5 - Enlace de subida VHF

Neste enlace são transmitidos os mesmos sinais de comando do enlace USB de subida. As características gerais são as seguintes:

- Frequência da portadora recebida: 154,2 MHz
- Modulação: PCM/FSK - AM/AM
- Índice de modulação da portadora: 80% AM (pico)
- Subportadoras de comando: 8,0 KHz a 8,6 KHz
- Velocidade de comando: 128 bps
- Probabilidade de erro na deteção de comando: menor que 10^{-6}
- Banda ocupada: 30 KHz

CAPÍTULO 4

CÁLCULO DOS ENLACES

4.1 - Enlace RBV (Return Beam Vidicon)

As três câmaras "Return Beam Vidicon" funcionarão simultaneamente e gerarão um sinal de vídeo que cobre as frequências de dc até 3.5 MHz. O sinal de saída das câmaras poderá entrar diretamente nos terminais de entrada do transmissor de banda larga para transmissão em tempo real ou entrar num dos gravadores de faixa larga (WBVTR 1 ou 2) para gravação e posterior reprodução para transmissão. Na estação de recepção de terra, um discriminador de banda larga processa o sinal recebido acima do limiar junto com o ruído, recuperando o sinal de vídeo com um aumento na relação sinal ruído (S/N) depois da deteção.

Para o enlace RBV foi especificada a frequência de 2265,5 MHz. A banda de RF ocupada de 20 MHz é também considerada como a banda ocupada pelo ruído. Usando um transmissor no satélite de potência 20 ou 10 Watts, para um ângulo de elevação da antena da estação de recepção de 5^{o}, obtém-se que:

- O ganho da antena do satélite para um ângulo de elevação de 5^{o} da antena de terra é melhor que 4,0 db. Este valor inclui as perdas de polarização.
- As perdas de transmissão foram calculadas em 1,35 db. Estas perdas incluem as perdas entre os terminais de saída do amplificador de potência e a entrada dos terminais da antena, incluindo perdas nos filtros, conectores, cabos, circuladores, etc. As perdas atmosféricas são consideradas para 5^{o} de elevação e estimadas em 0.7 db.
- As perdas do espaço livre são calculadas a partir da fórmula,

$$L_{FS} = 20 \log \frac{\lambda}{4\pi d}$$

onde,

$$d = (R_e + h) \frac{\text{sen } \delta}{\text{sen } (90^o + \alpha)} \text{ , e}$$

$$\delta = \cos^{-1} \left(\frac{R_e}{R_e + h} \right) - \alpha$$

Usando a altitude $h = 492$ milhas náuticas (910 km), ângulo de elevação $\alpha = 5^o$ e raio da Terra $R_e = 6380$ km encontramos

$\delta = 24{,}3^o$

$d = 1620$ nm (3000 km)

$L_{FS} = 169{,}1$ db

- A potência de ruído termal em uma banda equivalente de 20 MHz é calculada a partir de $N = KTB$

onde $K = 1{,}38.10^{-23}$ Joule/^{o}K

$N = 10 \log_{10} 1{,}38.10^{-23}$ dbw por ^{o}K por Hz, o que conduz a,

$N = -228{,}6$ dbw por ^{o}K por Hz

4.1.1 - Seleção dos parâmetros FM

A relação sinal ruído $(S/N)_o$ nos terminais de saída do discriminador é dada por

$$\left(\frac{S}{N}\right)_o = \frac{3}{2} \left(\frac{\Delta f}{f_m}\right)^2 . \frac{B_{RF}}{f_m} \frac{C}{N} \qquad (1)$$

onde

Δf	é o desvio de pico da frequência central de rádio-frequência (RF)
f_m	é a frequência de modulação
B_{RF}	é a banda de rádio-frequência (RF)
C/N	relação portadora ruído na entrada dos terminais do discriminador usando: $f_m = 3{,}5$ MHz $B_{RF} = 20$ MHz

o índice de modulação (β) foi calculado analisando as funções de Bessel, tendo sido escolhido de modo que a energia fora das bandas laterais não seja maior que 1% da energia total.

Com $\beta = 1{,}6$ a energia fora da banda de 20 MHz é aproximadamente 1,1%.

O fator de melhoria de modulação (MIF) é calculado a partir da fórmula

$$MIF = \frac{3}{2} \left(\frac{f}{f_m} \right)^2 \frac{B_{RF}}{f_m}$$

Com o índice $\beta = 1{,}6$ resulta um valor de

MIF = 22 ou 13,4 db

A equação (1) é válida para um sinal modulante senoidal; quando o sinal de vídeo é aplicado, as seguintes considerações têm que ser levadas em conta:

- O sinal de informação é 80% do sinal de vídeo pico a pico. A relação sinal ruído S/N na saída do detetor será então $(0{,}8)^2$ vêzes a relação sinal ruído de pico, correspondendo a uma redução de 2 db.
- O sinal de vídeo que produz o mesmo desvio pico a pico FM de um sinal senoidal tem uma potência 8 vêzes maior que a potência média do sinal senoidal. A relação sinal ruído terá então um aumento de 9 db.

Devemos considerar um acréscimo na relação portadora ruído de 13,4 devido ao MIF, uma redução de 2 db devido à primeira consideração acima e um aumento de 9 db devido à segunda consideração. Ou seja, um acréscimo de 20,4 db.

São considerados dois tipos de estação com as correspondentes especificações, ganho das antenas, temperatura de ruído das antenas e receptores, deixando uma margem de 6 db. Os **dois** tipos de estação são apresentados a seguir.

Estação receptora com antena parabólica de 9 metros de diâmetro

Para o enlace RBV pode ser usada uma potência de transmissão de 20 ou 10 watts.

- Potência do transmissor do satélite:

  P_T = 43 dbm para 20 watts
  P_T = 40 dbm para 10 watts
- Ganho da antena do satélite: 4,0 dB computando as perdas de polarização
- Perdas de transmissão: -1,35 dB
- Perdas no espaço: -169,8 dB

  Perdas no espaço livre: -169,1 dB
  Perdas atmosféricas: - 0,7 dB
  -169,8 dB
- Ganho da antena receptora:

  O ganho é computado a partir da fórmula

  $$G = \eta \left(\frac{\pi D}{\lambda} \right)^2$$

  para η = 55% e D = 30 pés $G \doteq 44$ dB
- Temperatura do sistema: $T_s = 125^\circ K$
- Potência do ruído na banda de 20 MHz: -104,6 dBm

  N = KTB $K = 1{,}38\ 10^{-23}$ Joule/$^\circ$K
  $T = 125^\circ K$
  B = 20 MHz

  N = -104,6 dbm
- Margem do sistema: - 6 dB
- Potência recebida: -86,15 dbm

  4 + 43 + 44 = 91 db
  169,8 + 6 + 1,35 = -177,15
  - 177,15 + 91 = -86,15 dbm

- Relação portadora ruído: + 18,45 db

  $- 86,15 - (-104,6) = + 18,45$
- Melhoria de FM: 13,4 db

  para $\beta = 1,6$
- Relação sinal ruído S/N

  $S/N = 18,45 + 13,4 - 2+9 = 38,85$ db

<u>Estação de recepção com antena parabólica de 6 metros de diâmetro</u>

- Potência transmitida do satélite

  43 dbm para 20 watts

  40 dbm para 10 watts
- Ganho da antena do satélite: 4,0 db
- Ganho da antena receptora:

  para $\eta = 55\%$

  $D = 20$ pés obtém-se $G = 40,5$ db
- Temperatura do sistema: $T_s = 125^{o}K$ ou $75^{o}K$
- Potência de ruído (20 MHz)

  $N = KTB \quad T_s = 125^{o}K \longrightarrow N = -104,6$ dbm

  $T_s = 75^{o}K \longrightarrow N = -106,85$ dbm
- Margem do sistema: - 6 db
- Relação portadora ruído

  para $T_s = 125^{o}K \longrightarrow 15,45$ db

  para $T_s = 75^{o}K \longrightarrow 17,70$ db
- Relação sinal ruído

  para $T_s = 125^{o}K \longrightarrow \frac{S}{N} = 35,85$ db

  para $T_s = 75^{o}K \longrightarrow \frac{S}{N} = 38,1$ db

Os resultados para um ângulo de elevação de 5^{o} e para um transmissor de 20 watts são mostrados na tabela 4.1.

TABELA 4.1 - CÁLCULOS DO ENLACE RBV

	5° de elevação		
Parâmetros	30 pés	20 pés	
Potência transmitida do satélite	43 dbm	43 dbm	43 dbm
Ganho da antena do satélite	4,0 db	4,0 db	4,0 db
Perda de transmissão	-1,35 db	-1,35 db	-1,35 db
Perdas no espaço	-169,8 db	-169,8 db	-169,8 db
Ganho da antena receptora	44,0 db	40,5 db	40,5 db
Temperatura do sistema	125°K	125°K	75°K
Potência de ruído	-104,6 dbm	-104,6 dbm	-106,85 dbm
Margem do sistema	-6,0 db	-6,0 db	-6,0 db
Potência recebida	-86,15 dbm	-89,15 dbm	-89,15 dbm
Relação portadora ruído	+18,45 db	+15,45 db	+17,70 db
Melhoria FM ($\beta = 1,6$)	+13,4 db	+13,4 db	+13,4 db
Relação sinal ruído (pico a pico)	+38,85 db	+35,85 db	38,1 db

4.1.2 - Degradação do sinal

A relação sinal ruído nas saídas das câmaras são 33,33 e 25 db para as câmaras I, II e III respectivamente.

Consideramos o enlace completo e examinamos a degradação sofrida pelo sinal transmitido em tempo real.

A relação sinal ruído nos terminais de saída do receptor da estação de terra é dada por ,

$$(S/N)_o = \left[\frac{1}{(S/N)_S} + \frac{1}{(S/N)_{TL}} \right]^{-1}$$

onde

$(S/N)_S$ - relação sinal ruído das câmaras

$(S/N)_{TL}$ - relação sinal ruído do enlace de transmissão

Considerando a câmara I ,

$(S/N)_S = 33$ db $\quad (S/N)_{TL} = 38{,}85$

33 db → $2{,}10^3$

38,85 db → $7{,}7.10^3$

$$(S/N)_O = \left[\frac{1}{2{,}10^3} + \frac{1}{7{,}7.10^3}\right]^{-1} \rightarrow 32{,}1 \text{ dB}$$

ou seja uma degradação de $\simeq$ 0,9 dB

A fig. 4.1 mostra que para ter uma degradação inferior a 1 db a relação sinal ruído $(S/N)_{TL}$ tem que ser maior que 38,7 db.

Podemos então calcular as degradações para as três condições de operação consideradas:

OPERAÇÃO	POTÊNCIA	$(S/N)_{TL}$	DEGRADAÇÃO
Antena de 9 m $T_s = 125°K$	20W	+ 38,85 db	$\simeq$ 0,9 db
Antena de 6 m $T_s = 125°K$	20W	+ 35,85 db	$\simeq$ 1,8 db
Antena de 6 m $T_s = 75°K$	20 W	+ 38,1 db	$\simeq$1,0 db

Êstes resultados mostram ser mais conveniente a operação com uma antena de 9 m. Observe-se que a temperatura do sistema ($T_s = 125°K$) considerada para ilustração dos cálculos só é conseguida em sistemas que utilizem um amplificador paramétrico refrigerado; em sistemas que utilizem amplificador paramétrico não refrigerado a temperatura do sistema será maior do que 200°K.

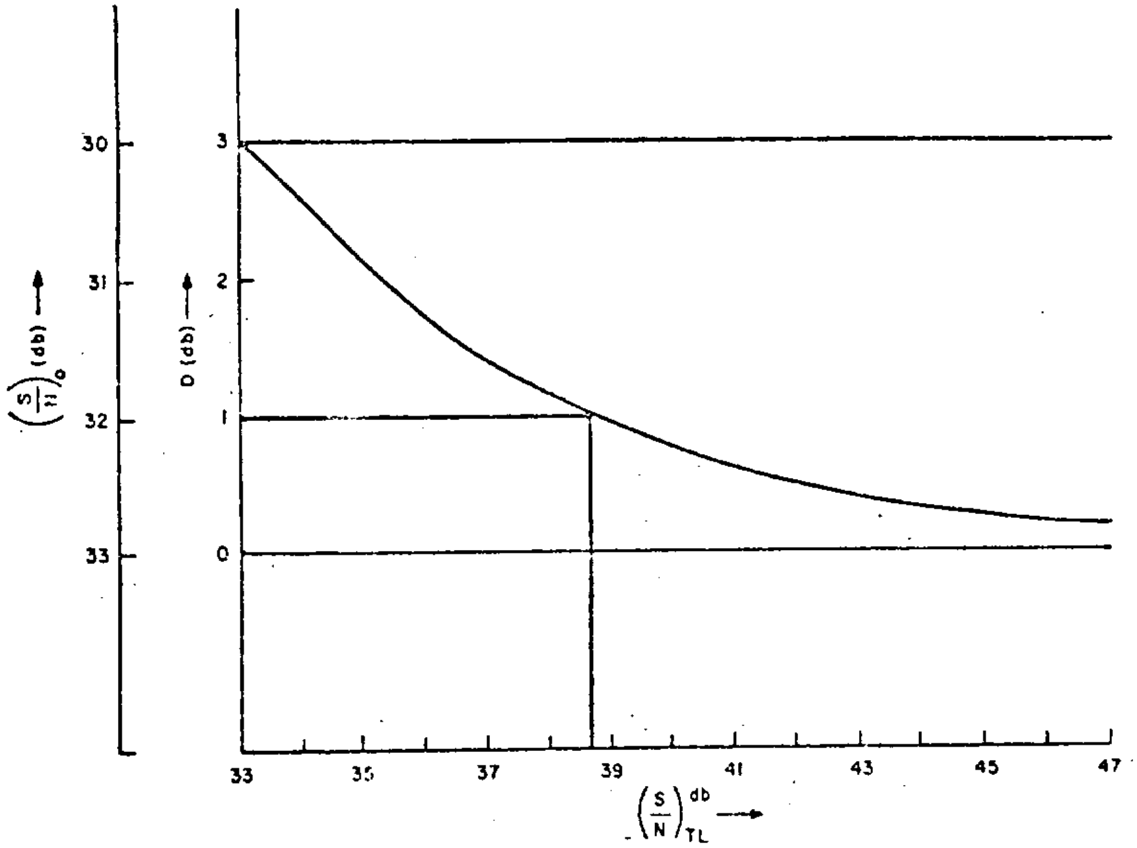


Fig. 4.1 - Degradação do sinal RBV $(S/N)_S = 33$ db.

4.2 - Enlace MSS

O enlace MSS de banda larga ocupa uma banda de 20 MHz com modulação PCM/FSK e frequência central de 2229,5 MHz.

Investigações teóricas e experimentais mostram que a relação energia da portadora-densidade de ruído influencia a probabilidade de erro na deteção; para uma probabilidade de erro de $P_e = 10^{-5}$ obtém-se uma relação de 14,0 db com discriminador de deteção. Com um ótimo receptor coerente obtem-se C/N = 13,0 db para $P_e = 10^{-5}$. Resultados experimentais indicam 13,5 db. A tabela 4.2 mostra os cálculos do enlace:

TABELA 4.2 - CÁLCULOS DO ENLACE MSS

5° de Elevação			
Parâmetros	9 m	6 m	6m
Potência do transmissor do satélite	43 dbm	43 dbm	43 dbm
Ganho da antena do satélite	4,0 db	4,0 db	4,0 db
Perdas de transmissão	-1,35 db	-1,35 db	-1,35 db
Perdas do espaço	-169,66 db	-169,66 db	-169,66 db
Ganho da antena receptora	44,0 db	40,5 db	40,5 db
Temperatura do sistema	125°K	125°K	75°K
Potência de ruído	-105,8 dbm	-105,8dbm	-108,05 dbm
Margem do sistema	-6,0 db	-6,0 db	-6,0 db
Potência recebida	-86,01 dbm	-89,01 dbm	-89,01 dbm
Relação portadora-ruído	+19,79 db	+16,78 db	+ 19,04 db

Tomando o valor mais pessimista de C/N = 14,0 db para uma probabilidade de erro $P_e = 10^{-5}$, teremos margens extras de 5,79 db, 2,78 db ou 5,04 db. Cada um destes números tem que ser reduzido de 1,5 db para levar em conta a degradação devida à distorção do tempo de atraso. Obtem-se então a tabela 4.3.

TABELA 4.3 - MARGEM EXTRA PAPA O ENLACE MSS

SISTEMA USADO	POTÊNCIA DO TRANSMISSOR	MARGEM EXTRA
Antena 9 m ($T_s = 125^oK$)	20 W(10W)	4,29 db (1,29 db)
Antena 6 m ($T_s = 125^oK$)	20W (10W)	1,28 db (-1,72db)
Antena 6 m ($T_s = 75^oK$)	20W (10W)	3,54 db (0,54 db)

Os parâmetros do enlace MSS são essencialmente os mesmos calculados para o enlace RBV, com as seguintes diferenças:

- A frequência central para o enlace MSS é 2229,5 MHz, o que resulta numa redução de 0,14 db nas perdas no espaço livre.
- A pre-deteção do enlace MSS é limitado à velocidade da informação (15 MHz entre os pontos de 3 db).

A mesma observação feita para o enlace RBV com relação à temperatura do sistema ($T_s = 125^oK$) utilizada para ilustrar os cálculos é válida.

4.3 - Enlace de descida USB

O sinal USB de descida S (t) é da forma

$$S(t) = \sqrt{2C}\,\cos\left[w_c t + \sum_{i=1}^{n} \theta_i \cos(w_{si}t+\phi_i(t)) + \theta_{n+1}U(t) + n(t)\right] \quad (2)$$

onde

C: potência total recebida

w_c: frequência da portadora

θ_i: desvio de pico da fase da portadora devido a i-ésima subportadora

θ_{n+1}: desvio de pico da fase da portadora devido ao "ranging signal"

w_{si}: frequência da i-ésima sub-portadora

$\phi_i(T)$: informação que modula o ângulo da i-ésima sub-portadora

$U(t)$: dois níveis ($\pm$ 1) sinal de onda quadrada

$n(t)$: ruído Gaussiano (densidade de N_o)

A Fig. 4.2 mostra um sistema típico de demodulação do sinal USB, sem o sinal PRN.

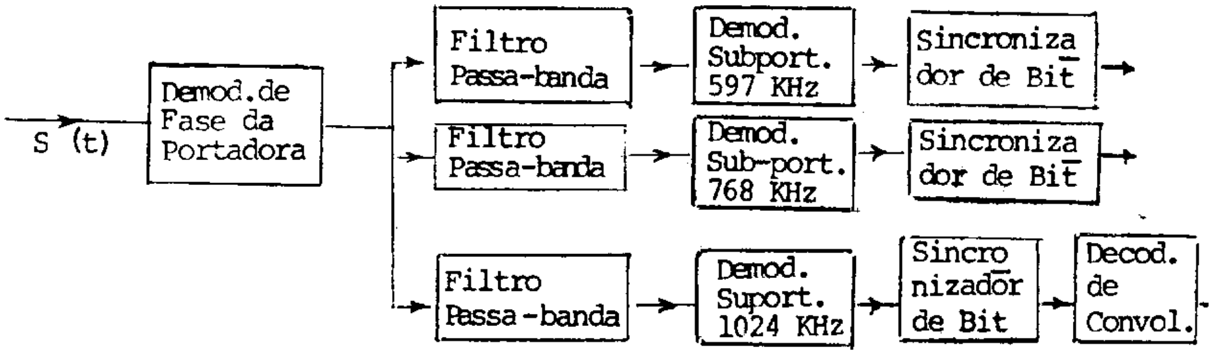


Fig. 4.2 - Demodulação do sinal USB

A tabela 4.4 mostra a banda ocupada IF para cada sub-portadora.

TABELA 4.4 - BANDA OCUPADA IF PARA AS SUB-PORTADORAS

SUB-PORTADORA	BANDA OCUPADA IF
1024 KHz	6 KHz, 150 KHz, 600 KHz
768 KHz	20 KHz, 35 KHz
597 KHz	suficiente pelo menos para 24 Kbs.

4.3.1 - Relação S/N_o para cada sub-portadora

Canal de 597 KHz

O sinal PCM de telemetria armazenado modula uma sub-portadora de 597 KHz.

Um detetor perfeito de PCM/PSK precisa de uma relação energia por bit-densidade de potência de ruído (E/N_o) na entrada do detetor conforme mostra a Fig. 4.3 em função da probabilidade de erro, P_e.

Para uma probabilidade de erro menor que 10^{-6}, E/N_o, deve ser maior que 10,5 db para um detetor perfeito. Acrescentando 2,5 db para um detetor real, E/N_o deverá ser maior que 13,0 db para conseguir uma probabilidade de êrro menor que 10^{-6}.

$$\frac{E}{N_o} = \frac{ST}{N_o}$$

S-potência média na sub-portadora

T-período por bit $= \dfrac{1}{\text{velocidade de informação}}$

$\dfrac{1}{T} = 24$ Kbit/seg

$$\frac{S}{N_o} = \frac{1}{T}\left(\frac{E}{N_o}\right) = 13{,}0 \text{ db} + 10 \log_{10} 2{,}4.10^4$$

$$= 13{,}0 + 43{,}8 = 56{,}8 \text{ db Hz}$$

$$\left(\frac{S}{N_o}\right)_1 = 56{,}8 \text{ db-Hz}$$

onde $(S/N_o)_1$ é a relação sinal-ruído necessária para a sub-portadora de 597 KHz.

Canal de 1024 KHz

O canal de 1024 KHz é usado para receber os sinais do DCS. Este sinal consiste de uma senoide com frequência central de 1024 KHz a qual é modulada em frequência pela informação e pelo ruído. No enlace de descida é adicionado mais ruído ao sinal de informação. A relação sinal-ruído total $(S/N)_{total}$ na entrada do processador na estação de recepção deverá ser zero db numa banda ocupada de 100 KHz centrada em 1024 KHz.

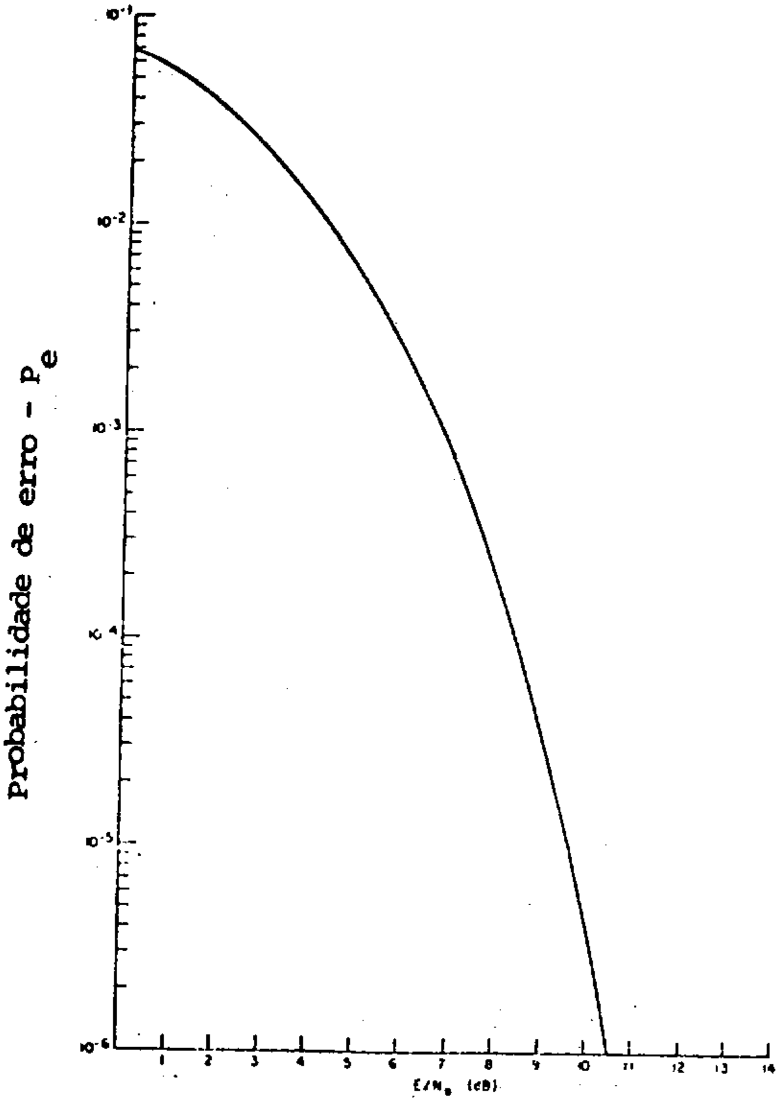


Fig. 4.3 - Relação entre P_e e E/N_o para um receptor ideal coerente PCM/PSK

O cálculo da relação sinal ruído para este canal fornece $(S/N_0)_2$ = 66,0 db-Hz

Canal de 768 KHz

Este canal é usado para transmitir o sinal PCM de telemetria em tempo real. Este sinal modula uma sub-portadora de 768 KHz.

A Fig. 4.4 mostra o diagrama de blocos do detetor para o sinal do canal de 768 KHz.

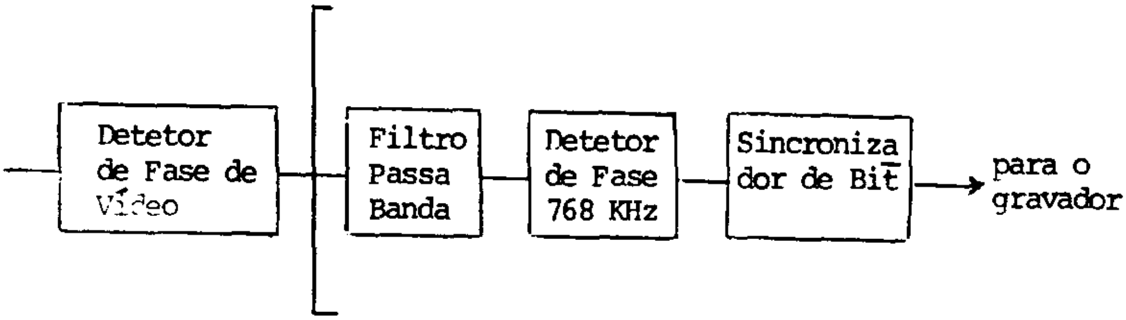


Fig. 4.4 - Deteção do canal de 768 KHz

O valor de S/N_0 calculado para o canal de 768 é $(S/N_0)_3$ = 44,0 db-Hz para $P_e = 10^{-6}$.

A Tabela 4.5 mostra o cálculo do enlace USB para antenas de 9 e 6 m.

TABELA 4.5 - ENLACE USB DE DESCIDA

PARÂMETROS		9m	6 m
Potência do transmissor	dbm	30,0	30
Perdas nos circuitos de transmissão	db	-2,0	-2,0
Ganho da antena de transmissão (inclui perdas de polarização)	db	-1,0	-1,0
Perdas do espaço livre	db	-169,3	-169,3
Frequência do transmissor	MHz	2287,5	2287,5
Ganho da antena receptora (inclui perdas nos circuitos)	db	43,4	39,9
Margem do sistema	db	-6,0	-6,0
Potência total recebida	dbm	-104,9	-108,4
Densidade de potência de ruído	dbm/Hz	-174,5	-178,0
Temperatura do sistema	^{o}K	250	-10
Relação $\frac{C}{N_o}$ disponível	db/Hz	69,6	69,6
Relação C/N_o necessária	db/Hz	48,5	48,5
Margem extra	db	21,1	21,1

4.4 - Enlace de Subida USB

Êste enlace de subida USB é necessário para transmitir o sinal "Pseudo Random Noise"-PRN e a sub-portadora de 70 KHz para os dados de comando.

A Tabela 4.6 mostra os cálculos para o enlace USB com antenas de 9 e 6 m.

TABELA 4.6 - ENLACE USB DE SUBIDA

PARÂMETROS	9m	6 m	
Potência transmitida	70,0	70,0	dbm
Perdas nos circuitos de transmissão	0,0	0,0	db
Ganho da antena transmissora	43,0	39,5	db
Perdas no espaço	-169,9	-169,9	db
Atenuação atmosférica	-0,7	-0,7	db
Frequência da portadora	2106,4	2106,4	MHz
Ganho da antena receptora (inclue perdas de polarização)	+4,0	+ 4,0	db
Perdas nos circuitos de recepção	-1,5	-5,0	db
Perdas de apontamento da antena receptora	-5,0	-5,0	db
Margem do sistema	-6,0	-6,0	db
Potência total recebida	-66,1	-66,1	dbm
Perdas de modulação	0,0	0,0	db
Potência da portadora disponível	-66,1	-66,1	dbm
Potência da portadora necessária	-109,0	-109,0	dbm
Margem extra	42,9	42,9	db

CAPÍTULO 5

MODELO DA ESTAÇÃO DE RASTREIO E RECEPÇÃO

O INPE pretende instalar uma estação que faça o rastreio do satélite, recebendo e gravando as informações por ele transmitidas.

A Fig. 5.1 mostra um diagrama de blocos de uma possível estação de rastreio e recepção incluindo o sistema de gravação.

O enlace de subida não é necessário para o Brasil porque os comandos do satélite são gravados em memórias de elevada confiabilidade e redundantes; no caso de falhas das memórias o satélite ficaria não operacional.

A Fig. 5.1 mostra os equipamentos usados para receber os dados transmitidos nos enlaces MSS, RBV e USB além dos sistemas de gravação destes dados.

O equipamento de recepção para receber os dados transmitidos pelas plataformas de terra (DCS) não é mostrado na figura porque numa fase inicial a estação não iria receber este sinal. Deve ser prevista a possibilidade de no futuro poder receber também estes dados.

5.1 - Especificações dos equipamentos

5.1.1 - Antena

O sistema utilizará uma antena parabólica de 9m de diâmetro com uma temperatura de ruído de aproximadamente 65°K.

Se a temperatura do sistema for 125°K (utilizada para ilustração dos cálculos) a margem de segurança será 6 db. Se a temperatura do sistema for superior a 125°K a margem de segurança será menor que 6 db. Ver tabela 4.1 e parágrafo 4.1.2, para o enlace RBV, que é o mais crítico.

A antena e pedestal deverão operar em condições normais com vento de até 60 km/h.

A antena deve ser sólida com rugosidade de superfície que permita operar na faixa 8025-8400 MHz. Esta consideração é importante porque o serviço de exploração de recursos da Terra por satélites para o futuro, será alocado nesta faixa, conforme resolução do ITU na reunião WARC-ST/71, realizada em Genebra em junho/71.

5.1.2 - Alimentação da antena

Deve ter capacidade para fornecer todos os sinais necessários para o rastreio.

Estes sinais darão origem aos sinais diferenças, ΔE e ΔA, injetados no receptor de rastreio e o sinal soma, Σ, para o amplificador paramétrico.

5.1.3 - Sistema de rastreio

A estação provavelmente terá dois sistemas de rastreio, um empregando o sistema automático e outro empregando o rastreio programado com a ajuda do computador. Poderia ter como opção, o rastreio manual para posicionamento inicial da antena.

O sistema automático emprega um iluminador com capacidade de gerar os sinais erros de azimute e elevação.

A antena deve ser inicialmente posicionada manualmente pelo operador, ou usando o rastreio programado.

A estação pode ter capacidade para aceitar os sinais de servo da estação de VHF de telemetria e fazer o rastreio do satélite através destes sinais.

5.1.4 - Amplificador paramétrico

O amplificador paramétrico deve ter uma banda de passagem superior a 72 MHz. Nos satélites futuros, de exploração de recursos da Terra, quando as frequências forem alocadas na banda de 8025 a 8400 MHz, conforme a WARC-ST/71 da ITU, este amplificador deverá ter provavelmente uma faixa de passagem maior.

Cálculos realizados mostram que um amplificador paramétrico não refrigerado, com temperatura de ruído de 100°K seria suficiente com uma antena de 9m , com uma margem inferior a 6 db para o enlace RBV, que é o mais crítico.

5.1.5 - Equipamento MSS

5.1.5.1 - Conversor de baixa frequência

A temperatura de ruído do conversor de baixa frequência deve ser tal que a temperatura de ruído do sistema seja igual a 125°K (antena de 9m com margem de 6 db para o enlace RBV).

5.1.5.2 - Demodulador FSK

Este dispositivo deve demodular o sinal PCM/FSK do enlace MSS.

5.1.5.3 - Condicionador do sinal

Esta unidade sincroniza os 15 Megabits por segundo (Mbs), fornecendo também informação de tempo para a posterior demultiplexação e/ou gravação.

5.1.5.4 - Demultiplexador/Gerador de Testes/Monitor

Esta unidade será utilizada para demultiplexar o sinal MSS reproduzido por um gravador tipo série (por exemplo, o TR70-CVR-3E modificado) ou para demultiplexar o sinal a ser gravado em um gravador tipo paralelo (por exemplo o AMPEX FR-1928). É previsto um osciloscópio para visualizarem em forma analógica os dados do MSS. O gerador de teste fornece o sinal MSS de teste que modula uma fonte FM, para verificar o funcionamento correto de todo o sistema.

5.1.5.5 - Gravador do Sinal MSS

O sistema de gravação deve ser completamente compatível com aquele usado pela NASA nos Estados Unidos.

Este gravador poderá ser um FR - 1900 modificado (gravador tipo paralelo) para gravar 28 faixas (Modelo FR-1928), ou algum outro gravador tipo série no qual não seria necessário o demultiplexador para a gravação.

O gravador tipo paralelo grava a uma velocidade de 60 pol./seg, 25 canais com os dados digitais, um canal com a informação de tempo, um canal com o sinal PCM de telemetria, e um canal com o sinal frequência de referência do servo do "capstain", além de um canal de voz. Os canais do gravador poderão ser usados como se segue:

Canal 1 - frequência de referência do servo do"capstain"
Canais - 2, 4, 6, 8, 10, 12 - grupo 1
Canais - 14, 16, 18, 20, 22, 24 - grupo 2
Canais - 3, 5, 7, 9, 11, 13 - grupo 3
Canais - 15, 17, 19, 21, 23, 25 - grupo 4
Canal 26 - grupo 5 (ERTS B somente)
Canal 27 - Informação de tempo
Canal 28 - Sinal PCM de telemetria

As fitas usadas deverão ser de 1 pol. de espessura em rolos $10^1/2$ ou 14 pol. de diâmetro.

5.1.6 - Equipamento RBV

5.1.6.1 - Conversor de baixa frequência

Ver o parágrafo 5.1.5.1

5.1.6.2 - Demodulador FM

Este demodulador deve demodular o sinal video/FM (dados do RBV)

5.1.6.3 - Processador de Vídeo e Separador de Sincronismo (VPASS)

Esta unidade deve processar o sinal vídeo RBV para permitir a gravação e visualização (quick - look) das imagens.

5.1.6.4 - Gravador do sinal RBV

Este gravador deve ser completamente compatível com aquele usado pela NASA.

O gravador a ser usado será o RCA TR - 70 - CVR - 3E, (ou equivalente) que é uma modificação do gravador comercial TR-70.

Este gravador pode usar fitas 3M 500 que vem em rolos de comprimentos de 1.200 - 2.400 - 3.600 - 4.800 ou 5.600 pés; em termos de tempo de gravação os comprimentos são equivalentes a 738 - 1.476 - 2.214 2.952 - ou 3.444 segundos.

As fitas usadas devem ser de 2 polegadas de largura em rolos com 14 polegadas de diâmetro.

5.1.7 - Equipamento USB

5.1.7.1 - Conversor de baixa frequência

Ver parágrafo 5.1.5.1

5.1.7.2 - Demodulador PM

Este demodulador deve demodular as informações na portadora USB.

5.1.7.3 - Filtros passa faixa

O filtro para o sinal PCM de telemetria armazenado deve ter uma frequência central $f_o = 597$ KHz, e banda passante suficiente para pelo menos 24 kbps. O filtro para o sinal PCM de telemetria em tempo real deve ter uma frequência central $f_o = 768$ KHz e uma banda passante de 35 KHz.

5.1.7.4 - Demoduladores de sub-portadoras

Estes discriminadores devem demodular as duas sub-portadoras $f_s = 768$ KHz e $f_s = 597$ KHz.

5.1.7.5 - Sincronizadores de Bit

Estas unidades (2) proporcionam a sincronização dos dados de 24 kbps e 1 kbps dos canais de 597 e 768 KHz respectivamente, para posterior gravação

5.1.7.6 - Sistema de gravação para os sinais do enlace USB

Estes sinais serão gravados nos canais auxiliares dos gravadores AMPEX FR-1928 (ou equivalente) e RCA TR - 70 (ou equivalente) ou podem ser gravados separadamente em outro gravador digital qualquer (pode ser o AMPEX FR - 1900 já existente no INPE).

Para a gravação dos sinais DCS, em uma fase posterior, este gravador digital (FR - 1900) seria certamente necessário.

5.1.8 - Geradores de teste: TPG (RBV) e RSE (MSS)

As funções destes equipamentos são as seguintes:

- Gerar os sinais de teste para simulação dos sinais do MSS e RBV;
- Gerar e simular o espectro de ruído que pode ser combinado com os sinais de testes, para simular a recepção dos sinais do satélite.

5.1.9 - "Quick - look Monitor" (QLM) para visualizar os sinais do RBV

Este dispositivo permite uma visualização rápida das 3 câmaras do RBV. Aceita também os sinais fornecidos pela unidade TPG; estes sinais são mandados primeiramente para a unidade VPASS.

O QLM permite a visualização num tubo de raios catódicos dos dados RBV e do sinal de teste do TPG para a avaliação das características do sistema. Está equipado com uma câmara Polaroid que fotografa continuamente as imagens das 3 câmaras do RBV.

5.1.10 - Sistema gerador de tempo

A estação geradora de tempo consiste de um conjunto de equipamentos que incluem:

- Dois geradores de código de tempo;
- Sintetizador de frequência;
- Sincronizador;
- Osciloscópio.

5.1.11 - Fonte do sinal FM para teste

Este é um dispositivo gerador de sinais de precisão na faixa de 2200 a 2300 MHz.

A saída pode ser contínua ou modulada pelo sinal fornecido pelo gerador de teste TPG do RBV ou pelo sinal de teste do MSS gerado no RSE.

O gerador TPG fornece o sinal de vídeo-teste (0 a 3.5 MHz) para controle do equipamento de recepção e gravação do sinal RBV.

O gerador MSS-RSE de teste fornece o sinal de 15 Mbps para controle do equipamento de recepção e gravação do sinal MSS.

Estes sinais do TPG e MSS-RSE modulam o sinal FM de teste; este sinal modulado é injetado na entrada de teste do amplificador paramétrico e posteriormente nos circuitos de recepção e gravação para avaliar as condições de operação do sistema completo.

CAPÍTULO 6

ESTAÇÃO DE PROCESSAMENTO DE IMAGENS

A estação de processamento das imagens tem as seguintes funções principais:

- Transformar os dados RBV recebidos em filmes, mediante o controle das fitas IAT (Fita de Anotação de Imagem) as quais contêm anotações, e informações de correção obtidas dos dados de telemetria contidos no enlace USB de descida e das fitas de erros fixos. Os filmes obtidos correspondem em qualidade ao processamento preliminar (bulk process). Com estes filmes são feitas medidas manuais a partir da posição de objetos cujas coordenadas são previamente conhecidas, de modo que, um conjunto de coeficientes de correção é obtido e aplicado ao "video tape" original do RBV obtendo-se imagens de qualidade correspondentes ao processamento de precisão (Precision Process).
- Transformar os dados do MSS em filmes de qualidade preliminar e posteriormente de qualidade precisa.
- Transformar os dados do MSS em fitas digitais de acesso direto ao computador (CCT).

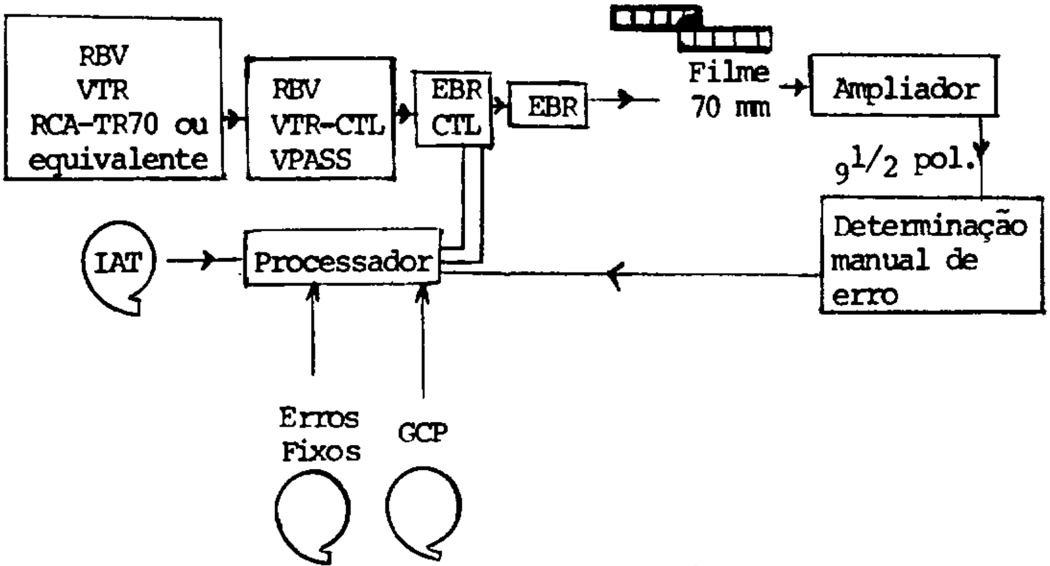
6.1 - Fita de Anotação de Imagem(IAT)

Para a produção destas fitas, usadas para a correção sistemática de erro, são necessárias as fitas com os dados de efemérides que serão fornecidas pela NASA assim como os dados com as características do satélite contidas no enlace USB de descida. Com estas duas fitas é possível a produção da fita IAT.

Correções geométricas são feitas determinando os ângulos do satélite em relação a posições de referência e o desvio da altura nominal do satélite. Os ângulos do satélite são determinados a partir dos dados de telemetria em PCM. Os dados de efemérides permitem calcular o desvio da altura nominal.

6.2 - Transformação dos dados do RBV

Os dados gravados do RBV são reproduzidos e enviados ao VPASS e logo após ao "Eletron Beam Recorder Control" (EBR-CTL) e em seguida ao "Eletron Beam Recorder" (EBR).



Inicialmente são feitas correções mediante o controle da fita IAT e da fita dos erros fixos; este primeiro passo produz imagens de qualidade preliminar; depois de revelado o filme de 70 mm e escolhidas algumas imagens, estas podem ser ampliadas para 9 1/2 polegadas.

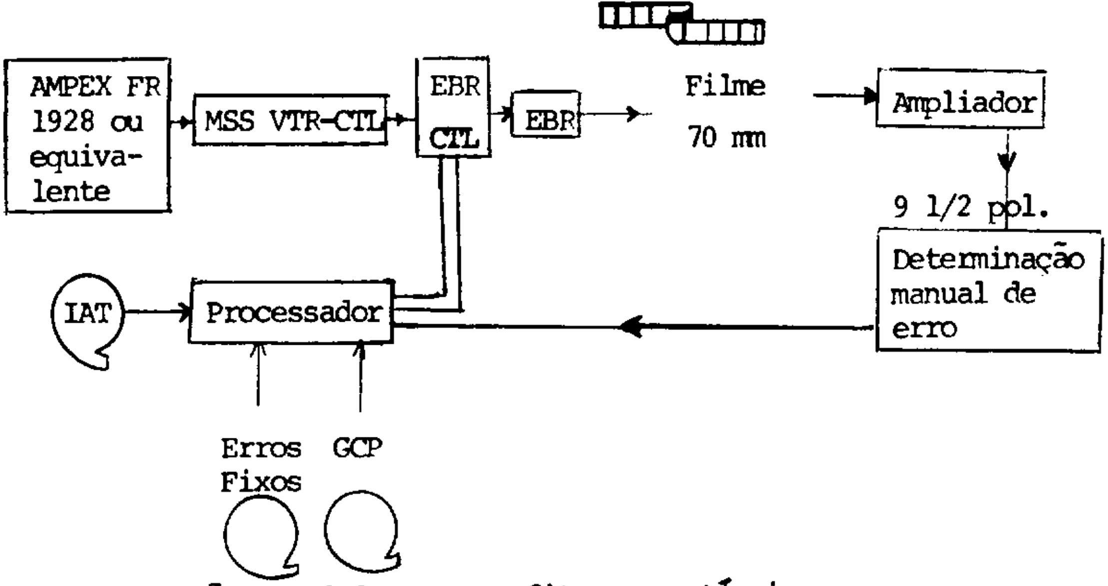
Algumas imagens são selecionadas para ulteriores correções; para determinar estas correções, medidas manuais são feitas a partir da localização exata de alguns pontos e do conhecimento das distorções das lentes. Estas medidas são colocadas no processador para obter os coeficientes de correção. Estes coeficientes são aplicados no "Eletron Beam Recorder Control".

Usando novamente os "video-tapes" originais do RBV e aplicando os coeficientes de correção durante uma segunda passagem, imagens serão novamente produzidas depois da ampliação, com qualidade de precisão.

6.3 - Transformação dos dados MSS

Os dados gravados do MSS são convertidos em filmes mediante o controle da fita IAT e da fita de erros fixos. Esta primeira passagem produz imagens de qualidade preliminar.

Com medidas manuais obtém-se os coeficientes de correção para a produção de imagens de precisão mediante uma segunda passagem da fita original com os dados MSS.



6.4 - Conversão dos dados MSS em fitas compatíveis com o computador (CCT)

Os dados do MSS são convertidos em fitas compatíveis com o computador mediante unidades de fita magnética (HP MTU).

CAPÍTULO 7

LOCALIZAÇÃO E COBERTURA

7.1 - Localização

Como já foi ventilado anteriormente, o sistema em apresentação neste documento deverá ser constituído de 2 subsistemas, a Estação de Rastreio e Recepção e a Estação de Processamento de Imagem. Como as mesmas são complementares a situação ideal seria aquela em que ambas fossem localizadas no mesmo ponto ou em pontos próximos. O critério de proximidade entretanto, é flexível, no sentido de que ele é função de vários fatores, por exemplo, a facilidade de acesso a cada uma das estações e o meio de transporte que as interligará.

A título de ilustração, e como base para cálculo de quantidade de dados a serem recebidos, apresentamos a seguir estudos calcados na localização da Estação de Rastreio e Recepção nas proximidades da cidade de São José dos Campos (23°S e 46°W)

7.2 - Cobertura

A cobertura foi calculada, levando em consideração os ângulos de elevação de 2° e 5°.

A geometria utilizada para o cálculo está esquematizada, na figura 7.1.

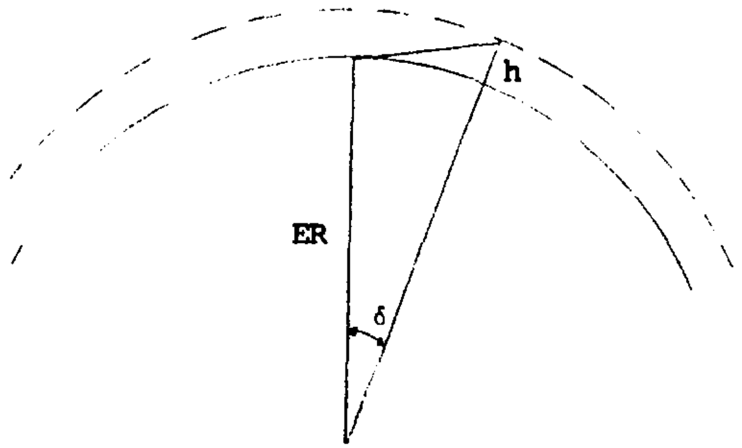


Fig. 7.1 - Geometria para o cálculo do ângulo central

O cálculo do ângulo central (δ) foi feito para os dois casos de elevação, obtendo-se a tabela 7.1.

Desta tabela tira-se os valores abaixo:

Ângulo Central (δ)	Altura (h)	Elevação (α)
24.3°	910 Km	5°
27.0°	910 Km	2°

Com os valores dos ângulos centrais pode-se traçar a cobertura da Fig. 7.2 para elevação 2° e 5°.

A Fig. 7.2 mostra que quase a totalidade do Brasil seria coberta, e também os seguintes países:

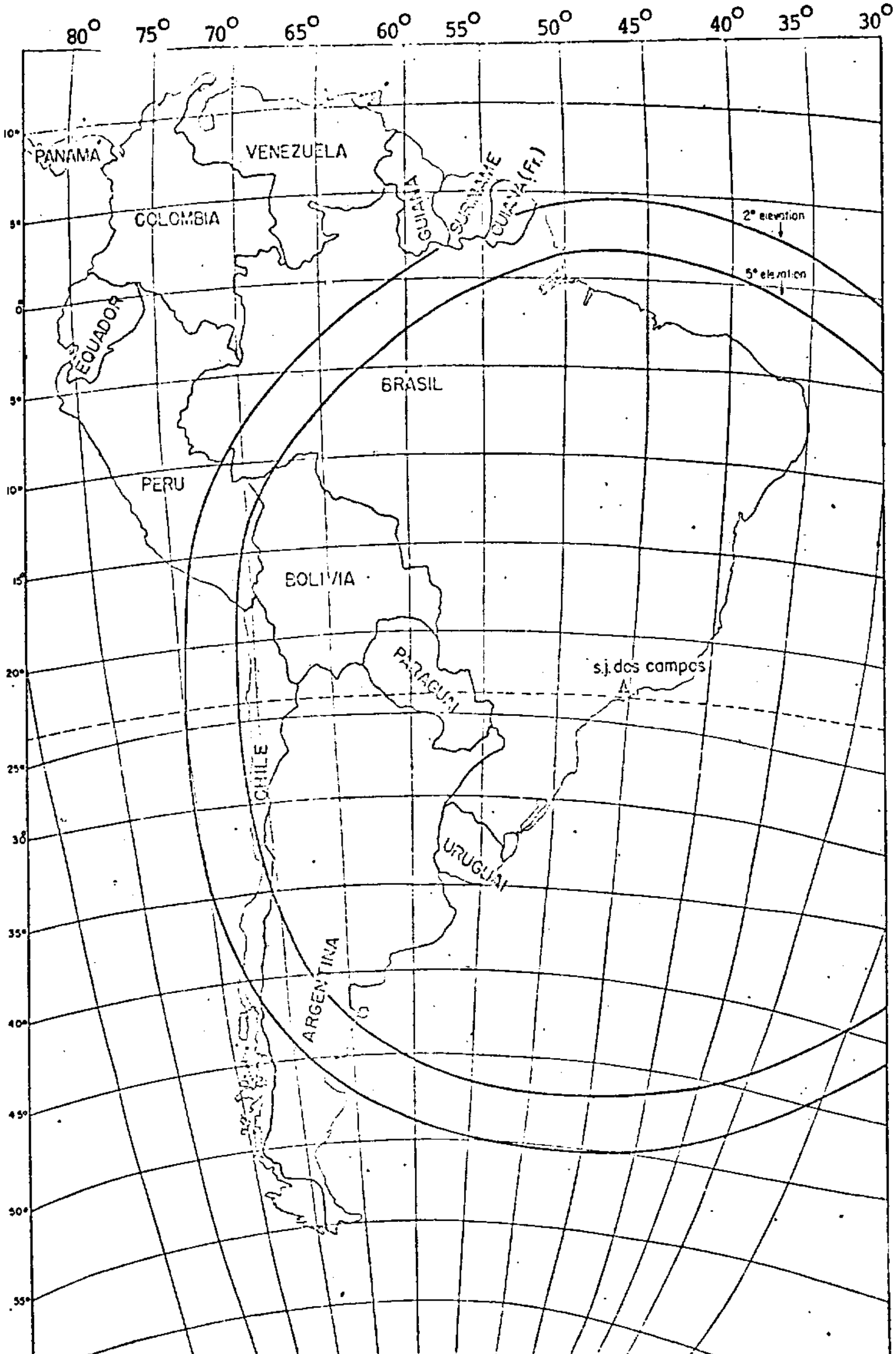
Cobertura Total	Cobertura Parcial
Bolívia	Argentina
Paraguai	Chile
Uruguai	Peru
	Guiana Francesa

TABELA 7.1 - CÁLCULO DO ÂNGULO CENTRAL

Ângulos medidos em graus

Altura: 910 kilômetros

Ângulo Central	Elevação
1	82.03
2	74.31
3	67.03
4	60.33
5	54.25
6	48.80
7	43.93
8	39.60
9	35.73
10	32.27
11	29.17
12	26.36
13	23.80
14	21.47
15	19.33
16	17.35
17	15.52
18	13.80
19	12.20
20	10.69
21	9.26
22	7.91
23	6.62
24	5.39
25	4.22
26	3.09
27	2.00
28	.95



7.2 - COBERTURA DA ESTAÇÃO LOCALIZADA EM SÃO JOSÉ DOS CAMPOS

CAPÍTULO 8

QUANTIDADE DE DADOS RECEBIDOS NA ESTAÇÃO

A localização da estação em estudo permitiria colher dados sobre o Brasil e outros países da América do Sul.

A quantidade de dados disponíveis para gravação nesta estação, será calculada em se considerando que o ângulo de elevação do satélite visto de São José dos Campos seja superior a 5^o. O ângulo de elevação é limitado por este valor devido a problemas de cintilações atmosféricas e efeitos de refração. O ângulo de elevação de 5^o é um caso pessimista. Com um bom sistema de rastreio e condições favoráveis, seria possível aumentar a quantidade de dados recebidos.

8.1 - Parâmetros Orbitais

Os parâmetros orbitais, usados para o cálculo da quantidade de dados, são os seguintes:

Ponto de inserção	130^o W long, 0^o lat.
Altura	910 Km (492,35 min.)
Inclinação	99,088 graus
Período	103 min
Excentricidade	0,0001
Duração de um ciclo de cobertura	18 dias (251 rev.)
Distância entre trajetórias adjacentes	160 Km (1 4338 graus)
Separação entre trajetórias consecutivas	25,8167 graus

8.2 - Método gráfico para determinar o tempo gasto pelo satélite para cobrir a área da estação de São José dos Campos.

O método gráfico empregado para determinar este tempo é o seguinte: no primeiro dia são previstas na área de cobertura da estação, as órbitas 10 e 11 separadas em longitude de 25,8167 graus; no segundo dia são previstas as órbitas 24 e 25, e assim por diante. Para cada dia são previstas um certo número de órbitas, como mostrado na figura 8.1. O comprimento das trajetórias foi transformado em tempo empregado pelo satélite, para descrever estas trajetórias.

O cálculo foi feito somente para cobertura continental, seja para o Brasil como também para outros países, dentro da faixa de cobertura da estação. Para o cálculo, foi suposto que, as trajetórias, dentro da área de cobertura da estação sejam paralelas.

O ângulo de iluminação solar depende da latitude e das estações do ano; isto é mostrado na Fig. 8.2. É oportuno ter em mente que dentro da área coberta pela estação de recepção de São José dos Campos, o ângulo solar é sempre maior que 17 graus. Para os nossos propósitos este ângulo deve ser considerado satisfatório.

Para 5^{o} de elevação, trinta e três (33) órbitas cortam a área de cobertura da estação. Destas, vinte e duas (22), cortam a parte terrestre coberta pela estação.

O tempo empregado pelo satélite em cada dia e as correspondentes, 22 passagens, são mostrados na tabela 8.1.

O maior tempo empregado pelo satélite, dentro da cobertura terrestre, é de cerca de 694 segundos.

No primeiro dia (ver tabela 8.1), o satélite descreve as trajetórias 10 e 11, mas somente a órbita 11 corta a parte terrestre. No dia 6, por exemplo, o satélite descreve as órbitas 80 e 81 e analogamente assim para cada um dos 18 dias do ciclo. A tabela 8.1 mostra também o tempo empregado para cobrir cada país.

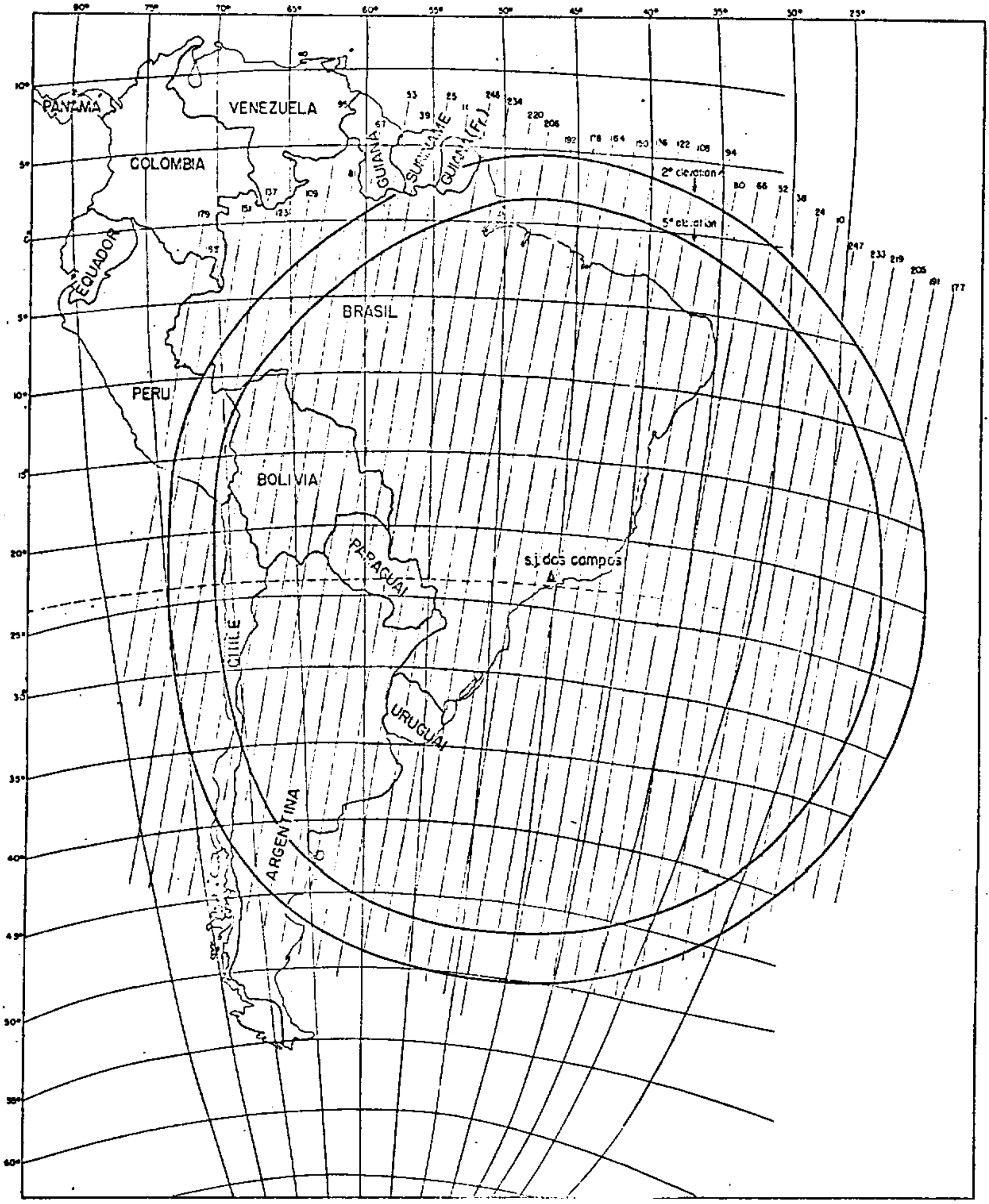


Fig. 8.1 - COBERTURA NA ESTAÇÃO LOCALIZADA EM SÃO JOSÉ DOS CAMPOS

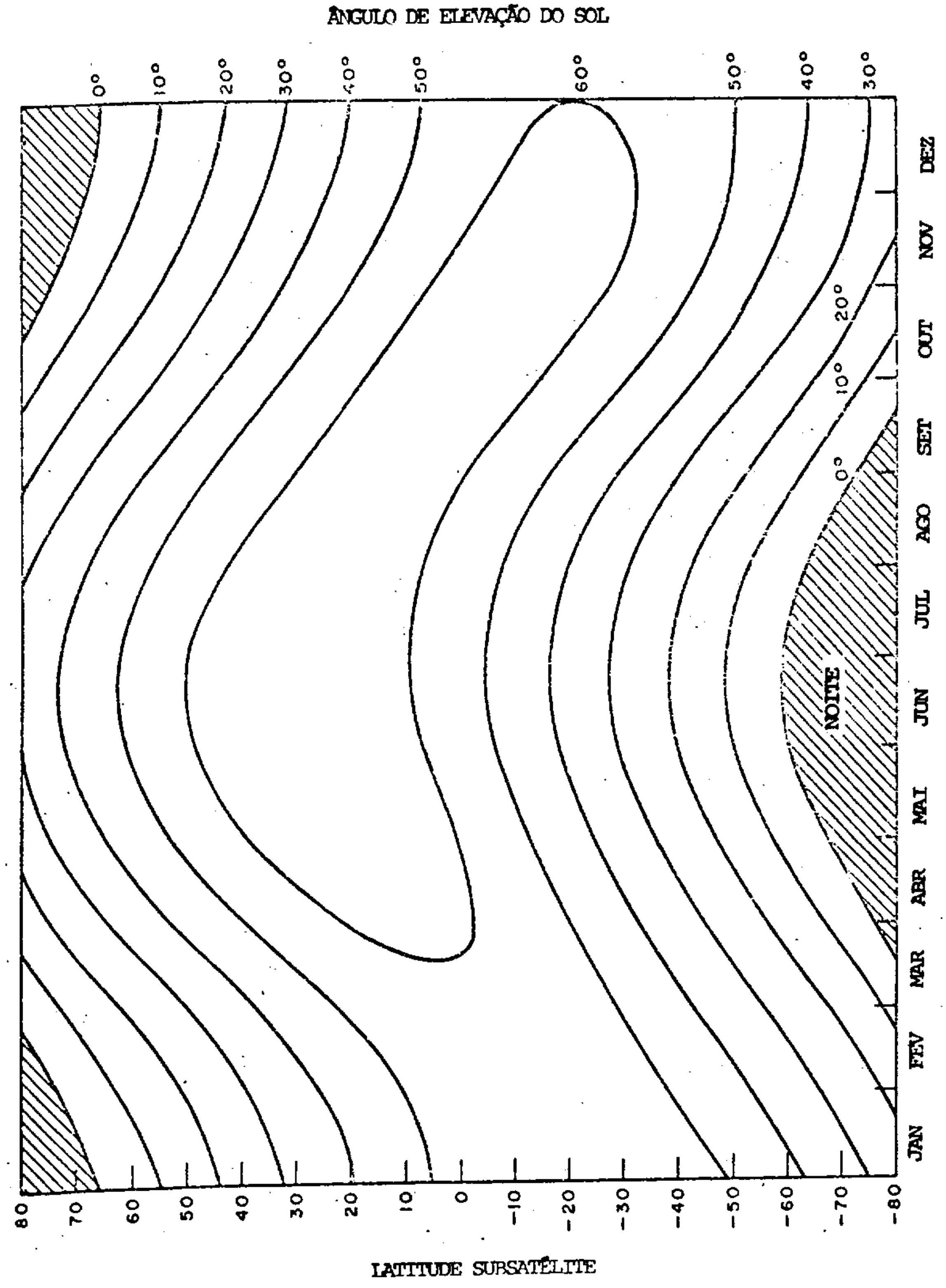


Fig. 8.2 - ÂNGULO DE ELEVAÇÃO DO SOL

TABELA 8.1 - TEMPO GASTO PARA COBERTURA CONTINENTAL

DIA	Nº DA PASSAGEM		TEMPO GASTO (SEGUNDOS)													
			BRASIL		BOLÍVIA		ARGENTINA		CHILE		PARAGUAI		URUGUAI		TOTAL	
	1ª	2ª	1ª	2ª	1ª	2ª	1ª	2ª	1ª	2ª	1ª	2ª	1ª	2ª	1ª	2ª
1	10	11	-	380	-	-	-	243	-	-	-	49	-	-	-	672
2	24	25	-	281	-	39	-	288	-	-	-	86	-	-	-	694
3	38	39	-	259	-	52	-	310	-	-	-	69	-	-	-	690
4	52	53	-	190	-	120	-	300	-	-	-	43	-	-	-	653
5	66	67	-	172	-	87	-	350	-	-	-	-	-	-	-	609
6	80	81	86	138	-	163	-	243	-	-	-	-	-	-	86	544
7	94	95	121	95	-	181	-	157	-	35	-	-	-	-	121	468
8	108	109	281	35	-	173	-	-	-	190	-	-	-	-	281	398
9	122	123	348	9	-	121	-	-	-	111	-	-	-	-	348	241
10	136	137	348	-	-	-	-	-	-	-	-	-	-	-	348	-
11	150	151	348	-	-	-	-	-	-	-	-	-	-	-	348	-
12	164	165	430	-	-	-	-	-	-	-	-	-	-	-	430	-
13	178	179	465	-	-	-	-	-	-	-	-	-	-	-	465	-
14	192	193	520	-	-	-	-	-	-	-	-	-	-	-	520	-
15	206	207	550	-	-	-	-	-	--	-	-	-	19	-	569	-
16	216	217	516	-	--	-	-	-	-	-	8	-	78	-	602	-
17	234	235	465	-	-	-	35	-	-	-	35	-	85	-	620	-
18	248	249	396	-	-	-	202	-	-	-	56	-	-	-	654	-
			4874	1559											5392	4969

8.3 - Fitas Magnéticas Necessárias

As fitas magnéticas para o gravador AMPEX FR 1928 vem rolos de 9.200 pés (280 m), ou em termos de tempo de gravação, 1840 segundos.

As fitas magnéticas para o gravador RCA TR-70-CVR-3E vem em rolos de comprimento de 1.200, 2.400, 3.600, 4.800, ou 5.600 pés, ou em termos de gravação, 738, 1.476, 2.214, 2.952, 3.444 segundos, a uma velocidade de 19,5 poleg. p.s.

O cálculo de número de fitas foi feito, considerando a gravação em um só rolo do maior número de passagens consecutivas possíveis.

Este método está ilustrado na tabela 8.2, para o AMPEX FR 1928 ou equivalente. O tempo de gravação para a passagem 11 no primeiro dia e 25 no segundo dia, são somados. O tempo total de gravação para cobertura terrestre destas 2 passagens é de 1.366 segundos, ficando então 474 segundos de fita não usados.

A tabela 8.3 mostra o número de fitas necessárias para o gravador RCA TR 70-CVR-3E, ou equivalente, num período de 18 dias. O método usado para o cálculo de fitas para o RCA TR 70-CVR-3E, ou equivalente, é o mesmo empregado no cálculo de nº de fitas para o AMPEX FR 1928, ou equivalente, com a ulterior condição de que a quantidade de fita não usada seja mínima. Se por exemplo:

(dia, passagens)	tempo de gravação	tempo de todo rolo	tempo não gravado
(1,11) + (2,25) + (3,39)	2056 seg	2214 seg	158 seg
(1,11) + (2,25) + + (3,39) + (4,53) + (5,67)	3318 seg	3444 seg	126 seg

Usando um rolo de 3.600 pés (2214 seg), pode-se gravar 3 passagens; o tempo não gravado da fita corresponde a 158 seg. Usando um rolo de 5.600 pés (3444 seg) pode-se gravar 5 passagens; o tempo não gravado da fita corresponde a 126 seg. O método empregado do mínimo tempo de fita não usado, escolhe o rolo de 3444 seg de gravação disponível.

As tabelas 8.2 e 8.3 mostram o número total de fitas não usadas em segundos/rolo.

A tabela 8.4 mostra o número de rolos para os dois gravadores, para um período de 18 dias. A tabela 8.5 mostra o custo de fitas magnéticas para o período de 18 dias.

O custo de cobertura total (terrestre + mar) será aproximadamente o dobro do custo mostrado na tabela 8.5.

8.4 - Estimativa da quantidade de fotografias

Os dados gravados no sistema de gravação da Estação de Rastreio e Recepção serão posteriormente processados e transformados em fotografias.

Daremos uma estimativa da quantidade final de fotografias que o sistema fornecerá.

Baseando-se nos dados da tabela 8.1, o número de cenas (185 Km x 185 Km), que a estação receberá por ciclo (18 dias), foram calculadas para a cobertura continental do Brasil e também para a cobertura continental total (Brasil e outros países sulamericanos. Foi considerado que 30% das imagens não seriam aproveitadas devido a excessiva cobertura de nuvens. Das 70 % restantes serão feitas 10 cópias preliminares (consideramos 10 usuários) em papel e transparência branco e preto. Destas imagens preliminares considerou-se que 20 % seriam compostas em cores. Das imagens preliminares (bulk), considerou-se que 30% serão transformadas em imagens de precisão e copiadas para 10 usuários. Considerou-se que todas as imagens de precisão serão compostas em cores. As tabelas 8.6, 8.7 e 8.8 ilustram estas considerações e cálculos.

Com as estimativas acima mencionadas a quantidade total de fotografias fornecidas aos usuários por dia está mostrado na tabela, 8.9.

As tabelas, 8.10 e 8.11, mostram os custos do processamento fotográfico por dia para o Brasil e para cobertura continental total.

A tabela 8.12 mostra o custo anual total para as coberturas indicadas.

O usuário brasileiro vai demandar anualmente 75 % de imagens preliminares e 25 % de precisas; as imagens coloridas, preliminares e de precisão, representam 9 % do total de imagens.

TABELA 8.2 - TEMPO GRAVADO POR FITA PARA O AMPEX FR 1928

COBERTURA CONTINENTAL TOTAL		
(dia, Nº da Passagem)	Tempo gravado (segs)	Fitas nao usadas (segs/rolo)
(1,11) + (2,25)	1366	474
(3,39) + (4,53)	1343	497
(5,67) + (6,80) + (6,81)+ + (7,94) + (7,95	1828	12
(8,108) + (8,109) +(9,122)+ + (9,123) + (10,136)	1616	224
(11,150) + (12,164) + + (13,178) + (14,192)	1763	77
(15,206) + (16,216) + + (17,234)	1791	49
(18,248)	654	1186
TOTAL:	10361	2519

BRASIL		
(dia, Nº da passagem)	Tempo gravado (segs)	Fitas não usadas (segs/rolo)
(1,11) + (2,25) + + (3,39)+(4,53) + + (5,67)+(6,80) + + (6,81)+(7,94) + + (7,95)	1722	118
(8,108)+(8,109) +(9,122)+(9,123) +(10,136) + +(11,150)+ +(12,164)	1799	41
(13,178)+(14,192)+ +(15,206)	1535	305
(16,216)+(17,234)+ +(18,248)	1377	463
	6433	927

TABELA 8.3 - TEMPO GRAVADO POR FITA PARA O RCA TR 70-CVR-3E

COBERTURA CONTINENTAL TOTAL				BRASIL			
(Dia, Nº da passagem)	Tempo gravado (segs)	Compr.rolo em segs	Fitas não usadas (seg/rolo)	(Dia, Nº da passagem)	Tempo gravado (segs)	Comp. rolo em segs	Fitas não das(seg/r
(1,11) + (2,25) +(3,39) + +(4,53) + (5,67)	3318	3444	126	(1,11) + (2,25)	661	738	77
(6,80) + (6,81) + (7,94) + +(7,95) + (8,108) +(8,109)+ +(9,122)+(9,123)+(10,136)	2835	2952	117	(3,39) + (4,53) + (5,67) + + (6,80)	707	738	31
(11,150)+(12,164)+(13,178)+ +(14,192)+(15,205)+(16,216)	2934	2952	18	(6,81) + (7,94) + (7,95) + + (8,108) + (8,109)	670	738	68
(17,234) + (18,248)	1274	1476	202	(9,122) + (9,123) +(10,136)	705	738	33
				(11,150)+(12,164)+(13,178)+ +(14,192)+(15,206)+(16,216)+ +(17,234)	3294	3444	150
				(18,248)	396	738	342
TOTAL	10361		463		6433		701

TABELA 8.4 - ROLOS DE FITAS NECESSÁRIOS

	AMPEX FR 1928	RCA TR 70 -CVR-3E
COBERTURA CONTINENTAL TOTAL	7 rolos de 9200 pés	1 rolo 2400 pés 2 rolos 4800 pés 1 rolo 5600 pés
BRASIL	4 rolos de 9200 pés	5 rolos de 1200 pés 1 rolo 4800 pés

TABELA 8.5 - CUSTO DAS FITAS MAGNÉTICAS

	AMPEX FR 1928	RCA TR 70-CVR-3E	TOTAL US$ (18 dias)	CUSTO ANUAL * US$
COBERTURA CONTINENTAL TOTAL	7 rolos de 9200 pés US$ 2200	1 rolo (2400 pés): US$ 110 2 rolos (4800 pés): US$ 440 1 rolo (5600 pés): US$ 256 US$ 806	US$ 3006	US$ 61000
BRASIL	4 rolos de 9200 pés US$ 1250	5 rolos (1200 pés): US$ 275 1 rolo (4800 pés): US$ 220 US$ 495	US$ 1745	US$ 36000

* Na hipótese de que todas as fitas gravadas sejam preservadas.

TABELA 8.6 - QUANTIDADE DE IMAGENS RECEBIDAS NA ESTAÇÃO

	BRASIL		COBERTURA CONTINENTAL TOTAL	
	RBV	MSS	RBV	MSS
Tempo/18 dias	6433	6433	10.361	10.361
Cenas/18 dias	257	257	414	414
Cenas/dia	14	14	23	23
Imagens/dia	42(3x14)	56(4x14)	69(3x23)	92(4x23)
Cenas sem cobertura de nuvens excessiva/dia (70 % do total)	10	10	16	16
Imagens sem cobertura de nuvens excessiva/dia (70 % do total	30(3x10)	40(4x10)	48(3x16)	64(4x16)

TABELA 8.7 - CÓPIAS FOTOGRÁFICAS DAS IMAGENS PRELIMINARES ("BULK")

	BRASIL		COBERTURA CONTINENTAL TOTAL	
	RBV	MSS	RBV	MSS
Papel branco e preto	300 (30x10)	400 (40x10)	480 (48x10)	640
Transparências branco e preto	300 (30x10)	400 (40x10)	480 (48x10)	640
Papel colorido (20 % do total)	20 (20% de 10x10)	20 (20% de 10x10)	40 (20% de 16x10)	40
Transparências coloridas (20 % do total)	20 (20 % de 10x10)	20 (20 % de 10x10)	40 (20 % de 16x10)	40
TOTAL	640	840	1040	1360

TABELA 8.8 - CÓPIAS FOTOGRÁFICAS DAS IMAGENS PRECISAS ("PRECISION")

	BRASIL		COBERTURA CONTINENTAL TOTAL	
	RBV	MSS	RBV	MSS
Papel branco e preto	90 (30% de 300)	120 (30% de 400)	150	200
Transparências branco e preto	90 (30% de 300)	120 (30% de 400)	150	200
Papel colorido (100% do total)	30	30	50	50
Transparência colorida (100% do total)	30	30	50	50
TOTAL	240	300	400	500

TABELA 8.9 - TOTAL DE FOTOGRAFIAS PROCESSADAS POR DIA

	BRASIL	COBERTURA CONTINENTAL TOTAL
Fotografias preliminares	1.480	2.400
Fotografias precisas	540	900
TOTAL	2.020	3.300

TABELA 8.10 - CUSTO DO PROCESSAMENTO FOTOGRÁFICO POR DIA PARA O BRASIL

Processamento preliminar	US$
Filme 70 mm	5.0
Revelação de 98 imagens/dia	13.0
700 cópias em papel branco e preto	150.0
700 cópias em transparências branco e preto	150.0
40 cópias em papel colorido	14.0
40 cópias em transparências coloridas	14.0
TOTAL/DIA	346.0
Processamento preciso	
Filme 70 mm	2.0
Revelação de 21 imagens/dia	3.0
210 cópias em papel branco e preto	45.0
210 cópias em transparências branco e preto	45.0
60 cópias em papel colorido	21.0
	137.0

TABELA 8.11 - CUSTO DO PROCESSAMENTO FOTOGRÁFICO POR DIA PARA COBERTURA CONTINENTAL TOTAL

Processamento preliminar	US$
Filme 70 mm	9.0
Revelação de 161 imagens/dia	20.0
1120 cópias em papel branco e preto	242.0
1120 cópias em transparências branco e preto	242.0
80 cópias em papel colorido	28.0
80 cópias em transparências coloridas	28.0
TOTAL/DIA	569.0
Processamento preciso	
Filme 70 mm	3.0
Revelação de 35 imagens	4.0
350 cópias em papel branco e preto	54.0
350 cópias em transparências branco e preto	54.0
100 cópias em papel colorido	35.0
100 cópias em transparências coloridas	35.0
TOTAL/DIA	185.0

TABELA 8.12 - CUSTO ANUAL DE PROCESSAMENTO FOTOGRÁFICO

	BRASIL	COBERTURA CONTINENTAL TOTAL
Processamento Preliminar	US$ 126,290	US$ 207,685
Processamento Preciso	US$ 50,005	US$ 67,525
TOTAL	US$ 176,295	US$ 275,205

CAPÍTULO 9

CUSTO DA ESTAÇÃO DE TERRA

Analisaremos o custo para a implantação de uma estação de terra para receber e processar as informações transmitidas pelo satélite ERTS. A implantação poderia ser por partes iniciando-se com a Estação de Rastreio e Recepção e posteriormente com a Estação de Processamento de Imagens. Com a primeira parte da estação (Rastreio e Recepção) seria possível rastreiar o satélite, receber as informações e gravá-las em fitas magnéticas. Estas fitas seriam então enviadas para a NASA, onde seriam processadas na NDPF (NASA Data Processing Facility) e seriam posteriormente devolvidas ao Brasil.

Para evitar a necessidade de que as fitas magnéticas sejam enviadas para os EE.UU., teríamos que comprar simultaneamente com a Estação de Rastreio e Recepção a segunda parte da estação de terra, a referente ao processamento de imagens, isso possibilitaria o tratamento das fitas magnéticas anteriormente gravadas na Estação de Rastreio e Recepção, aqui mesmo no Brasil.

Apresentaremos separadamente o custo da Estação de Rastreio - Recepção e da Estação de Processamento de Imagens com os respectivos custos operacionais.

9.1 - Estação de Rastreio e Recepção

É uma estação onde teríamos as informações do RBV, MSS e sinal PCM de telemetria em tempo real, gravadas em fitas magnéticas. O custo dos constituintes básicos desta estação seria aproximadamente os mostrados na tabela 9.1.

TABELA 9.1 - CUSTO DOS CONSTITUINTES DA ESTAÇÃO DE RASTREIO E RECEPÇÃO

CONSTITUINTES	PREÇO (US$)
1. Pedestal, refletor parabólico 30 pés, alimentador, extensão da base, receptor de rastreio, programador de rastreio, servo amplificadores, amplificadores de potência, conversor de rastreio, gerador de códigos de varredura, cabos, multiacoplador, conversor de baixa frequência, painel de interligação de RF, controle da antena.	250.000
2. Amplificador paramétrico (não refrigerado)	15.000
3. Receptores para MSS e RBV	20.000
4. Receptor para USB e Demodulador PM de subportadora 768 KHz	18.000
5. Condicionador do sinal e Demultiplexador para MSS	100.000
6. Processador de video e separador de sincronismo (VPASS)	100.000
7. Equipamento de teste	40.000
8. Estação geradora de tempo	5.000
9. Gravador AMPEX FR 1928	70.000
10. Gravador RCA TR 70-CVR-3E	200.000
11. "Quick-look Monitor" para RBV	90.000
12. Sincronizador de Bit para o sinal PCM de telemetria em tempo real	60.000
13. Prédio (300 m^2)	50.000
TOTAL	1.000.000

TABELA 9.2 - CUSTO ANUAL DE OPERAÇÃO E MANUTENÇÃO DA ESTAÇÃO DE RASTREIO E RECEPÇÃO

CONSTITUINTES	PREÇO (US$)
1. Fitas magnéticas (na hipótese que todas as fitas gravadas sejam conservadas no INPE)	60.000
2. Pessoal	
1 engenheiro eletrônico	
2 técnicos em eletrônica para manutenção	
4 operadores	30.000
3. Material de reposição	50.000
TOTAL	140.000

A tabela 9.2 mostra o custo de operação e manutenção da Estação de Rastreio e Recepção.

O preço total desta estação poderia ser diminuido de aproximadamente US$ 100.000 se trocarmos o "Quick-look Monitor" (ítem 11) por um simples osciloscópio e eliminarmos a compra de equipamentos de teste (ítem 7).

Se trocássemos o gravador de gravação paralela, AMPEX-FR-1928, por um gravador de gravação série, como por exemplo o TR70-CVR-3E modificado, o preço desta estação aumentaria de aproximadamente .... US$ 50.000.

Para que o sistema ficasse altamente confiável, seria interessante a compra de algumas unidades de reservas.

Há a possibilidade de crescimento desta estação com a compra dos equipamentos para recepção dos outros sinais transmitidos no canal de USB. Estes outros sinais seriam o DCS (Data Collection System) e o PCM de telemetria armazenado. Este crescimento talvez acarrete a compra de um gravador digital, por exemplo o AMPEX FR-2000. A efetivação deste crescimento aumentaria o preço da estação de aproximadamente US$ 150.000, sem considerar o preço das DCP (Data Collection Platform). e dos sensores correlatos a estas plataformas.

Há também a possibilidade de crescimento para receber satélites meteorológicos na banda S, tais como o TIROS N e SMS/GOES, bastando para isso a compra de três receptores.

9.2 - Estação de Processamento de Imagens

Esta estação de processamento permite o completo processamento dos sinais RBV, MSS e USB (PCM de telemetria e DCS) no Brasil; dispõem de capacidade para gerar as imagens preliminares e precisas para RBV e MSS e as CCT (Computer Compatible Tapes) para MSS, além de fazer análises multiespectrais.

A figura 9.1 apresenta a configuração desta estação completa de processamento; notar que o processamento para as imagens precisas é obtido com determinação manual dos erros locais em todas as fotos uma por uma; notar também que nesta figura não está mostrado o processamento DCS, a geração das fitas CCT e o analizador multiespectral.

A estação proposta pode ser separada esquematicamente, em termos de custo, conforme mostra a tabela 9.3.

TABELA 9.3 - CUSTO DA ESTAÇÃO DE PROCESSAMENTO DE IMAGENS

ÍTENS	PREÇO (US$)
1. Eletron Beam Recorder (com controles)	200.000
2. RBV e MSS processamento preliminar (bulk) ...	1.200.000
3. RBV e MSS processamento preciso	800.000
4. Fitas CCT para MSS	100.000
5. Processamento DCS	200.000
6. Analizador multiespectral	250.000
TOTAL	2.750.000

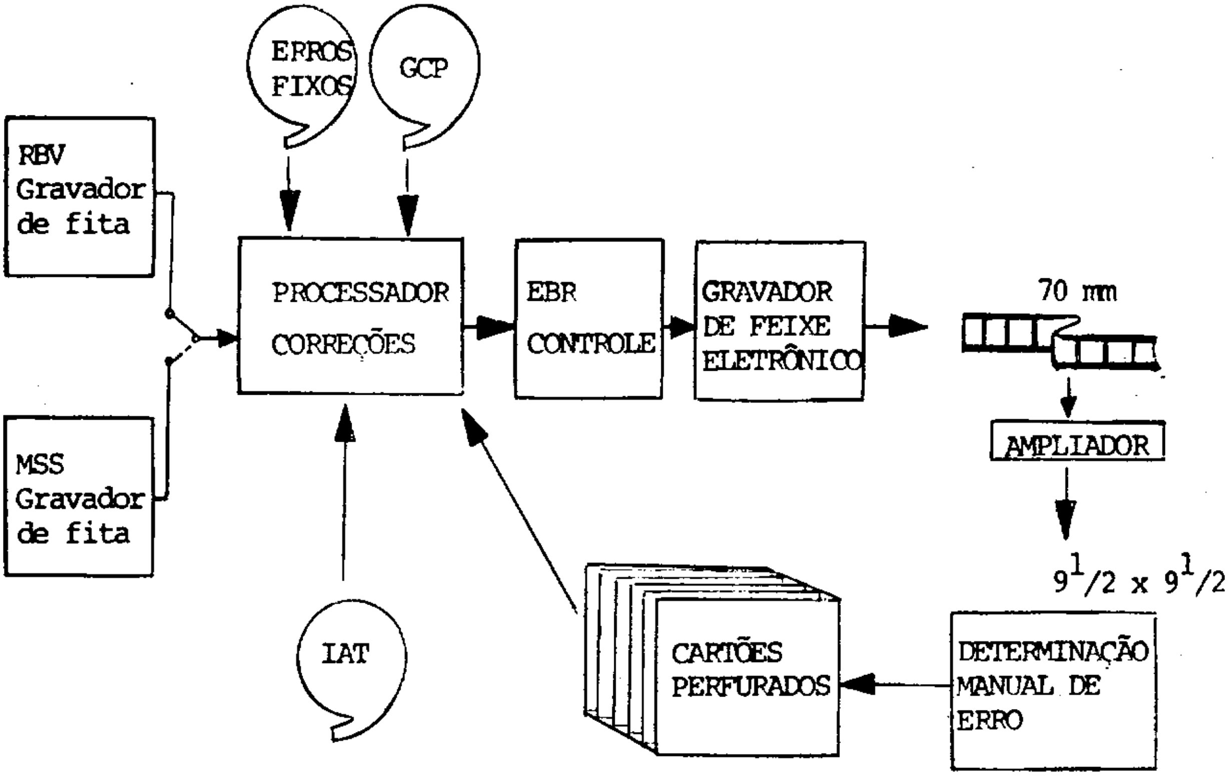


Fig. 9.1 - Estação de Processamento de Imagens

Notar que o processador está incluído no ítem referente ao processamento preliminar; notar também que neste ítem não está incluído o preço da geração das fitas IAT (Image Annotation Tapes) e das fitas "Erros Fixos", pois considerou-se que a NASA fornecerá ao Brasil estas fitas para as correções preliminares e anotações.

No ítem 3 a geração destas duas fitas já está incluída; ou seja, para passar do processamento preliminar ao processamento preciso com geração das fitas IAT e "Erros Fixos" haveria um aumento de aproximadamente US$ 800.000.

Os graus de sofisticação do sistema podem ser considerados como:

ESPECIFICAÇÕES	PREÇO (US$)
1º) Imagens sem correções e anotações	200.000
2º) Imagens preliminares anotadas, com fitas IAT e "Erros Fixos" fornecidas pela NASA	1.400.000
3º) Imagens preliminares e precisas anotadas, com fitas IAT e "Erros Fixos" geradas no INPE	2.200.000
4º) Ítem 3º) mais geração de fitas CCT para MSS ..	2.300.000
5º) Ítem 4º) mais processamento DCS	2.500.000
6º) Ítem 5º) mais análises multiespectrais	2.750.000

Notar que os gravadores utilizados para reproduzir as fitas gravadas na Estação de Rastreio e Recepção, para o consequente processamento, não estão aqui cotados, pois considera-se que as estações de rastreio-recepção e processamento estão em um mesmo lugar. Se isto não for possível, o custo da estação de processamento aumentaria do preco correspondente aos gravadores (US$ 270.000).

A tabela 9.3 mostra o custo anual de operação e manutenção da Estação de Processamento de Imagens, incluindo o processamento fotográfico.

TABELA 9.4 - CUSTO ANUAL DE OPERAÇÃO E MANUTENÇÃO DA ESTAÇÃO DE PROCESSAMENTO DE IMAGENS

DESCRIMINAÇÃO	PREÇO (US$)
1. Fitas digitais de computador (CCT)	20.000
2. Pessoal	
. 3 engenheiros	
. 2 técnicos para manutenção	
. 8 operadores	60.000
3. Material de reposição	100.000
4. Processamento fotográfico	176.000
TOTAL	356.000

9.3 - Resumo do Custo Total da Estação

O custo da Estação de Rastreio e Recepção mostrado na tabela 9.1 (US$ 1.000.000) seriam acrescidos de US$ 150.000 (para possibilitar a recepção dos sinais DCS e PCM de telemetria armazenado não cotados na tabela 9.1) e de mais US$ 50.000 para a aquisição de algumas unidades de reservas que seriam quase indispensáveis. Então o custo da Estação de Rastreio e Recepção seria de US$1.200.000. O custo operacional para um ano seria conforme mostra a Tabela 9.2 de US$ 140.000.

O custo de investimento para a aquisição da Estação de Processamento de Imagens seria acrescido de US$ 270.000 correspondente aos gravadores adicionais; resultaria então no total de US$3.020.000.O custo operacional para um ano seria conforme a tabela 9.4 de US$356.000.

Então teríamos resumidamente o custo total de investimento e operação para um ano da estação:

INVESTIMENTO DE COMPRA	PREÇO (US$)
1. Estação de Rastreio e Recepção	1.200.000
2. Estação de Processamento de Imagens	3.020.000
Total	4.220.000

OPERAÇÃO ANUAL	
1. Estação de Rastreio e Recepção	140.000
2. Estação de Processamento de Imagens	356.000
Total	496.000

Então o investimento na compra dos equipamentos em cruzeiros considerando o valor atual do dólar (Cr$ 5,845) será de .... Cr$ 24.665.900,00.

O desembolso desta quantia ocorre de acordo com o Cronograma da Fig. 9.2; é previsto 25% do total na assinatura do contrato com as firmas; 15% do total no fim do segundo, terceiro e quarto mes após a assinatura do contrato; 20% do total no embarque dos equipamentos; 10% do total no término das instalações.

É oportuno lembrar que as firmas que estão se propondo a vender os equipamentos para a estação estão dispostas a conseguirem financiamento internacional.

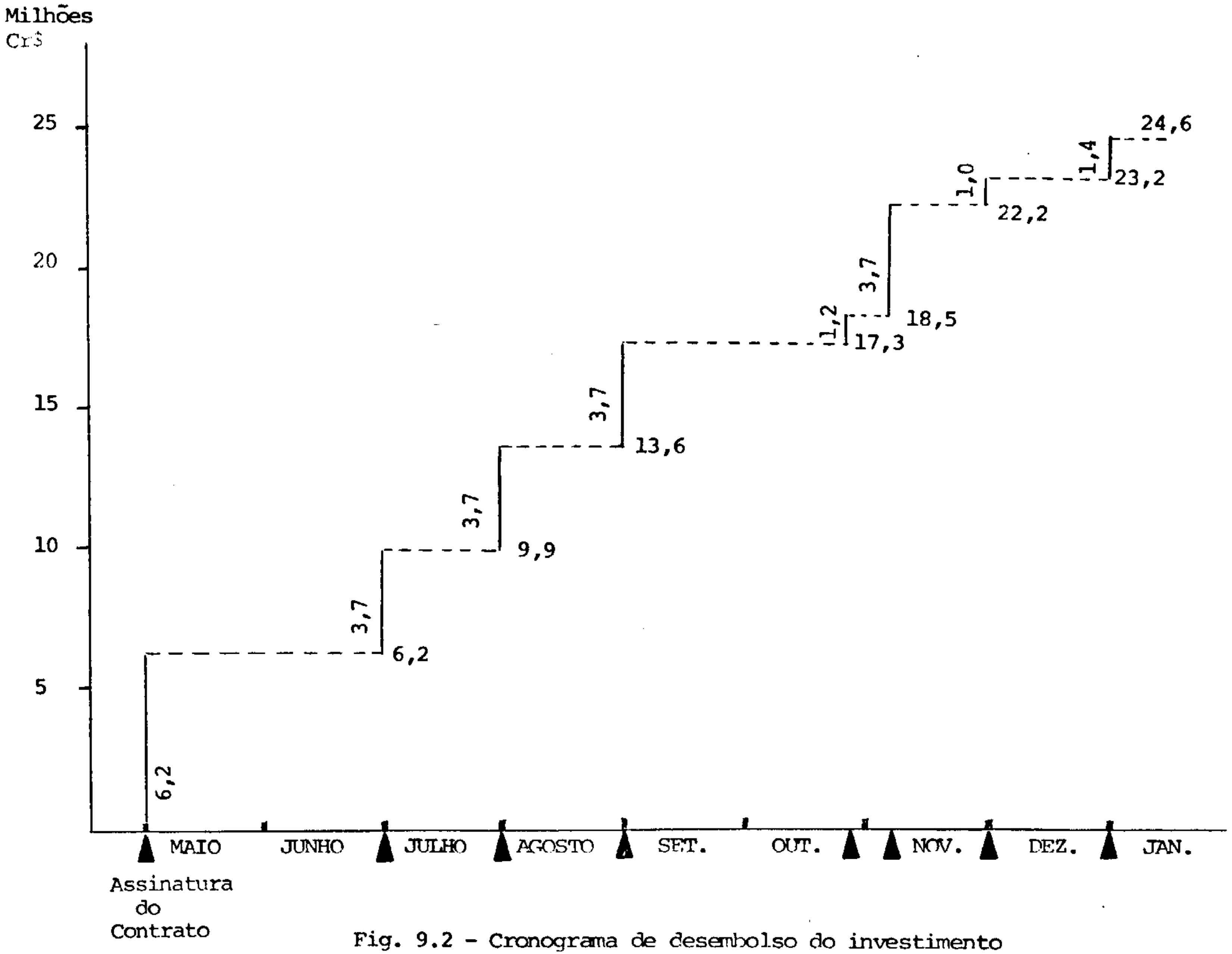


Fig. 9.2 - Cronograma de desembolso do investimento

CAPÍTULO 10

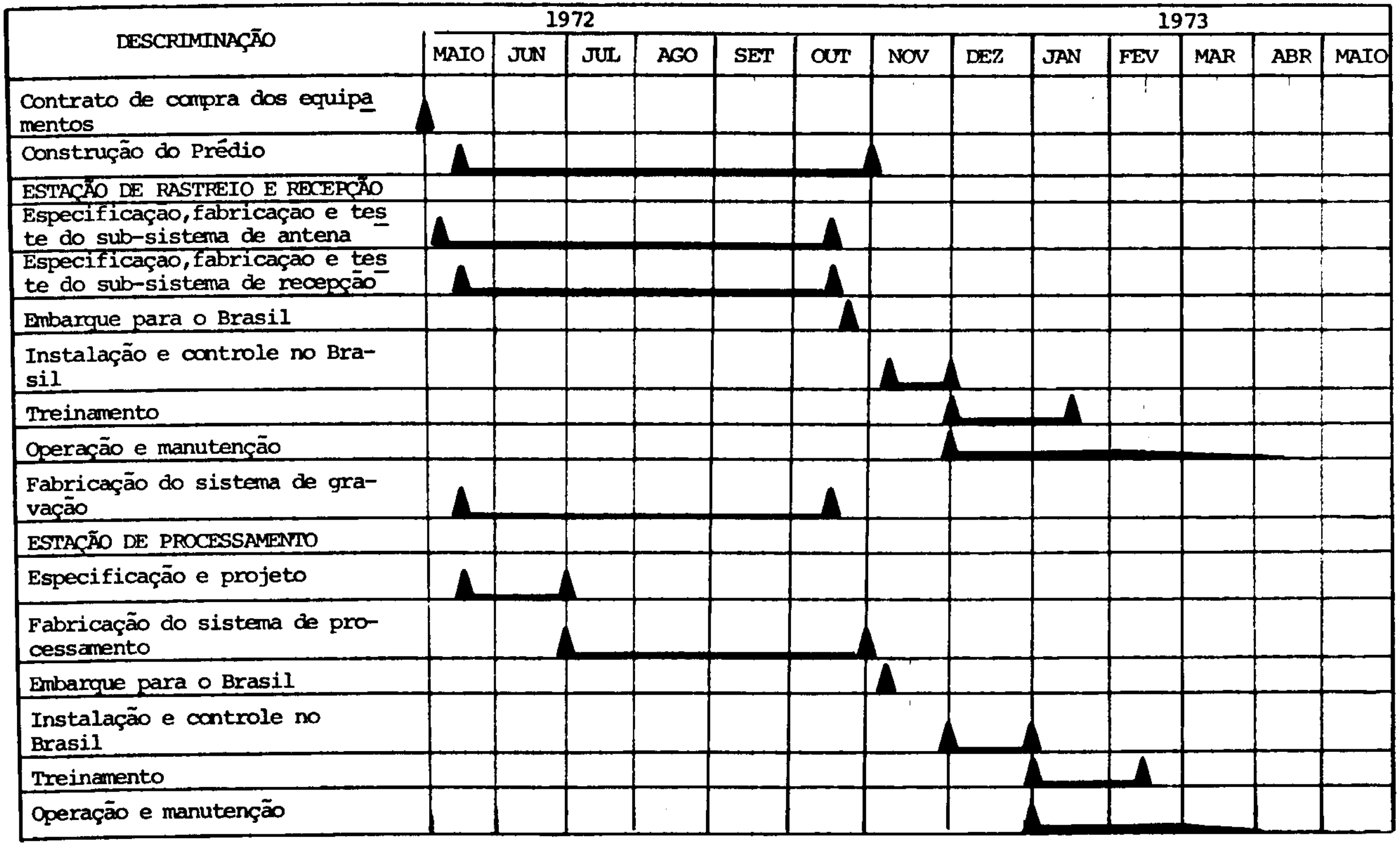
CRONOGRAMA DE IMPLANTAÇÃO DA ESTAÇÃO

O lançamento do satélite ERTS-A está previsto para 18 de junho de 1972. Se a encomenda for feita em maio a parte de recepção e gravação estaria operacional em novembro de 1972. A parte de processamento de imagens, um a dois meses depois.

Satélites de exploração dos recursos da Terra tais como EOS e porventura outros ERTS darão continuidade ao programa.

A tabela 10.1 mostra o cronograma de implantação da estação; a tabela mostra que o prédio onde será instalada a estação deve estar concluído até o início de novembro de 1972.

TABELA 10.1 - CRONOGRAMA DE IMPLANTAÇÃO DA ESTAÇÃO



DESCRIMINAÇÃO	1972								1973				
	MAIO	JUN	JUL	AGO	SET	OUT	NOV	DEZ	JAN	FEV	MAR	ABR	MAIO
Contrato de compra dos equipamentos	▲												
Construção do Prédio	▲—	—	—	—	—	—▲							
ESTAÇÃO DE RASTREIO E RECEPÇÃO													
Especificaçao, fabricaçao e teste do sub-sistema de antena	▲—	—	—	—	—	—▲							
Especificaçao, fabricaçao e teste do sub-sistema de recepção	▲—	—	—	—	—	—▲							
Embarque para o Brasil						▲							
Instalação e controle no Brasil							▲—▲						
Treinamento								▲—	—▲				
Operação e manutenção								▲—	—	—	—	—	
Fabricação do sistema de gravação	▲—	—	—	—	—	—▲							
ESTAÇÃO DE PROCESSAMENTO													
Especificação e projeto	▲—	—▲											
Fabricação do sistema de processamento			▲—	—	—	—▲							
Embarque para o Brasil							▲						
Instalação e controle no Brasil								▲—▲					
Treinamento									▲—	—▲			
Operação e manutenção									▲—	—	—	—	

CAPÍTULO 11

CONCLUSÃO

Esperamos que através dos capítulos anteriores tenha ficado claro que a instalação da referida estação no Brasil representará uma técnica valiosa no levantamento e preservação das riquezas do país.

O esforço do INPE em dotar o Brasil desta estação é de relevante importância principalmente no que tange à solução de problemas fundamentais do país, tais como aqueles enumerados no capítulo 1.

A estação proposta pelo INPE em sua versão completa irá permitir ao Brasil receber os dados de todo o território nacional e transformá-los em um conjunto de sete fotografias nas faixas espectrais do visível e infravermelho próximo; estas fotografias poderiam ser distribuídas para todas as entidades brasileiras interessadas;este conjunto de 7 imagens (3 fornecidas pelo sistema de televisão e 4 pelo sistema imageador) são renovadas de 18 em 18 dias, devido à cobertura repetitiva do satélite. Esta estação na sua versão mais completa custaria da ordem de Cr$ 24.650.000,00.

A participação do Brasil no programa ERTS e consecutivamente nos futuros programas de exploração e levantamento de recursos da Terra, utilizando plataformas orbitais,resultará em enormes benefícios ao país a custos relativamente baixos comparados com a grande vastidão do nosso território.

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APÊNDICE A

EQUIPAMENTO SENSOR DA ESTAÇÃO ORBITAL AMERICANA (SKYLAB)

Alguns dos equipamentos de sensoriamento a serem utilizados nos experimentos de observação da Terra incluem:

i) Equipamento fotográfico multi-espectral (S-190)

Este experimento emprega seis câmeras de alta precisão de 70 mm, com casamento entre as distorções e lentes de distância focal de 15,2 cm (21.2º campo de visão através de planos) dando uma cobertura de área de 163 x 163 km (88 x 88 milhas náuticas) e uma escala de foto de 1:2.800.00. As lentes são alinhadas e montadas num painel de lentes simples com seus eixos óticos paralelos a menos de um minuto de arco. As imagens serão registradas dentro de 5 microns. As câmeras são equipadas com obturadores síncronos, compensados para o movimento do veículo espacial. Espera-se que o sistema atinja uma resolução (filme-lente) de mais de 100 linhas por milímetro em cor. A resolução terrestre efetiva poderá ser de, aproximadamente, 30 metros. O sistema é planejado para as seguintes combinações espectrais de comprimento de onda/filme:

0,5 a 0,6 microns - Pan X filme preto e branco
0,6 a 0,7 microns - Pan X filme preto e branco
0,7 a 0,8 microns - Filme infravermelho preto e branco
0,8 a 0,9 microns - Filme infravermelho preto e branco
0,5 a 0,88 microns - Infravermelho colorido
0,4 a 0,7 microns - Hi-Res colorido

As faixas espectrais cobertas pela missão S-190, geralmente, correspondem à cobertura espectral planejada para os aparelhos de varredura (Scanners) multi-espectrais e para as câmeras "Return Beam Vidicon" (RBV) do ERTS. Sensores semelhantes serão usados em aviões para permitir a correlação de observações simultâneas do "SKYLAB", ERTS, aéreas e terrestres.

ii) Aparelho de Varredura (Scanner) multi-espectral (S-192)

Este sensor proverá valores de radiação em várias faixas espectrais, através de varredores com ângulo de 10º para produzir faixas de 78 km. Cada faixa terá um campo instantâneo de visada de 80 metros quadrados. As faixas espectrais são, aproximadamente:

1) 0,410 a 0,460 microns
2) 0,460 a 0,510 microns
3) 0,520 a 0,556 microns
4) 0,565 a 0,609 microns
5) 0,620 a 0,670 microns
6) 0,680 a 0,762 microns
7) 0,783 a 0,880 microns
8) 0,980 a 1,080 microns
9) 1,090 a 1,190 microns
10) 1,200 a 1,300 microns
11) 1,550 a 1,750 microns
12) 2,100 a 2,350 microns
13) 10,200 a 12,500 microns

iii) O conjunto de câmeras considerado para o "SKYLAB" consiste de uma câmera modificada Hycon KA-74.

Este equipamento tem uma lente com distância focal de 18 polegadas de comprimento e produz imagens de 4.1/2 x 4.1/2 polegadas em rolos de filmes de 5 polegadas de largura. O equipamento foi qualificado para uso em satélites tripulados mas, embora possa ser usado para fotografias vertical e oblíqua não é uma câmera de mapeamento.

O equipamento que está sendo considerado para os possíveis futuros vôos do "SKYLAB" II ou III, inclue uma câmera de mapeamento de terreno com um comprimento focal de 12 polegadas, com formato de filme de 9 x 14.1/2 polegadas, para o qual lentes dando adequada cobertura podem ser obtidas; uma câmera de altitude estelar com comprimento focal de 6 polegadas usando filme de 70 mm; um altímetro de laser; e uma câmera de comprimento focal de 12 polegadas com formato de filme de 9 x 18 polegadas. Uma câmera panorâmica do programa lunar, também poderá ser usada. Esta câmera tem comprimento focal de lentes de 24 polegadas, 108° de varredura, caixilho de 4.1/2 x 45 polegadas, abertura F3.5 e, é capaz de produzir 1.650 exposições. Considera-se que fotografias desta câmera dariam detalhes de mapeamento na escala de 1:50.000 e 1:25.000. Copiadores de retificação e transformação que, essencialmente duplicam a geometria do sistema adotado estão sendo desenvolvidos.

PRESIDÊNCIA DA REPÚBLICA
CONSELHO NACIONAL DE PESQUISAS
INSTITUTO DE PESQUISAS ESPACIAIS
São José dos Campos - Estado de S. Paulo - Brasil

APÊNDICE B

20 de março de 1972

Of.:144/72

Senhor Presidente:

Como principal órgão de pesquisas espaciais (Decreto 68532/72; art. 2º; parágrafo único) e executante do programa de sensoriamento remoto iniciado em 1968, com autorização do Presidente da República, pedimos vênia para apresentar uma situação problema que interessa do Brasil e sugerir solução.

- Considerando que a agência espacial civil dos EEUU, NASA, irá lançar em junho do corrente ano o primeiro satélite do programa ERTS (Earth Resources Technology Satellite), destinado ao levantamento dos recursos naturais da Terra(Vide Anexo 1);

- Consederando que a NASA não estende, via de regra a outros países, a possibilidade de ter em seus territórios estações próprias, para recepção direta dos dados coletados e transmitidos por tais engenhos espaciais, tendo entretanto aberto exceção nos casos do Brasil e do Canadá, em reconhecimento ao razoável sucesso que ambos tem obtido no estudo e no emprêgo de técnicas de sensoriamento remoto para o levantamento de recursos naturais (Anexo II);

- Considerando que o Brasil, em instalando em seu território, uma estação para recepção dos dados transmitidos pelos satélites do programa ERTS, estará, através de um investimento relativamente pequeno, se beneficiando enormemente de um sistema que está custanto para os EEUU uma quantia 60 vezes maior.

- Considerando que o fato de recebermos tais dados diretamente no Brasil, sem outro país como intermediário, se constitue em mais um fator de salvaguarda dos interêsses e da segurança nacionais (Vide Anexo III);

Ao Exmo. Sr,
General Arthur Mascarenhas Façanha
DD. Presidente
Conselho Nacional de Pesquisas
Av. Marechal Câmara, 350
Rio de Janeiro - GB

Anexos: I,II,III,IV

- Considerando que todas as instituições brasileiras ligadas à cartografia, ao levantamento e à exploração de recursos naturais, se beneficiarão de tais dados;
- Considerando que para que o Brasil possa, como almejam todos os brasileiros, conseguir um lugar de destaque no consenso mundial de nações, terá que superar os vários anos de estagnação a que esteve submetido, queimar etapas, através de adoção de medidas de natureza da que é motivo o presente documento;
- Considerando que o INPE, já vem desde alguns anos fazendo estudos sôbre o problema (Vide Anexo IV);

vimos solicitar ao Conselho Nacional de Pesquisas, urgente providências no sentido de que sejam alocadas a êste Instituto, verbas extra-orçamentárias para a aquisição do sistema terrestre que possa habilitar-nos à recepção e ao processamento dos dados transmitidos pelos satélites da série ERTS. O caráter de urgência é ditado pelo fato de que tal sistema terrestre deverá estar operando o mais tardar em dezembro de 1972 e para que isso seja possível, dever-se-á passar imediatamente ao processo de compra do mesmo.

Mais especìficamente, as verbas solicitadas assim se distribuiriam:

- Sistema de Recepção e Armazenamento dos Dados:	aprox.Cr$ 6.000.000,00
- Sistema de Processamento de Imagens	Cr$18.000.000,00
Total	aprox.Cr$24.000.000,00

Informo outrossim que a NASA concordaria em fazermos convênios com a Bolívia, Paraguai, Uruguai, parte do Peru, do Chile e da Argentina, para levantamento de dados de seus territórios, caso interessem a estes países.

Tal estação permitiria, além disso ampliar por um grande fator de rentabilidade do Projeto RADAM, o qual já foram alocados recursos da ordem de cem milhões de cruzeiros.

A arrancada para o progresso que está sendo conseguida pelo atual governo tem sido possível graças à pronta adoção de medidas como a que ora é sugerida - daí termos decidido apresentar a idéia de obter os Cr$24.000.000,00 de recursos extra orçamentários para que, ainda neste exercício, possa o Brasil beneficiar-se de mais uma realização de impacto.

Fernando de Mendonça
Diretor Geral

EBT/ekm

BRAZILIAN STATION FOR TRACKING, RECEPTION AND PROCESSING FOR EARTH RESOURCES TECHNOLOGY SATELLITES (ERTS)

REPORT LAFE-188

April 1972

PR — National Research Council
Institute For Space Research (INPE)
São José dos Campos - SP - Brazil

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PRESIDÊNCIA DA REPÚBLICA
CONSELHO NACIONAL DE PESQUISAS
INSTITUTO DE PESQUISAS ESPACIAIS
São José dos Campos - Estado de S. Paulo - Brasil

BRAZILIAN STATION FOR TRACKING, RECEPTION AND PROCESSING FOR EARTH RESOURCES TECHNOLOGY SATELLITES (ERTS)

This document, whose publication was authorized by the undersigned, contains a detailed description of the specifications for the INPE station for ERTS program.

It is possible to able to record the MSS and RBV channels by late 1972 and have the automatic data processing system ready by March 1973.

This document is the result of team work on the subject, and the engineers Ronaldo V. Guimarães and Marne C. Serrano had a special participation in it.

Fde Mendonça
Fernando de Mendonça
General Director

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CHAPTER 1

INTRODUCTION

1.1 - General Considerations

The purpose of this document is to present a study on a ground station to receive in Brazil the information transmitted by satellites of the ERTS series, the first of which will be launched by NASA in June 1972.

According to the final document submitted to NASA by General Electric (firm contracted by NASA to do the study of the ERTS program), the satellite and its recording system has a life span of one year and one thousand hours of operation, respectively. Taking into account that the data obtained by ERTS are of great usefulness for many countries, one might estimate that the one thousand hours of operation forecast for the wide-band tape recorder will be attained within approximately 6 months after the satellite lauching. So that the information destined to Brazil is not interrupted, it should receive it directly from the satellite through a ground station. As the station installed in the Brazilian territory could receive real time data covering many other South American countries, the Brazilian government with NASA concurrency may eventually contact the governments of those countries to verify if they are interested in participating in the program.

With such a station, Brazil could have at its disposal the necessary means to monitor in a repetitive way the resources of its territory. At any given day we could have information in image form and digital magnetic tapes from the most remote and farthest points of the national territory. These data could be provided to all the Brazilian agencies, private or not, which are linked to Carthography and Surveying and/or Exploration of natural resources.

Brazil's participation in the ERTS Program and in future programs on natural resource satellites would make it possible:

- To develop a map on the use of the Brazilian soil;
- To classify per areas the geological characteristics of the Brazilian soil;
- To develop an agricultural map for Brazil;
- To develop a map of the Brazilian forest reserves;
- To reduce losses in the agriculture through fast identification of plague infestation;
- To plan the distribution of the yearly production to the whole Brazil through estimating of the crops per area;
- To increase the production through the determination of soil characteristics and water reserve control;
- To plan in a better way the rural and urban development;
- To identify geological features, such as faults, folds, lithology, etc.;
- To monitor dynamic phenomena such as sedimentation,coastal changes, erosion, crop growing, water reserves, level, etc.;
- To evaluate the development at the constructing of big highways such as those under construction in the Amazon region;
- To collect data at fixed stations in remote points of the Brazilian territory, such as: level of the waters of lakes, reservoirs and dams; soil humidity, surface temperature; ocean salinity; ocean currents; atmospheric pollution; direction and velocity of the winds, etc.;
- To make an inventory of the water sources;
- To identify, monitor and evaluate the atmosphere and water pollution;
- To increase the fish production through the localization of the cold sea currents, of areas biologically rich and

of ideal temperature conditions for fishing;
- To plan in a better way sea voyages through sea conditions detected;
- To detect big navigation disasters;
- To make cartography surveying of the whole Brazilian territory;
- To make surveying of cloud coverages;
- To provide surveying of cloud coverages;
- To provide information with demographic inferences,etc.;
- To better plan the occupation of areas, such as Amazon region, and fiscalize such an occupation so as to make it rational, without major modification of its ecological equilibrium.

1.2 - The Brazilian Environment and the Imagery collected by Satellite

A way to take advantage of an immense region like the interior of Brazil, an area of 6 million square kilometers with a populational density of only 2 inhabitants per square kilometer, would be to develop in it activities compatible with its vastness and low population density. These activities could initially be restricted to points of limited areas where emphasis could be put on the exploration of local natural resources. The satellite capability to cover extensive areas of the Earth Surface in a short time and with relatively moderate expenses suits the necessity for ample initial surveying of these remote areas. This basic surveying, in its turn, will make possible the concentration of later surveys with airplane or conventional methods of surface in relatively small areas.

In relation to intermediary regions, between the central areas and the coast, also vast with about 2.5 million square kilometers but, in contrast, with a population density of 35 inhabitants per square kilometer, the use of sensors in airplanes, flying at high altitudes or on orbital platform, besides allowing the finding of new sources of natural resources or additional exploration of existing productive source, will certainly be useful in the economical exploration and control of the agriculture and forests on a regional level. The necessities of current information about the use of the earth and about the growing and condition of plants present an almost unlimited demand for data collected by remote sensing . Data collected from orbital altitudes have a special meaning for a country where extensive agriculture is predominant and the forests are in general huge. The data collected for specialists in agriculture and silviculture will probably be of equal importance for geographers and planners interested in ample regional developments.

On the other hand, there are at present in Brazil,organized efforts to solve the problems of economic development of immense regions with extremely different characteristics such as the humid Amazonic Basin and the dry Northeast.

An example of the application of data on soils, collected by satellite, would be that of help in the changing of existing conditions in the "campos cerrados", found in an area of about 1.5 million of square quilometers in Central Brazil and in above mentioned intermediary region. The research has shown that the problem is essentially of high acidity of the soil, what can be minimized through the addition of dolomitic calcareous and fertilizers. Along the extensive Brazilian Coast with more than 7 thousand kilometers, the data collected from orbital altitudes could delineate temperature contrasts which characterize the configurations of the Brazil current, on South and East Coast, and of Falklands currents (Malvinas) which reach the shores of extreme South during the Winter. Besides being important to the navigation, this information presents correlation to the movement to sea biological communities and therefore to commercial fishing.

1.3 - Systematic Survey of Natural Resources and the Images of Satellites

With surveys in 5 height levels as described later we could present a generic program which would permit to execute fast and economically:

- regional mapping, and
- selective mappings of more promising areas for the development of a determined region.

In this program, links of a dependency have been established, with increasing details, where it is presumed that a level of detection may serve as "truth" for the preceding higher level besides bringing a contribution of new information.

This approach results in a filtering system which besides making it possible to select more promising areas in each level of survey, would lead to a process for fast reduction of areas, where the evaluation or interpretation of data on larger areas would permit a rapid elimination of the parts of these areas that would show less potential.

In order to better locate the problem some information items on the collecting vehicle and the type and format of the data produced are then shown.

1.3.1 - Level for Orbital Survey (Highest Level)

1.3.1.1 - ERTS Satellites

The first Earth Resources Technology Satellite, known as ERTS-A, mentioned previously, will be launched by NASA in June 1972.Further information about it and its sensing and recording equipments will be presented in this report.

1.3.1.2 - SKYLAB

In addition to the satellites of the ERTS series, NASA will launch in 1973 an experimental space station, with a crew of three people, known as "SKYLAB WORKSHOP". This spacecraft will orbit at altitudes of 435 km (235 nautical miles), with an inclination of 50° and will rotate crews during three periods, the first of 28 days and the second and third of 56 days. In a total period of 8 months, 5 months will, practically,have manned operation.

Besides a great many scientific experiments, observations of the Earth are programmed for this project. As the Brazilian territory will be entirely covered by orbits of 50° of inclination in relation to the Equator, these observations will be particularly interesting to Brazil.

The sensing equipments of the Orbital station are described in the Appendix A.

Brazil, through INPE, proposed to NASA to participate in such program.

1.3.2 - Aircraft Survey Level at High Altitude

To give an example of this level we take the case of the Amazon Region where a CARAVELLE, of "LASA Engenharia e Prospecções S.A."; flying at a speed of 700 km/hour (380 knots) and at an altitude of 11.000 to 12.000 meters (36,000 to 40,000 feet) above the ground, is utilized for acquisition of radar imagery and photographic data. The Side Looking Radar (SLAR) utilizing synthetic aperture, type Good-Year model 102, presents spatial resolution better than 20 meters in all points of the images. It works in "X" band (3 cm of wavelength).

All the flights, controlled by a inertial navigation system, are performed along lines in the orientation N-S, making a lateral scanning of 37 km width, with adjacent scannings overlap of 30%. The presentation of the results is being performed in mosaics of 1° x 1.5°, in the scale of 1:250.000.

The geographical linking of the lines of flight has been obtained through the use of SHORAN stations with determined geographic coordinates by observation of satellites with a Transit ground station operated by LASA and AEROSERVICES.

Besides the radar, a metric camera ZEISS is being utilized with a super-big-angular lens, provided with false-color infrared film.Its field of view permits overlapping with radar images.

The photos are being taken with 60% of longitudinal overlapping and small lateral overlapping and are presented in film format 23 x 23 cm (9 x 9 inches), in a scale of 1:130,000.

Simultaneously with the photos of the metric camera, multispectral photos in black and white have been obtained with a I^2S camera of four lenses. The scale is of 1:73,000 with four images displayed on every film frame of 23 cm. The coverage is therefore partial, almost 25% of the total.

1.3.3 - Aircraft Survey Level at Medium Altitude

In the third level, which would be an aerial reconnaissance on regional scale, performed at this time at medium altitudes, it would be sought to conciliate the employment of geophysical sensors, considered today as a basic requirement for the geological reconnaissance of great areas, such as multispectral aerial photographies, in scales of current use among the photo-interpreters interested in the additional disciplines.

The flight altitude in this survey, which might be qualified as a transition, would be between 9,000 to 11,000 feet above the ground (3,000 m nominal) with flight lines spaced 5 km, cut by transversal lines each 25 km.

To control flight lines and their geographic positioning, inertial or doppler navigation systems are used.

It is appropriate to say that the utilization of other sensors such as electromagnetometers, thermal imagers, spectrometers of gama or mercury radiation, due to the fact that their maximum altitudes of aerial use are very low and, therefore, are incompatible with that specified to this stage.

The two preceding stages, where we would seek to take advantage of sensors susceptible of being applied in large scale areas, would be complemented by the one just outlined, in which a survey of transition from regional to local is suggested. This survey, in acceptable conditions of performance, time and cost, would give data whose nature and degree of definition would permit more selective studies. The information obtained through these surveys would certainly make possible not only the basic mapping but also the choise of more promising areas which would be the targets of the conventional detailed surveys mentioned next.

This selection would be obviously facilitated by a study of existing information about the region and by the consideration of the data collected during the visual aerial reconnaissance, forecasted also for this stage.

The set of accumulated data in the thirdstage would serve as the "truth" for the preceding higher levels of reconnaissance.

1.3.4 - Aerial Detailing Level at Medium and Low Altitude

The services for detailed surveying of the areas selected as more promising in the preceding stage would require a specific planning for each case. However, certain steps seem to be indispensable. It is included, in this case, a preliminary measure which aims at eliminating the natural uncertainties of interpretative processes: a short trip for reconnaissance of the ground, to the areas, qualified as promising. Probably, the data of greater interest to be obtained in loco would be geochemical ones. Distances and difficulties to reach the areas would be factors considered in the priority classification of the areas considered as promising.

Initially, at this level the utilization of the following sensors in combined system would be considered.

- Imagers (thermal in the visible in the ultraviolet,etc.);
- Magnetometers;
- Electromagnetometers;
- Mercury Spectrometers;
- Gamma radiation Spectrometers.

All these sensors should be used in flights at low altitude. The plotting of the data collected would be in scale of photomosaics obtained by aerial photographic coverage in scales more convenient to cartographic needs of each target-area.

In the same way as in the third stage, the flights would continue to be utilized for visual observation. Once again this level would serve as "truth" for the preceding levels by a re-evaluation of the areas qualified as promising and would permit a final selection of those which would deserve the studies of the next stage.

1.3.5 - Ground

Although the surveys at this level are qualified as "ground truth", the work which would be done in it should also have an exploratory feature. The sites chosen should be considered as advanced bases for relatively prolonged operation and even as eventual poles of development of the area.

Considering these conditions, bigger investments in the development of the chosen areas would be justified. Such a development should include, for example, the building of landing fields and other material resources which, besides allowing a longer permanence of the personnel at the place, would permit the efficient execution of the field works.

In a more critical form than in the preceding stage, the research on the ground to be performed in these areas should be object of careful specific planning .

CHAPTER 2

ERTS SYSTEM

The control and conservation of the natural resources of the earth is vital to the future of mankind. An attempt for such control and conservation will be done through the ERTS Program (Earth Resources Technology Satellite), under NASA responsibility.

The ERTS-A will be the first of a serie of satellites aiming at providing the first data about the natural and cultural resources of the Earth collected by a systematic way and will be launched in June 1972. This satellite with a forecasted lifetime of one year, will have a quasi polar circular, sun-synchronous orbit, so that each point of the earth surface be repeated covered each 18 days always at the same time.

The ERTS satellite will carry a Multispectral Scanner System (MSS), Return Beam Vidicon (RBV), Wide Band Tape Recorders (WBTR), and a Data Collection System (DCS) for the acquisition of data from earth based Data Collection Platforms (DCP). The satellite's payload will include, in addition to the two sensing systems, equipment to transmit outputs from the sensor plus information about housekeeping and the status of the spacecraft. The satellite will transmit synchronization and calibration signals along with the video signals.

The data originated by the MSS and RBV, the DCS signals, the tracking signals and the information on the operating status of the system will be transmitted to ground in the S-band frequency range. On the ground such data will be received, recorded and transformed later in photographic images and digital tapes for direct access to the computer (CCT - Computer Compatible Tapes).

The ERTS Program is the precursor of the EROS Program which comprises satellites for observation of Earth Resources (EOS) and which should be implemented by NASA in the second half of the this decade.

2.1 - Sensors

The spectral band covered by the two types of sensors (RBV and MSS) has been chosen with great care and with the help of several user agencies of the ERTS Program.

The television cameras (RBV) have been designed for the following spectral bands:

0.475 - 0.575 microns (blue-green);

0.580 - 0.680 microns (orange-red);

0.690 - 0.830 microns (red).

The lower band, 0.475 - 0.575 microns, will allow the study, for example, of areas where the water predominates. The upper band, 0.690 - 0.830 microns, centered more or less in 0.750 microns (peak of radiation for chlorophyll) will allow the study of areas covered by green vegetation. The upper limit of 0.830 microns represents the limit response of the television system. The information of the infrared is located above this limit, also required by the users of ERTS; to provide this information and to also cover the same band of the television system, the multispectral scanner (MSS) was especified. The MSS provides information in the following bands:

0.500 - 0.600 microns (green to orange);
0.600 - 0.700 microns (orange to red);
0.700 - 0.800 microns (red to near infrared);
0.900 - 1.100 microns (near infrared).

The three first bands are in the visible spectrum and the last one in the near infrared. In each band there are six photodetectors. A simple scanning of the mirror of the multispectral scanner will provide information about a strip of 100 nautical miles for all the 24 photodetectors. Table 2.1 shows the main characteristics of the two sensors (RBV and MSS) and of wide band tape recorder (WBVTR) of the satellite.

The resolution or definition of the resulting multispectral images of the two types of sensors are from 60 to 130 meters, but it has been forecasted that some objects of smaller dimensions can be discovered and recognized. The images will have scale of about 1:1.000.000 and may be transformed, on the ground, in black and white photographs for each sensor spectral band. Thus, for each area of 100 x 100 nautical miles there will be seven images. The several images may be composed so as to provide color or false color images.

The second Earth Resources Technology Satellite, ERTS-B, will have essentially the same specifications of the ERTS-A, except for the addition of an extra spectral band in the multispectral scanner (10.4 to 12.6 microns - thermal infrared).

Table 2.1 - Multispectral Sensors (RBV and MSS) and Recorder (WBVTR) Characteristics.

RBV Camera Subsystem

Characteristic	Camera No. 1	Camera No. 2	Camera No. 3
Spectral Bandwidth (nanometers)	475-575	580-680	690-830
Resolution (at maximum scene highlight contrast)	4500 TVL	4500 TVL	3400 TVL
Edge Resolution (percentage of center)	80	80	80
Signal-to-Noise Ratio (at 10 TVL)	33 dB	33 dB	25 dB
Dynamic Range	50:1	50:1	50:1
Gray Scale ($\sqrt{2}$ transmission steps)	10	10	8
Horizontal Scan Rate (lines/sec)	1250	1250	1250
Number of Scan Lines	4200	4200	4200
Readout Time (seconds)	3.5	3.5	3.5
Video Bandwidth (MHz)	3.5	3.5	3.5
Time Between Picture Sets (seconds)	25	25	25
Exposure Time (milliseconds)	8, 12 or 16	8, 12 or 16	8, 12 or 16
Image Distortion (maximum)	1%	1%	1%
Deflection Skew (maximum)	+0.5%	+0.5%	+0.5%
Size and Centering Shift (maximum)	± 2%	± 2%	± 2%

Multispectral Scanner Subsystem

Spectral Bandwidth (microns)	Channel 1	0.5 to 0.6
	Channel 2	0.6 to 0.7
	Channel 3	0.7 to 0.8
	Channel 4	0.8 to 1.1
	Channel 5	10.4 to 12.6 (ERTS B only)
Scanning	Object Plane	
Scan Rate	13.6 Hz	
Scan Efficiency	50%	
Detectors/Band/Scan (Channels 1 thru 4)	6	
Instantaneous Field of View	260 ft x 260 ft	
Multiplexer Output	15 Mbps PCM	

Wideband Video Tape Recorder/Reproducer

Scanning Principle	Transverse Scan
Video Processing Technique	FM
Tape Width	2 in.
Tape Length	2000 ft
Record Time	30 minutes
Rewind Speed	4 times record speed
High Speed Forward	4 times record speed
Bandwidth	DC to 3.5 MHz (-6 dB), DC to 6 MHz
Signal-to-Noise Ratio	42 dB p-p/rms @ 2.5 MHz, BW
Transient Response	Approx 5% peak (overshoot)
Linearity	± 3%
Drift	± 5% input to output
Switching Transients	Below peak-to-peak noise
Head Wheel Start Power	Approx 250 watts peak decreasing to average power in 4 seconds

2.2 - The Orbit

The satellite orbit is circular, quasi polar, sun synchronous and keeps a constant inclination of 99.088 degrees. Whith this orbit, the satellite sensors will always scan the same area with the same solar illumination, making it simpler to detect changes in vegetation and levels of water. The satellite will cover 100 nautical mile wide strip, returning to scan the same area at the same local time, each 18 days. The equipment controlling the attitude of the satellite detect position errors so that the satellite can be positioned correctly with errors inferior to 0.7 degrees in relation to the three axes of position.

The orbital parameters of the ERTS are adjusted so that the adjacent strips have sidelap of 10% on each side in the absence of any attitude error.

The ERTS orbit has a semi-major axis of 7,300 km and an approximate period of 103 minutes. The geographical longitude of subsequent passages of the ERTS under the Equator shifts by 25.8167 degrees towards West. Coverage of adjacent bands occur each 14 revolutions and are separated in longitude of 1.4338 degrees, i.e, 160 km at the Equator. At the end of 18 days or conclusion of 251 revolutions the period of coverage is completed.

Table 2.2 shows some nominal orbital parameters.

Table 2.2 - Nominal Orbital Parameters

Orbital Parameters	Nominal Orbit
Altitude	492.35 mn (912 km)
Inclination	99.088 degrees
Period	6196.015 sec (103 min)
Eccentricity	0.0001
Local time when the satellite crosses the Equator descending	09:30 h
Duration of the cycle of coverage	18 days (251 revolutions)
Distance between adjacent ground tracks at Equator	86.028 mn (160 km)

CHAPTER 3

ERTS LINKS

The frequency assignments and bandwidths for the ERTS-A and B are as follows:

Link 1: USB - Uplink for command

RF carrier: 2106.4 MHz
Bandwidth: 3.6 MHz
Modulation: PCM/FSK - FM/PM

Link 2: MSS - Downlink (MSS Data)

RF carrier: 2229.5 MHz
RF bandwidth: 20 MHz
Modulation: PCM/FSK
Bit rate: 15 mb/sec

Link 3: RBV - Downlink (RBV Data)

RF carrier: 2265.5 MHz
Video bandwidth: 3.5 MHz
RF bandwidth: 20 MHz
Modulation: Video/FM

Link 4: USB - Downlink (narrowband data)

RF carrier: 2287.5 MHz
Bandwidth: 5 MHz
Modulation: PM

Link 5: VHF - Downlink (telemetry data)

RF carrier: 137.86 MHz
Bandwidth: 90 KHz emergency; 30 KHz normal
Modulation: PCM/PM

Link 6: DCS - Data collection uplink

RF carrier: 401.9 MHz
Bandwidth: 100 KHz
Modulation: PCM/FSK

Link 7: VHF - Uplink for command

RF carrier: 154.2 MHz
Bandwidth: 30 KHz
Modulation: PCM/FSK - AM/AM

For the reception and processing of ERTS imagery only links 2,3, and 4 are relevant. Link 5 provides a back-up for telemetry data also transmitted by link 4. Brazil's station may eventually receive these data also via link 5. Link 6 is used to transmit data from ground platforms to the satellite (DCS system). Links 1 and 7 are required to command and control the satellite and sensor interrogation; the Brazilian station will not need equipments for these links since NASA could program the satellite for Brazilian coverage.

3.1 - Wideband links (RBV and MSS)

The main characteristics of these two links are summarized in table 3.1.

Table 3.1 - Wideband Links

	MSS	RBV
Center frequency	2229.5 MHz	2265.5 MHz
RF bandwidth	20 MHz	20 MHz
Transmitter power	20* watts	20* watts
Modulation	PCM/FSK	Video/FM

* Commutable power of 10 or 20 watts

3.2 - USB downlink

This link is capable of transmitting all narrowband data plus PRN signal.

The general specifications are the following:

Carrier frequency: 2287.5 MHz ± 0.0015%, non coherent mode.

240/221 times USB uplink carrier frequency, coherent mode.

Modulation: Phase modulation

RF bandwidth: 5 MHz

It is necessary to transmit simultaneously the following signals on the USB downlink carrier:

1 - DCS signal

2 - Real time PCM telemetry

3 - Stored PCM telemetry

The stored PCM telemetry signal normally transmitted is the one recorded by the satellite narrowband tape recorder (NBTR). In case these tape recorders fail, the signal to be transmitted is the one recorded on the auxiliary channels of the wideband tape recorders (WBVTR). A description of the main characteristics of each signal follows.

DCS signal

Signal description: frequency modulated sine wave

Bandwidth: 100 KHz centered in the frequency of 1024 KHz

Real time PCM telemetry

Signal description: PCM split-phase

Bit rate: 1 kilobit/sec.

Detection error probability: less than 10^{-6}

Stored PCM telemetry signal

Sinal description: PCM split-phase

Bit rate: 24 kilobit/sec when the signal is recorded in the NBTR, or
1 kilobit/sec. when the signal is recorded in the WBVTR.

Detection error probability: less than 10^{-6}

In order to transmit the three signals simultaneously on the USB downlink carrier it is necessary to use several subcarriers. The subcarriers used are the following:

Subcarrier	Subcarrier modulation type
1024 KHz	PCM/FSK/PM
768 KHz	PCM/PSK/PM
597 KHz	PCM/PSK/FM

3.3 - VHF downlink

This link is used to transmit either the real time PCM telemetry signal or the stored PCM telemetry signal. This link provides a back-up for the USB downlink.

The general characteristics of this link are the following:

- Center frequency of transmission: 137.86 MHz
- Channel bandwidth: 30 KHz, in real time
  90 KHz, stored

The description of each signal follows:

Real time PCM telemetry signal

Signal description: PCM split-phase

Bit rate: 1 kilobit/sec.

Detection error probability: less than 10^{-6}

Stored PCM telemetry signal

Signal description: PCM split-phase

Bit rate: 24 kilobit/sec. or 1 kilobit/sec.

3.4 - USB uplink

In this link the following signals are transmitted:

- Pseudo randon-noise (PRN) ranging signals
- Command signal

The general characteristics are the following:

- Carrier frequency 2106.4 MHz
- Carrier modulation: phase
- Information bandwidth: 1.5 MHz
- Command subcarrier frequency: 70 KHz

3.5 - VHF uplink

In this link the same signals of command of the USB uplink are transmitted. The general characteristics are the following:

- Carrier frequency: 154. 2 MHz
- Modulation: PCM/FSK - AM/AM
- Carrier modulation index: 80% AM (peak)
- Command subcarriers: 8.0 KHz to 8.6 KHz
- Command bit rate: 128 bps

- Probability of error in command detection: less than 10^{-6}
- Bandwidth: 30 KHz

CHAPTER 4

LINK CALCULATIONS

4.1 - RBV Link (Return Beam Vidicon)

The three "Return Beam Vidicon" cameras will operate simultaneously and will generate a video signal covering the frequencies from DC to 3.5 MHz. The output signal of the cameras may enter the input terminals of the wide band transmitter for transmission in real time or enter one of the wide band tape recorders (WBVTR 1 or 2) for recording and later play-back for transmission. At the ground receiving station, a wide band discriminator processes the signal received above the threshold together with the noise, recovering the video signal with an increase in the signal/noise (S/N) ratio after the detection.

For the RBV link the frequency of 2265,5 MHz was specified. The RF bandwidth of 20 MHz is also considered as the noise bandwidth. Using a power of 20 or 10 watt transmitter in the satellite for an angle of elevation of the antenna of the receiving station of 5^0, we conclude that:

- The gain of the satellite antenna for an elevation angle of 5^0 for the ground antenna is better than 4.0 db. This value includes the polarization losses;
- The transmission losses were calculated at 1.35 db. These losses include the losses between the ouput terminals of the power amplifier and the input of the antenna terminals, including losses in the filters, connectors, cables, circulators, etc. The atmospheric losses are considered for 5^0 of elevation and estimated at 0.7 db.
- The losses of the free space are calculated from the formula:

$$L_{FS} = 20 \log \frac{\lambda}{4\pi d}$$

where,

$$d = (R_e + h) \frac{\text{sen } \delta}{\text{sen}(90^0+\alpha)} \text{, and}$$

$$\delta = \cos^{-1} \left(\frac{R_e}{R_e + h} \right) - \alpha$$

Using the altitude $h = 492$ nautical miles (910 Km), elevation angle $\alpha = 5^0$ and radius of the Earth $R_e = 6380$ Km, we find

$$\delta = 24.3 \text{ degrees}$$

$$d = 1620\text{nm} \quad (3000\text{km})$$

$$L_{FS} = 169.1 \text{ db}$$

- The thermal noise power in a 20 MHz equivalent band is calculated from $N = KTB$, where

$$K = 1.38.10^{-23} \text{ Joule}/^0\text{K}$$

$N = 10 \log_{10} 1,38.10^{-23}$ dbw by ^{0}K by Hz, what leads to,

$N = -228.6$ dbw by ^{0}K by Hz.

4.1.1 - Selection of FM parameters

The signal to noise ratio $(S/N)_o$ in the discriminator output terminals is given by

$$(1) \quad (S/N)_o = \frac{3}{2} \left(\frac{\Delta f}{f_m}\right)^2 \frac{B_{RF}}{f_m} \; (C/N)$$

Where:

Δf is the peak deviation from center frequency of the RF signal

f_m is the modulating frequency

B_{RF} is the RF bandwidth, and

C/N is the carrier - to - noise ratio at

the input terminals of the discriminator

Using

$f_m = 3.5$ MHz

$B_{RF} = 20$ MHz

The modulation index (β) was calculated through the analysing of Bessel's functions so that the energy out of the lateral bands be no greater than 1 % of the total energy.

With $\beta = 1.6$ the energy outside the band of 20 MHz is approximately 1,1 %.

The Modulation Improvement Factor (MIF) is computed from

$$MIF = \frac{3}{2} \left(\frac{f}{f_m}\right)^2 \frac{B_{RF}}{f_m}$$

With the index $\beta = 1,6$ results a value of

MIF = 22 or 13,4 db.

The equation (1) is valid for a sine modulating signal; when the video signal is applied, the following consideration must be taken into account:

- The information signal is 80 % of the video signal peak to peak. The signal to noise ratio S/N at the detector output will then be $(0.8)^2$ times the signal to noise ratio of peak, corresponding to a reduction of 2 db.

- The video signal which produces the same peak to peak FM deviation of a sine signal has a power 8 times bigger than the average power of sine signal. The signal to noise ratio will have then an increase of 9 db.

We should consider an increase in the carrier to noise ratio of 13.4 due to MIF, a reduction of 2db due to the first consideration above and an increase of 9 db due to the second consideration. That is an increase of 20.4 db.

Two types of stations with the corresponding specifications, gain of antennas, antenna noise temperature and receivers with a margin of 6 db are considered. The two types of stations are presented next.

<u>Receiver station with parabolic antenna of 9 meters diameter</u>

For the RBV link a power of transmission of 20 or 10 watts can be used.

- Spacecraft transmitter power.

  P_T = 43 dbm for 20 watts

  P_T = 40 dbm for 1o watts

- Spacecraft antenna gain: 4.0 dB includes the polarization losses.
- Transmission losses:-1,35 dB.
- Space losses:-169,8 dB.

  Free space loss: -169,1 dB.

  Atmospheric loss: - 0,7 dB

  -169,8 dB

- Receiver antenna gain: The gain is computed from the formula:

$$G = \eta \frac{(\pi D)^2}{\lambda}$$

for η = 55 % and D = 30 feet G = 44 dB

- System temperature: T_s = 125°K
- Noise power in the band of 20 MHz: -104,6 dBm

N = KTB

K = 1,38 10^{-23} Joule/°K

T = 125°K

B = 20 MHz

N = 104,6 dbm.

- System margin: - 6 dB
- Received power: - 86,15 dbm

4 + 43 + 44 = 91 db

169,8 + 6 + 1,35 = -177,15

- 177,15 + 91 = -86,15 dbm

- Carrier to noise ratio: + 18,45 db

  - 86,15 - (-104,6) = + 18,45
- FM improvement: 13,4 db

  for β = 1,6
- Detected signal to noise ratio S/N

  S/N = 18,45 + 13,4 - 2+9 = 38,85 db

Receiver station with parabolic antenna of 6 meters diameter

- Spacecraft transmitter power

  43 dbm for 20 watts

  40 dbm for 10 watts
- Spacecraft antenna gain: 4.0 db
- Receiver antenna gain:

  for η = 55 %

  D = 20 feet we get G = 40.5 db
- System temperature: T_s = 125°K or 75°K
- Noise power (20 MHz):

$N = KTB \quad T_s = 125^{\circ}K \longrightarrow N = -104,6$ dbm

$T_s = 75^{\circ}K \longrightarrow N = -106,85$ dbm

- System margin: - 6 db
- Carrier to noise ratio

  For $T_s = 125^{\circ}K \longrightarrow 15,45$ db

  For $T_s = 75^{\circ}K \longrightarrow 17,70$ db

- Signal to noise ratio

  For $T_s = 125^{\circ}K \quad \frac{S}{N} = 35,85$ db

  For $T_s = 75^{\circ}K \quad \frac{S}{N} = 38,1$ db

The results for an elevation angle of 5° and for a transmitter power of 20 watts are shown in table 4.1

Table 4.1 - RBV Link Calculation

Parameters	5 Degree Elevation		
	30 Ft. Dish	20 Ft. Dish	
Spacecraft transm. pow.	43 dbm	43dbm	43 dbm
Spacecraft antenna gain	4.0 db	4.0 db	4.0 db
Transmission Loss	- 1.35 db	- 1.35 db	- 1.35 db
Space loss	- 169.8 db	- 169.8 db	- 169.8 db
Receiver antenna gain	44,0 db	40,5 db	40,5 db
System temperature	125^{0}K	125^{0}K	75^{0}K
Noise power	-104.6 dbm	- 104.6 dbm	- 106.85 dbm
System margin	- 6 db	- 6 db	- 6 db
Received power	- 86.15 dbm	- 89.15 dbm	- 89.15 dbm
Carrier-to-noise ratio	+ 18.45 db	+ 15.45 db	+ 17.70 db
FM improvement (β = 1.6)	+ 13.4 db	+ 13.4 db	+ 13.4 db
Detected signal-to-noise ratio (peak to peak)	+ 38.85 db	35.85 db	38.1 db

4.1.2 - Signal Degradation

The sensor output signal to noise ratios are given as 33,33 and 25 dB for I, II and III cameras respectively.

We consider the complete link and examine the degradation suffered by the signal transmitted in real time.

The signal to noise ratio at the output terminals of the receiver of the ground station is given by,

$$(S/N)_0 = \left[\frac{1}{(S/N)_S} + \frac{1}{(S/N)_{TL}} \right]^{-1} \qquad \text{where}$$

$(S/N)_S$ - signal to noise ratio of the cameras

$(S/N)_T$: - signal to noise ratio of the transmission link

Considering camera I,

$(S/N)_S = 33$ db $\qquad (S/N)_{TL} = 38,85$

$33 \text{ db} \longrightarrow 2,10^3$

$38,85 \text{ db} \quad 7,7.10^3$

$$(S/N)_0 = \left[\frac{1}{2.10^3} + \frac{1}{7,7.10^3} \right]^{-1} \longrightarrow 32,1 \text{ dB}$$

i.e, a degradation of $\simeq$ 0,9 dB

Figure 4.1 shows that if the degradation is to be maintained equal to or smaller than 1 dB, the $(S/N)_{TL}$ has to be in excess of 38.7 dB. We can then calculate the degradation for three considered ~~considered~~ conditions of operation:

Operation	power	$(\frac{S}{N})_{TL}$	degradation
Antenna 30 Ft $T_s = 125^oK$	20W	+38.85 db	-0.9 db
Antenna 20 Ft $T_s = 125^oK$	20W	+35.85 db	-1.8 db
Antenna 20 Ft $T_s = 75^oK$	20W	+38.1 db	-1.0 db

These results show a more convenient operation with an antenna of 30 Ft. Observe that the system temperature ($T_s = 125^oK$) considered for illustration of the calculations is attained in systems utilizing a cooled parametric amplifier; in systems utilizing uncooled parametric amplifier the system temperature will be bigger than 200^oK.

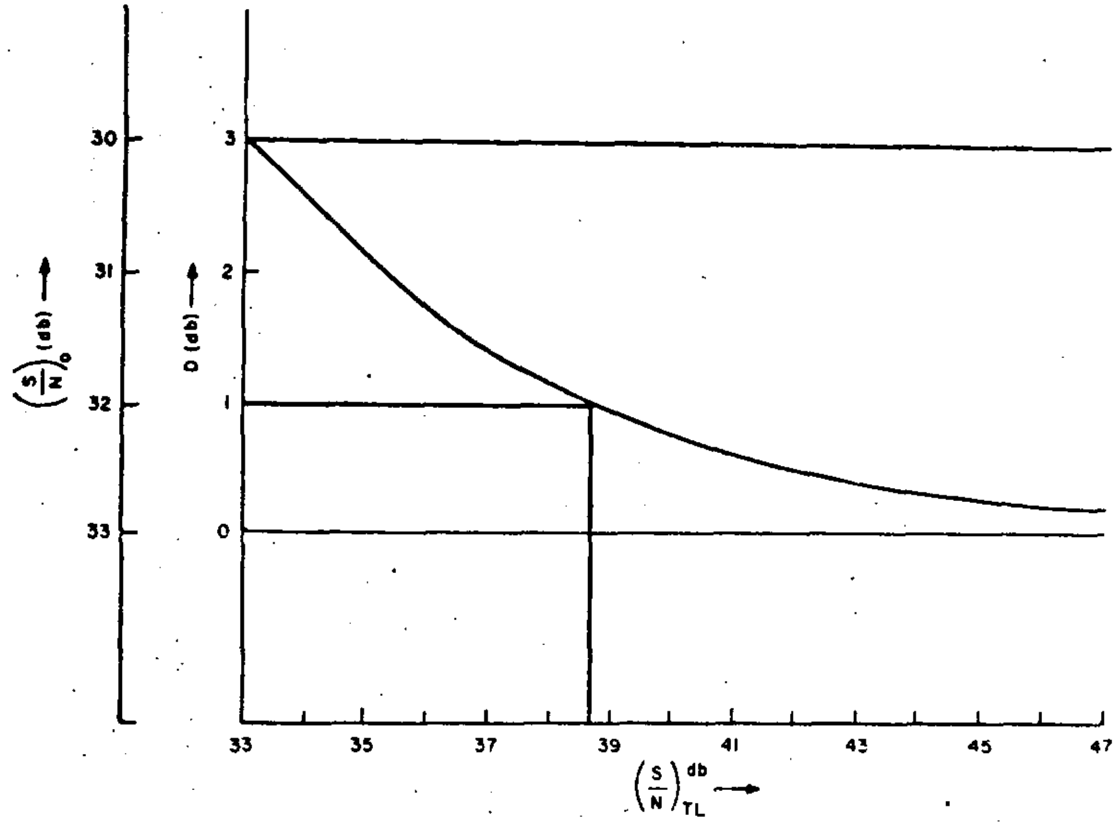


Fig. 4.1 - Signal Degradation (RBV).$(\frac{\bar{S}}{N})_S$ = 33 db

4.2 - MSS Link

The wideband MSS link occupies a band of 20 MHz with PCM/FSK modulation and center frequency of 2229,5 MHz.

Theoretical and experimental investigation show that the carrier energy to noise density ratio influences the probability of error at the detection; for a probability of error, $P_e = 10^{-5}$, a relation of 14.0 db with detection discriminator is obtained. With an optimum coherent receiver C/N = 13,0 db for $P_e = 10^{-5}$ is obtained. Experimental results indicate 13,5 db. Table 4.2 shows the link calculations:

Table 4.2 - MSS Link Calculations

5 Degree Elevation			
Parameters	30 Ft	20 Ft	20 Ft
Spacecraft transm. power	43 dbm	43 dbm	43 dbm
Spacecraft antena gain	4.0 db	4.0 db	4.0 db
Transmission loss	-1.35 db	-1.35 db	-1.35 db
Space loss	-169.66 db	-169.66 db	-169.66 db
Receiver antenna gain	44.0 db	40.5 db	40.5 db
Temp. System	125° K	125°K	75°K
Noise power	-105.8 dbm	-105.8 dbm	-108.05 dbm
System margin	-6 db	-6 db	-6 db
Received power	-86.01 dbm	-89.01 dbm	-89.01 dbm
Carrier-to-noise ratio	+19.79 db	+16.78 dbm	+19.04 db

Taking the more pessimistic value of C/N = 14.0 db for a probability of error $P_e = 10^{-5}$, we will have extra margin of 5.79 db, 2.78 db or 5.04 db. Each of these numbers must be reduced 1.5 db to take into account the degradation due to the distortion of delay time. Table 4.3 is then obtained.

Table 4.3 - Extra margin for the MSS link

Operation	Power	Margin
Antenna 30 Ft $T_s = 125^0K$	20W (10W)	4.29 db (1.29 db)
Antenna 20 Ft $T_s = 125^0K$	20W (10W)	1.28 db (-1.72 db)
Antenna 20 Ft $T_s = 75^0K$	20W (10W)	3.54 db (0.54 db)

The MSS link parameters are essentially the same calculated for the RBV link with the following exceptions:

- The central frequency for the MSS link is 2229.5 MHz, which results in a reduction of 0.14 in the loss of free space.
- The predetection of the MSS link is limited to the bit rate (15 MHz between the 3 db points).

The same observation made for the RBV link with relation to the system temperature ($T_s = 125^0K$) utilized to illustrate the calculations is valid.

4.3 - UBS downlink

The USB down signal S (t) has the following form:

$$S(t) = \sqrt{2C} \cos \left[w_c t + \sum_{i=1}^{n} \theta_i \cos(w_{si} t + \phi_i (t)) + \theta_{n+1} U(t) + n(t) \right] \qquad (2)$$

where:

c = received total power

w_c = carrier frequency

θ_i = peak phase deviation of carrier due to ith subcarrier

θ_{n+1} = peak phase deviation of carrier due to ranging signal

w_{Si} = i-th subcarrier frequency

$\phi_i(t)$ = information which is angle - modulation on i-th subcarrier

$U(t)$ = two level ($\pm$ 1) square wave ranging signal

$n(t)$ = Gaussian band limited noise (density N_0)

Figure 4.2 shows a typical demodulation system of the USB signal, without the PRN signal.

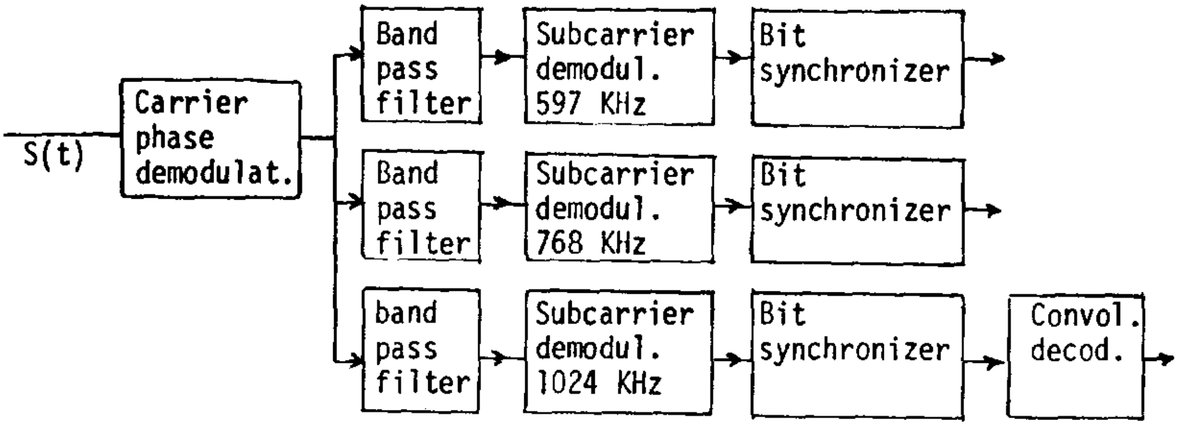


Fig. 4.2 - USB signal demodulation.

Table 4.4 shows the IF bandwidth for each subcarrier.

Table 4.4 - IF bandwidth for each subcarrier

SUBCARRIER	IF BANDWIDTH
1024 KHz	6 KHz, 150 KHz, 600 KHz
768 KHz	20 KHz, 35 KHz
597 KHz	sufficient for at least 24 Kbs.

4.3.1 - Required S/N_0 for each subcarrier channel

597 KHz Channel

The stored PCM telemetry signal modulates a subcarrier of 597 KHz.

A perfect detector for PCM/FSK needs an energy by bit to noise power density ratio (E/N_0) at the detector input according to Fig. 4.3 in function of the probability of error, P_e.

For a probability of error smaller than 10^{-6}, E/N_0,should be bigger than 10.5 db for a perfect detector. Adding 2.5 db for a real detector, E/N_0 must be bigger than 13.0 db to get a probability of error smaller than 10^{-6}.

$$\frac{E}{N_0} = \frac{ST}{N_0}$$

S - average power at the subcarrier

T - period by bit = $\frac{1}{\text{bit rate}}$

$\frac{1}{T}$ = 24 Kbit/sec.

$$\frac{S}{N_0} = \frac{1}{T}\left(\frac{E}{N_0}\right) = 13.0 \text{ db} + 10 \log_{10} 2.4.10^4$$

$$= 13.0 + 43.8 = 56{,}8 \text{ db Hz}$$

$$\left(\frac{S}{N_0}\right)_1 = 56.8 \text{ db hz}$$

where $(S/N_0)_1$ is the signal to noise ratio required for the 597 KHz subcarrier.

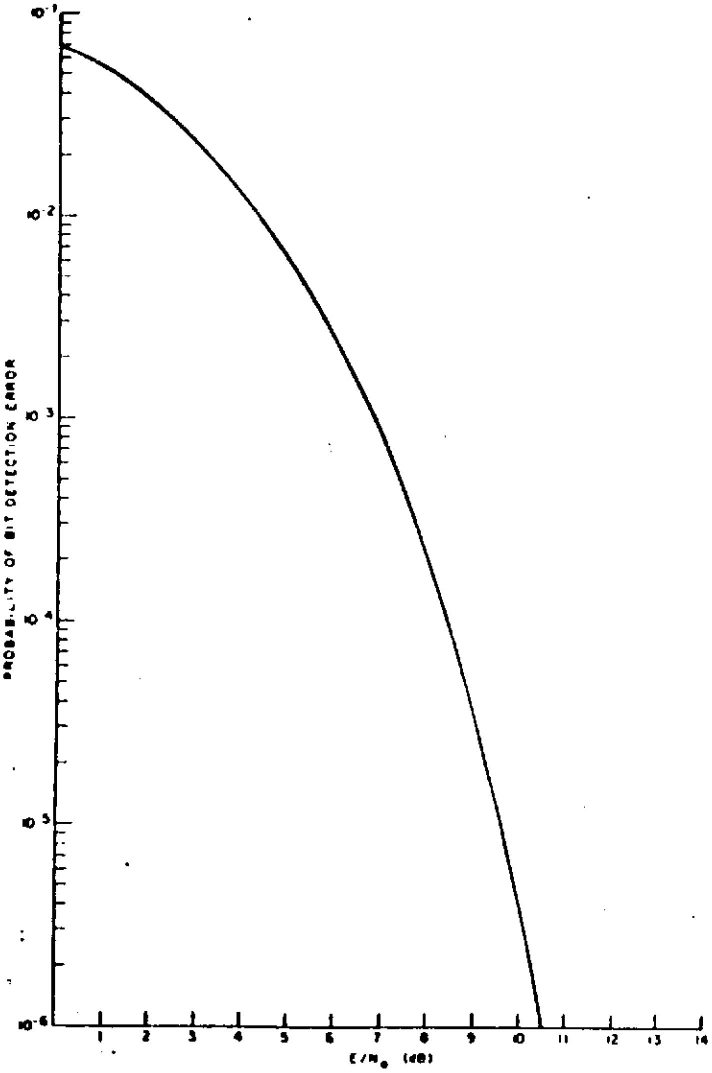


Fig. 4.3 - Relation between P_e and E/N_0 for an ideal coherent PCM/PSK

1024 KHz Channel

The 1024 KHz channel is used to receive the DCS signals. This signal consists of a sinusoid of center frequency 1024 KHz, which is frequency modulated by the information and noise. More noise is added to the information signal in the downlink. The total signal to noise ratio $(S/N)_{total}$ at the input of the processer at the receiving station should be zero db in a bandwidth of 100 KHz centered in 1024 KHz.

The calculation of the signal to noise ratio for this channel provides $(S/N_0)_2$ = 66.0 db Hz.

768 KHz Channel

This channel is used to transmit the real time PCM telemetry signal. This signal modulates a subcarrier of 768 KHz.

Fig. 4.4 shows the block diagram of the detector for the signal of the channel of 768 KHz.

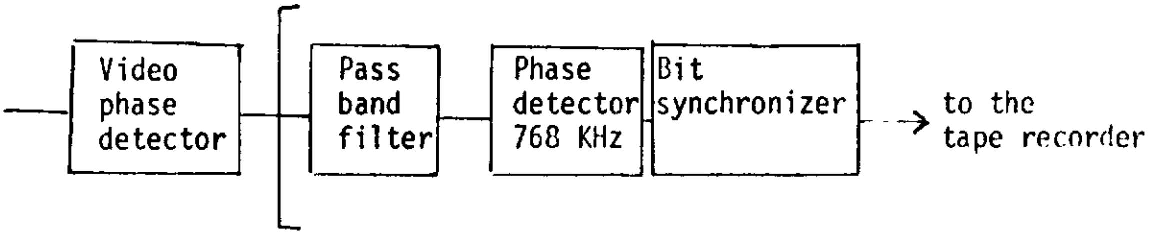


Fig. 4.4 - Detection of the channel of 768 KHz.

The value of S/N_0 calculated for the channel of 768 is $(S/N_0)_3$ = 44.0 db-Hz for $P_e = 10^{-6}$.

Table 4.5 shows the calculation of USB link for antennas of 9 and 6 m.

Table 4.4 USB Dowlink Calculation

Parameter		9 m	6 m
Transmitter power	dbm	30.0	30.0
Transmitting circuit less	db	-2.0	-2.0
Transmitting Antenna Gain (includes polarization loss)	db	-1.0	-1.0
Free space loss	db	-169.3	-169.3
Transmitter frequency	MHz	2287.5	2287.5
Receiving antenna gain (includes circuit less)	db	43.4	39.9
System margin	db	-6.0	-6.0
Received total power	dbm	-104.9	-108.4
Receiver noise Power density	dbm/Hz	-174.5	-178.0
System Temperature	^{o}K	250	110
Received $\frac{c}{N_o}$	db/Hz	69.6	69.6
Required $\frac{c}{N_o}$	db/Hz	48.5	48.5
Extra margin	db	21.1	21.1

4.4 - USB Uplink

This link is necessary to transmit the Pseudo Random Noise PRN ranging signal and command data subcarrier (70 KHz).

Table 4.6 shows the link calculation for an antenna of 9m and 6 m.

Table 4.6 - USB Uplink Calculation

Parameters	9 m	6 m	
Transmitted power	70.0	70.0	dbm
Transmitting circuit loss	0.0	0.0	db
Transmitting antenna gain	43.0	39.5	db
Space loss	-169.9	-169.9	db
Atmospheric attenuation	-0.7	-0.7	db
Carrier frequency	2106,4	2106.4	MHz
Receiving antenna gain (includes polarization loss)	+4.0	+4.0	db
Receiving circuit loss	-1.5	5.0	db
Pointing loss of the receiving antenna	-5.0	5.0	db
System margin	-6.0	6.0	db
Received total power	-66.1	-66.1	dbm
Modulation loss	0.0	0.0	db
Available carrier power	-66.1	-66.1	dbm
Necessary carrier power	-109.0	109.0	dbm
Extra margin	42.9	42.9	db

RECEIVING AND TRACKING STATION MODEL

INPF intends to install a station to track the satellite, receiving and recording the information transmitted by it.

Fig. 5.1 shows a block diagram for a possible tracking and receiving station including the recording system.

The uplink is not necessary for Brazil because the satellite commands are recorded in redundant memories of high reliabity, in case the memories fail the satellite would become non-operational.

Figure 5.1 shows the equipment used to receive the data transmitted in MSS, RBV and USB links and the recording system used to record these data.

The receiving equipment to receive the data transmitted by the Data Collection System (DCS) does not appear in the figure because in an initial phase the station would not receive this signal. It intends to study the possibility to receive these data in the future.

5.1 - Equipment Specifications

5.1.1 - Antenna

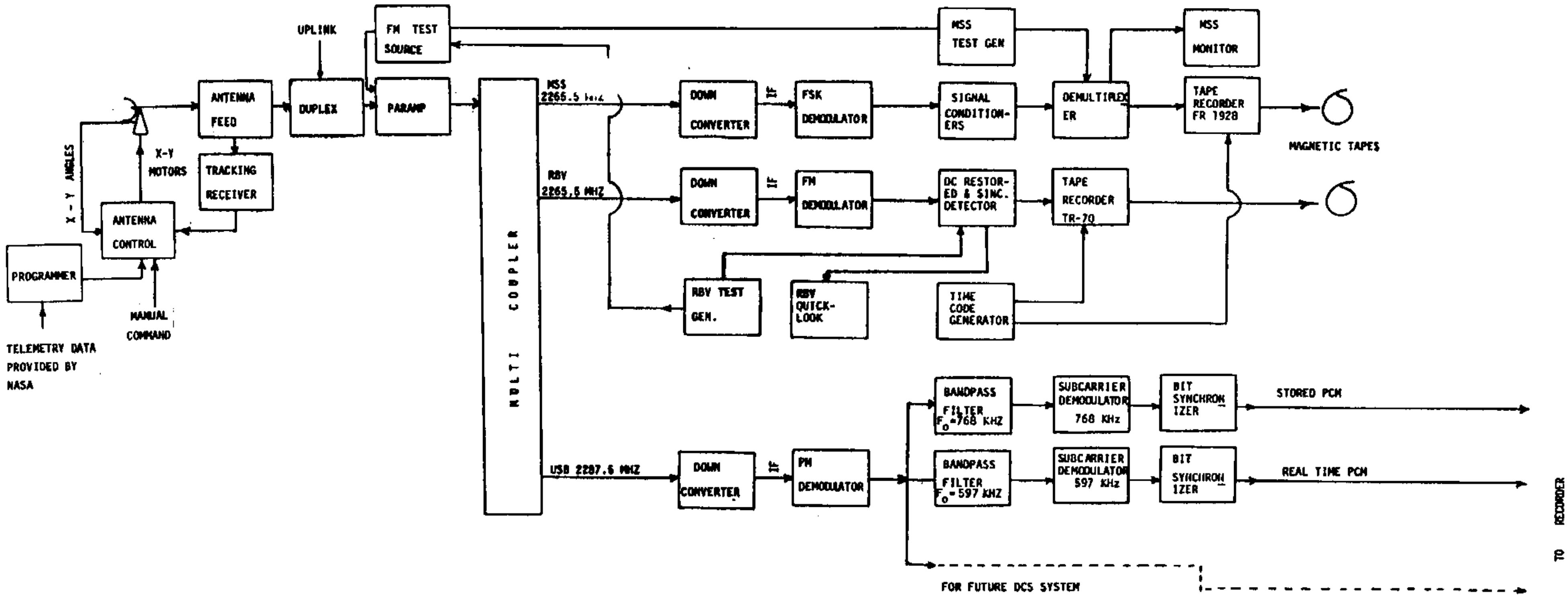
The system will use a 9 m diameter parabolic antenna with a noise temperature of nearly 65^{0}K.

If the system noise temperature is 125^{0}K (utilized in the illustration of the calculations) the safety margin will be 6 db. If the system temperature is greater than 125^{0}K the safety margin will be smaller than 6 db. See table 4.1 and paragraph 4.1.2 for the RBV link which is more critical.

The antenna and the pedestal must operate in normal conditions with wind of up to 60 km/h.

The antenna must be solid with surface roughness sufficient

FIG. 5.1 - ERTS TRACKING AND RECEIVING STATION BLOCK DIAGRAM



to operate on the band 8025-8400 MHz. This consideration is important because the service of exploration of the Earth Resources by means of satellites, in the future, will utilize this band in accordance with the resolution of the ITU at the meeting WARC-ST/71 held in Geneva in June 1971.

5.1.2 - Antenna Feed

It must have capacity to provide all the necessary signals for the tracking.

These signals will generate the signals differences, ΔE and Δa, for the tracking receiver and the sun signal, $\sum$, for the parametric amplifier.

5.1.3 - Tracking System

The station will probably have two tracking systems; one using the autotrack system and the other using the programmed tracking with the aid of a computer. It could have as an option, the manual tracking for initial positioning of the antenna.

The autotrack system uses an antenna feed with capacity to generate the azimuth and elevation error signals.

The antenna must be initially positioned either by the operator or by using the programmed tracking.

5.1.4 - Parametric Amplifier

The parametric amplifier must have a bandwidth greater than 72 MHz. In the future satellites for exploration of the Earth Resources, when the frequencies are allocated to the band from 8025 to 8400 MHz, in accordance with the WARC-ST/71, of the ITU, this amplifier will probably have a broad bandwidth.

Calculations made show that an uncooled parametric amplifier with noise temperature of 100^{0}K would be sufficient with an 9 m diameter antenna, with a lower margin to 6 db for the RBV link, which is the most critical.

5.1.5 - MSS Equipment

5.1.5.1 - Down Converter

The noise temperature of the down converter must be such that the noise system temperature was equal to 125^{0}K(9 m antenna with a lower margin to 6 db for the RBV link).

5.1.5.2 - FSK demodulator

This device must demodulate the PCM/FSK signal of the MSS link.

5.1.5.3 - Signal Conditioner

This unit synchronizes the 15 Megabits for second (Mbs), providing also time information for a later demultiplexation and/or recording.

5.1.5.4 - Demultiplexer/test Generator/Monitor

This unit will be utilized to demultiplex the MSS signal reproduced by a series type tape recorder (for example the TR 70 - CVR-3F modified) or to demultiplex the signal to be recorded in a parallel type tape recorder (for example the AMPEX FR-1928). A monitor will be used to visualize in analog form the MSS data. The test generator provides the test MSS signal which modulates a FM source to verify the correct operation of the whole system.

5.1.5.5 - MSS Tape Recorder

The recording system must be completely compatible with that used by NASA in the United States.

This tape recorder may be a FR-1900 modified (parallel type tape recorder) to record 28 tracks (model FR-1928) or some other series type tape recorder in which the demultiplexer would not be necessary for the recording.

A parallel type tape recorder records, at a speed of 60 inches/s, 25 tracks of digital data, one channel of time information, one of PCM telemetry signal, and one channel of capstan servo and a voice channel. The tape recorder tracks may be used as follows:

Channel 1 - capstan servo reference frequency
Channels - 2, 4, 6, 8, 10, 12 - Group 1
Channels - 14, 16, 18, 20, 22, 24 - Group 2
Channels - 3, 5, 7, 9, 11, 13 - Group 3
Channels - 15, 17, 19, 21, 23, 25 - Group 4
Channel 26 - Group 5 (ERTS-B only)
Channel 27 - time information
Channel 28 - PCM telemetry Signal

The tapes used must be 1 inch width in $10^1/2$ or 14 inches diameter reels.

5.1.6 - RBV Equipment

5.1.6.1 - Down Converter

See paragraph 5.1.5.1

5.1.6.2 - FM Demodulator

This demodulator must demodulate the video/FM signal (RBV data).

5.1.6.3 - Video Processor and Synchronism Separator (VPASS)

This unit must process the RBV video signal to permit the recording and display (quick-look) of images.

5.1.6.4 - RBV Tape Recorder

This tape recorder must be completely compatible with that used by NASA.

The tape recorder to be used will be the RCA TR 70-CVR-3E (or equivalent) which is a modification of the commercial tape recorder TR-70.

This tape recorder may use tapes 3M 500 that come in reel lengths of 1,200-2,400-3,600-4,800 or 5,600 feet; in term of recording time the lengths are equivalent to 738 - 1,476-2,214-2,952 - or 3,444 seconds.

The tapes used must be 2 inches wide in 14 inch diameter reels.

5.1.7 - USB Equipment

5.1.7.1 - Down Converter

See paragraph 5.1.5.1

5.1.7.2 - PM Demodulator

This demodulator must demodulate the information at the USB carrier.

5.1.7.3 - Band Pass Filters

The filter for the stored PCM telemetry signal must have a central frequency f_0 = 597 KHz and sufficient bandwidth for at least 24 kbps. The filter for the real time PCM telemetry signal must have a central frequency f_o = 768 KHz and a 35 KHz bandwidth.

5.1.7.4 - Subcarrier Demodulators

These discriminators must demodulate the two sub-carriers f_s = 768 KHz and f_s = 597 KHz.

5.1.7.5 - Bit Synchronizer

These units (2) provide the synchronization of the 24 kbps and 1 kbps data of the 597 and 768 KHz channels respectively,for later recording.

5.1.7.6 - Recording System for the Signals of the USB Link

These signals are recorded in the auxiliary channels of the tape recorders AMPEX FR-1928 (or equivalents) and RCA TR-70 (or equivalents) or can be recorded separately in any other digital tape recorder (it may be the AMPEX FR-1900 already existent at INPE).

For recording of the DCS signals in a later phase this digital tape recorder (FR-1900) would certainly be necessary.

5.1.8 - Test Generators: TPG (RBV) and RSE (MSS)

The function of these equipments are the following:

- To generate the test signals for simulation of the MSS and RBV signals;
- To generate and simulate the noise spectrum which can be combined with the test signals to simulate the receiving of the satellite signals.

5.1.9 - Quick-look Monitor (QLM) to Visualize the RBV Signals

This device permits a quick visualization of the three RBV cameras. It also accepts the signals provided by the TPG unit; these signals are first sent to the VPASS unit.

The QLM permits the visualization in a cathode ray tube of the RBV data and of the test signal of the TPG for evaluation of characteristics of the system. It is equipped with a Polaroid camera whic photographs continuously the images of the three RBV cameras.

5.1.10 - Timing System

The timing station consists of a group of equipment which include:

- Time code generator
- Frequency synthetizer
- Synchronizer
- Oscilloscope

5.1.11 - FM Signal Source for Test

This is a generator for precision signals in the band of 2200 to 2300 MHz.

The output may be continuous or modulated by the signal provided by the TPG test generator of the RBV or by the MSS test signal generated in the RSE.

The TPG generator provides the video test signal (0 to 3.5 MHz) for control of the receiving and recording equipment of the RBV signal.

The MSS-RSE test generator provides the 15 Mbps signal for control of the receiving and recording equipment of the MSS signal.

These signals of the TPG and MSS-RSE modulate the FM signal of test; this modulated signal is injected at the test input of the parametric amplifier and later on in the receiving and recording circuits to evaluate the conditions of operation of the complete system.

CHAPTER 6

IMAGE PROCESSING STATION

The image processing station has the following main functions:

- To transform the RBV data received in films through the control of IAT tapes (Image Annotation Tape) in which these are annotated. The information for correction is obtained from telemetry data contained in the USB downlink and from "fixed error" tapes. The films obtained correspond in quality to the preliminary processing (bulk process). Manual measurements are made with these films from the position of objects whose coordinates are previously known, so that a group of coefficients for correction is obtained and applied to the original video tape of the RBV, and images of quality corresponding to the precision process are obtained.
- To transform MSS data into films of preliminary quality and later into precise quality.
- To transform the MSS data in digital tapes for direct access to the computer (CCT).

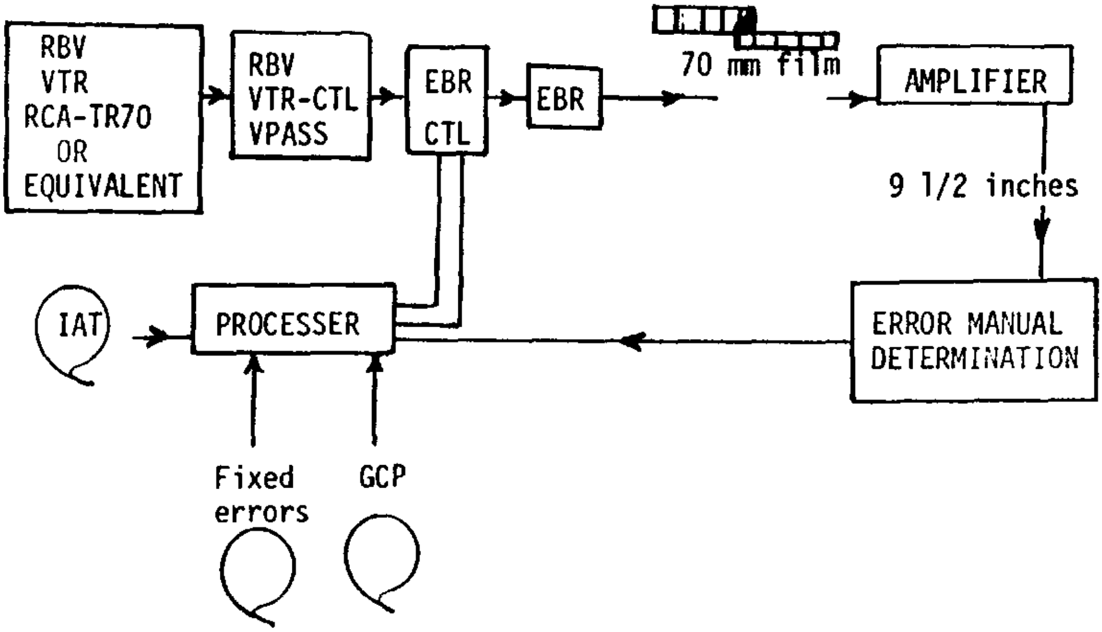
6.1 - Image Annotation Tape (IAT)

To produce these tapes use for error systematic correction, tapes with ephemeris data to be provided by NASA and the data with the satellite characteristics contained in the USB down link are necessary. With these two tapes it is possible to produce the IAT tape.

Geometrical corrections are made through the determination of the satellite angles in relation to reference position and the deviation of the nominal height of the satellite. The satellite angles are determined from PCM telemetry data. The ephemeris data permit calculation of the deviation of the nominal height.

6.2 - Transformation of RBV Data

The RBV data recorded are reproduced and sent to VPASS and next to a Electron Beam Recorder (EBR-CTL) and immediately after to a Electron Beam Recorder (EBR).



Initially corrections are made through the control of the IAT tape and "fixed error" tape; this first step produces images of preliminary quality; after developing the 70 mm film some images are chosen, these images can be enlarged to 9 1/2 inches.

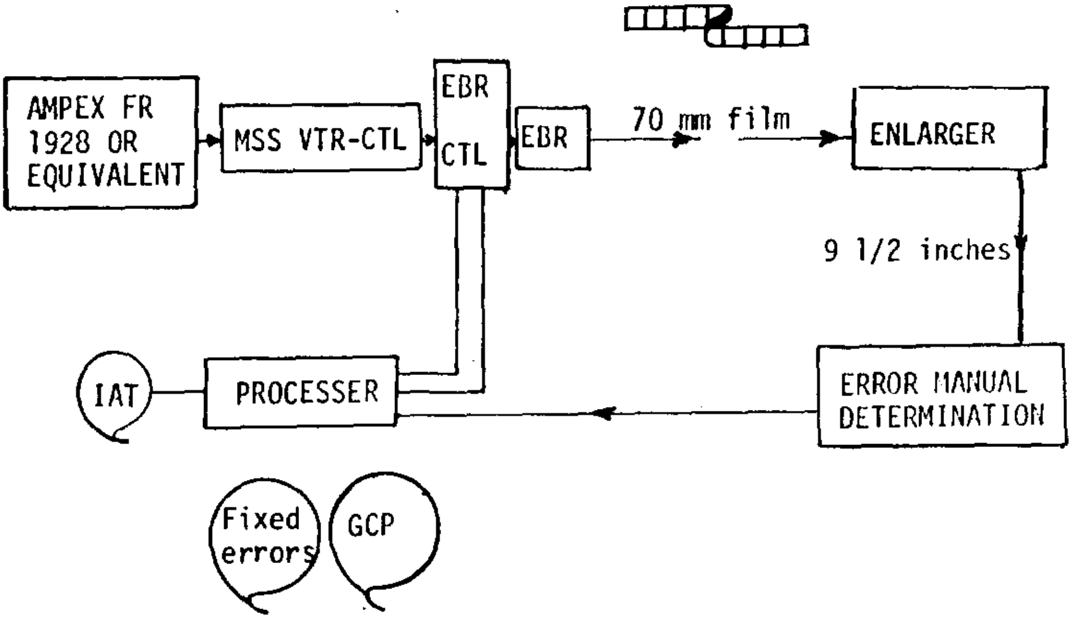
Some images are selected for further corrections; to determine these corrections, manual measurements are made from the exact localization of some points and knowledge of the distortions of the lenses. These measurements are put in the processor to obtain correction coefficients. These coefficients are applied to the Electron Beam Recorder Control.

Using again the original video tapes of the RBV and applying the correction coefficients during the second step, the images are produced again after the enlarging with precision quality.

6.3 - MSS Data Transformation

The MSS recorded data are converted into films through the control of the IAT tape and fixed error tape. This first passage produces images of preliminary quality.

With manual measurements the correction coefficients are obtained to produce the precision images through a second passage of the original MSS tape.



The MSS data are converted into tapes compatible with the computer through two magnetic tape units(HP MTU).

CHAPTER 7

LOCATION AND COVERAGE

7.1 - Location

As it was considered previously, the system presented in this document must be constituted of 2 subsystems, the tracking and receiving station and the Image Processing Station. Considering that they are complementary, the ideal situation would be that in which both were located at the same point or at near point. The proximity criterion is however, flexible in the sense that it is the function of several factors. For example, the access facility to each of the stations and the means of transportation which will interconnect them.

As an example and as basis for calculation of the amount of data to be received, we next present studies which put the location of the tracking and receiving station near the city of São José dos Campos (23°S and 46°W).

7.2 - Coverage

The coverage was calculated taking into consideration the elevation angles of 2^o and 5^o above the horizon.

The geometry utilized for the calculation is presented in Fig. 7.1.

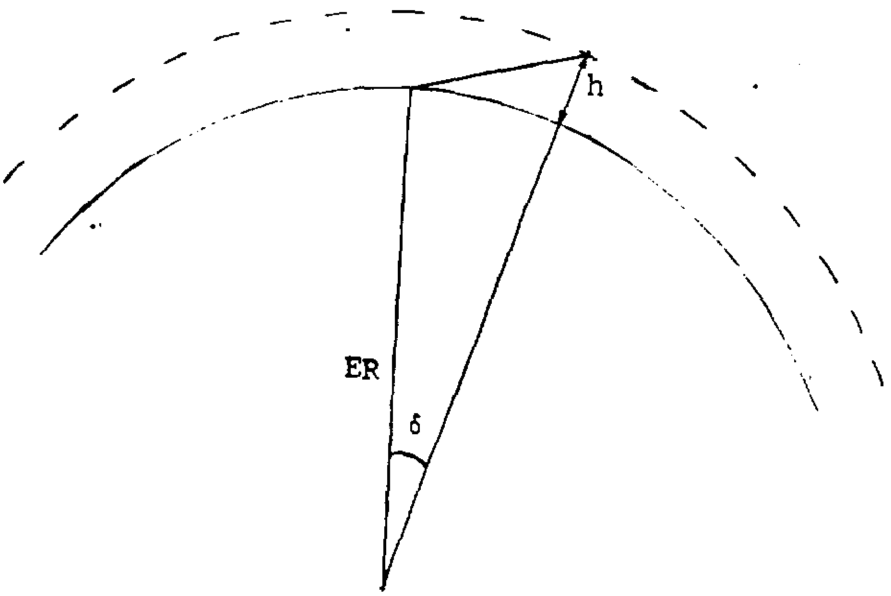


Fig. 7.1 - Geometry for the calculation of the central angle.

The calculation of the central angle (δ) for various elevation angles is included in table 7.1.

From this table the following values are obtained:

Central Angle (δ)	Height (h)	Elevation (a)
24.3°	910 km	5°
27.0°	910 km	2°

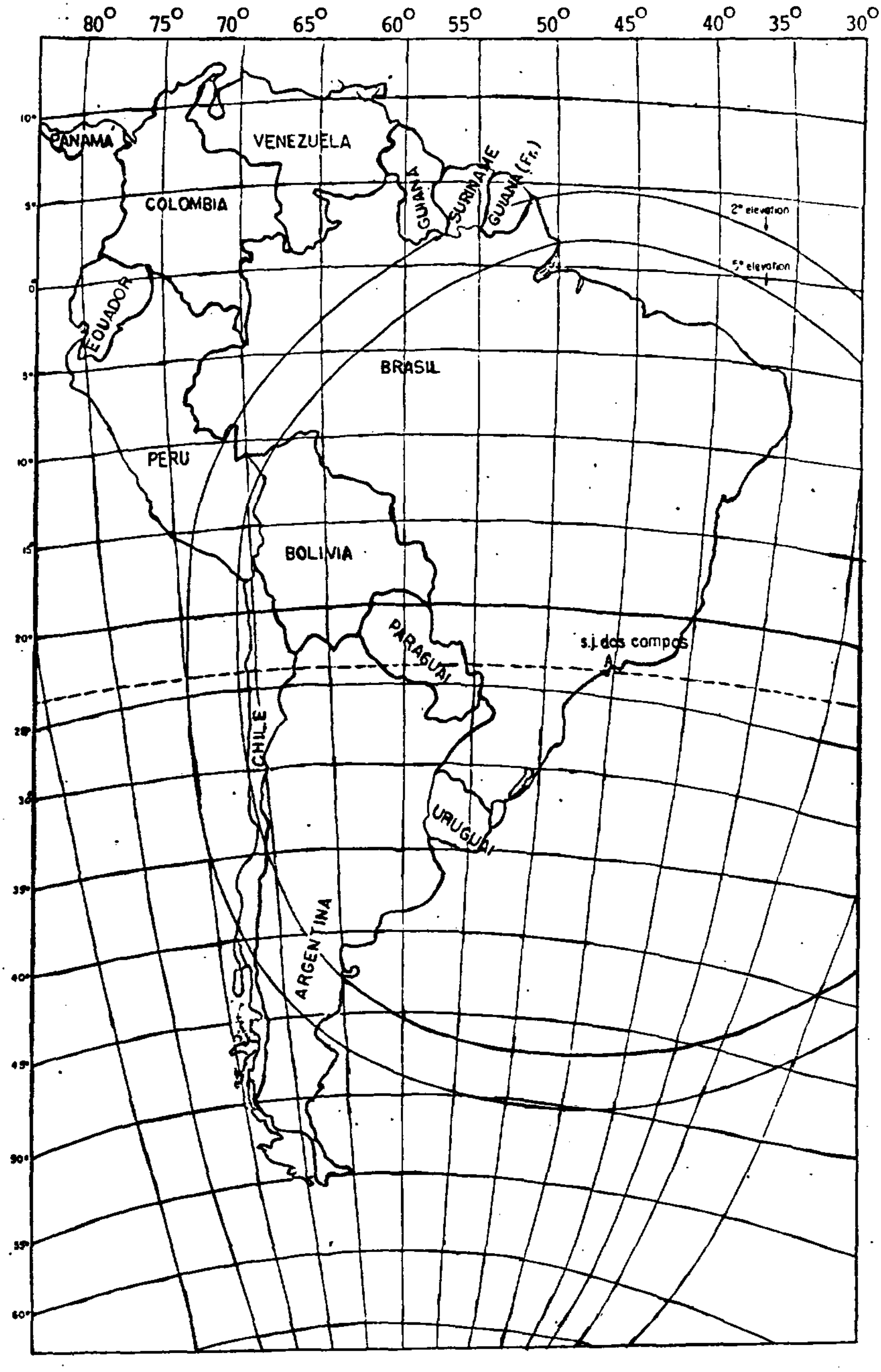
With the values of central angles one may trace the coverage of Fig. 7.2 for elevation 2° and 5°.

Fig. 7.2. shows that almost the whole of Brazil would be covered and the following countries as well:

Total Coverage	Partial Coverage
Bolivia	Argentina
Paraguay	Chile
Uruguay	Peru
	French Guiana

Table 7.1 - Central angle calculation
Angles measured in Degrees
Height: 910 Km

Central Angle	Elevation
1	82.03
2	74.31
3	67.03
4	60.33
5	54.25
6	48.80
7	43.93
8	39.60
9	35.73
10	32.27
11	29.17
12	26.36
13	23.80
14	21.47
15	19.33
16	17.35
17	15.52
18	13.80
19	12.20
20	10.69
21	9.26
22	7.91
23	6.62
24	5.39
25	4.22
26	3.09
27	2.00
28	.95



7.2 - COVERAGE OF THE STATION LOCATED IN SÃO JOSÉ DOS CAMPOS

CHAPTER 8

AMOUNT OF DATA RECEIVED BY THE STATION

The location of the station under study would permit gathering data for Brazil and other South American Countries.

The amounts of data available for recording at this station will be calculated considering that the satellite elevation angle considered in São José dos Campos is greater than 5°. The elevation angle is limited by this value owing to problems of atmospheric scintillations and refraction effects. The elevation angle of 5° is a pessimistic estimate. With a good tracking system and favorable conditions it would be possible to increase the amount of data received.

8.1 - Orbital Parameters

The Orbital Parameters used for the calculation of the amount of data are the following:

Point of insertion	130° W long, 0° lat.
Altitude:	910 Km (492.35 min)
Inclination:	99.088 degrees
Period:	103 min
Eccentricity	0.0001
Coverage cycle duration	18 days (251 rev.)
Distance between adjacent trajectories	160 Km (1.4338 degrees)
Separation in longitude between consecutive trajectories	25.8167 degrees

8.2 - Graphical method to determine the time spent by the satellite to cover the area of observation from the São José dos Campos station.

The graphical method used to determine this time is the following: on the first day the orbits 10 and 11 separated by 25.8167 degrees longitude are forecasted in the coverage area of the station;on the second day the orbits 24 and 25 are forecasted and so on. A certain number of orbits is forecasted for each day as shown in Fig. 8.1. The length of the trajectories was transformed in time used by the satellite, to describe these trajectories.

The calculation was done only for the continental coverage, either for Brazil or for other countries as well, within the coverage range of the station. For the calculation, it was assumed that the trajectories within the coverage area of the station are parallel.

The solar illumination angle depends on the latitude and on the seasons; this is shown in Fig. 8.2. It is convenient to keep in mind that within the area covered by the receiving station from São José dos Campos, the solar angle is always greater than 17 degrees. For our purposes this angle should be considered satisfactory.

For an elevation of 5^{0}, thirty-three (33) orbits cut the coverage area of the station. Twenty-two (22) of these orbits cut the continental part.

The time spent by the satellite in each day and the corresponding 22 passages are shown in Table 8.1.

The longest time spent by the satellite, within the continental coverage, is about 694 seconds.

In the first day (see Table 8.1) the satellite describes the trajectories 10 and 11 but only the orbit 11 cuts the continental part. On the 6th day, for example, the satellite describes the orbits 80 and 81 and similarly for each one of the 18 days of the cycle. Table 8.1 shows the time spent to cover each country.

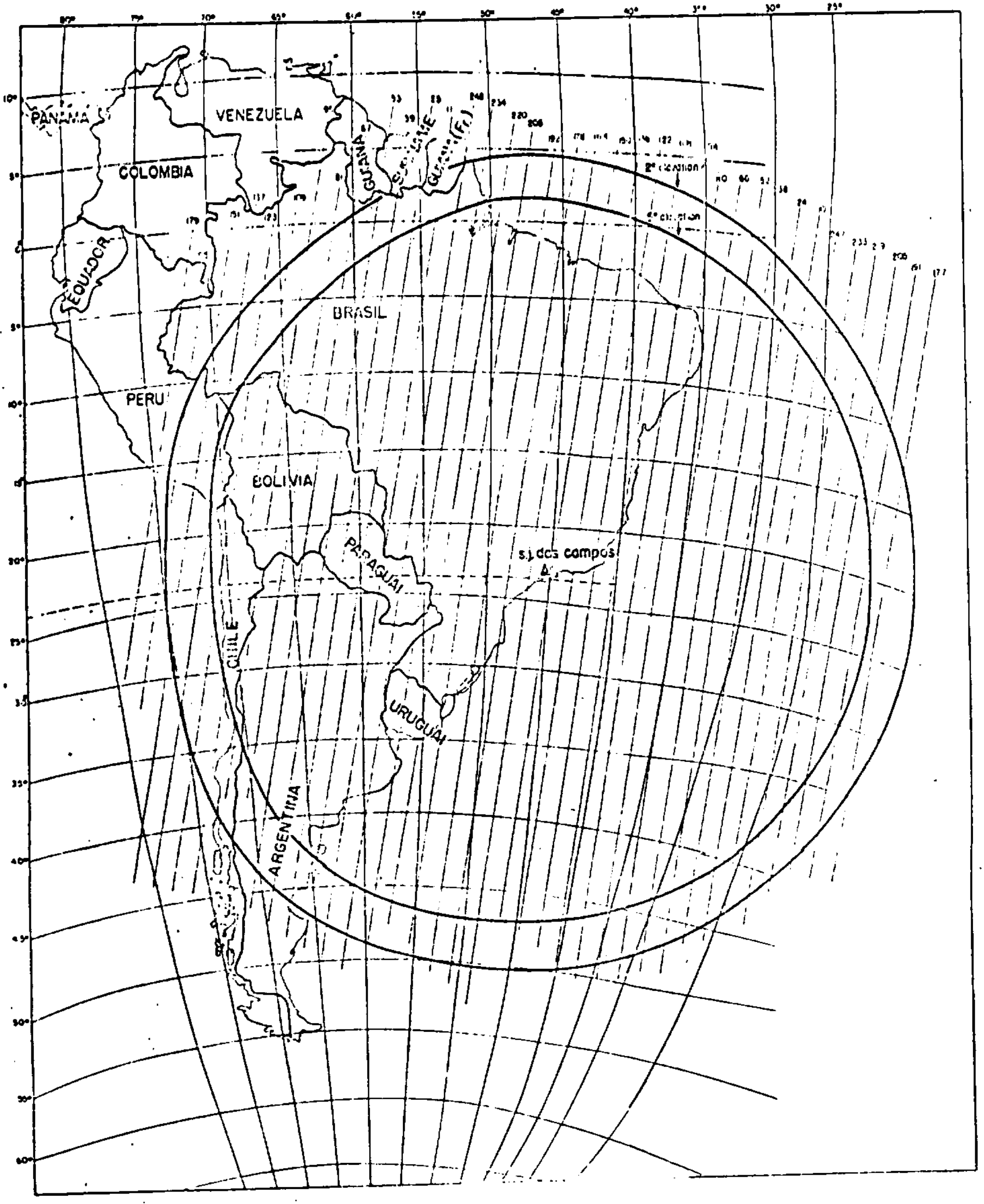


Fig. 8.1 - Coverage of the station located in São José dos Campos

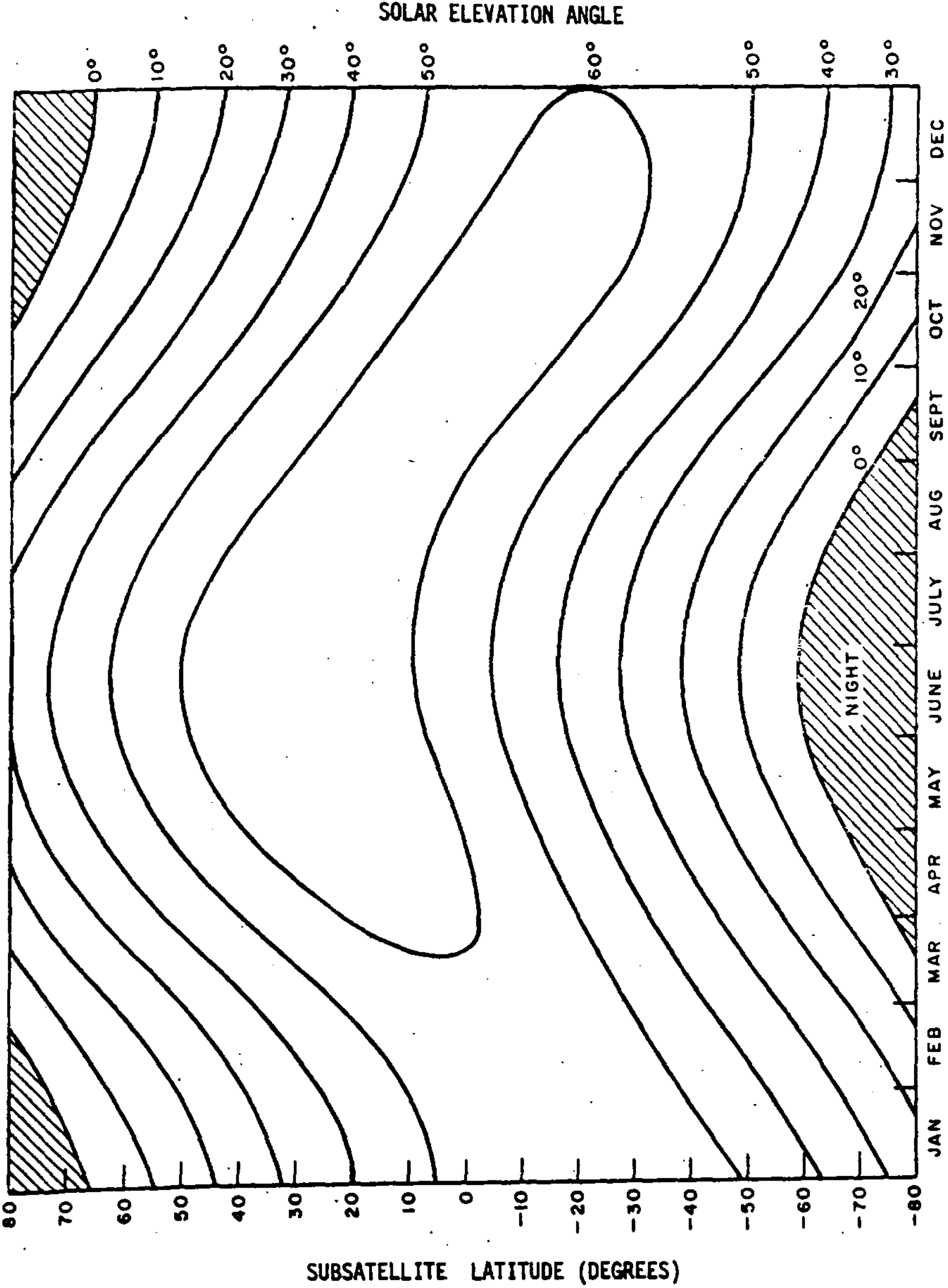


Fig. 8.2

SOLAR ANGLE ELEVATION

Table 8.1 - Time Spent on Continental Coverage

			TIME SPENT (SECONDS)													
DAY	PASSAGE NUMBER		BRAZIL		BOLIVIA		ARGENTINA		CHILE		PARAGUAY		URUGUAY		TOTAL	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1	10	11	-	380	-	-	-	243	-	-	-	49	-	-	-	672
2	24	25	-	281	-	39	-	288	-	-	-	86	-	-	-	694
3	38	39	-	259	-	52	-	310	-	-	-	69	-	-	-	690
4	52	53	-	190	-	120	-	300	-	-	-	43	-	-	-	653
5	66	67	-	172	-	87	-	350	-	-	-	-	-	-	-	609
6	80	81	86	138	-	163	-	243	-	-	-	-	-	-	86	544
7	94	95	121	95	-	181	-	157	-	35	-	-	-	-	121	468
8	108	109	281	35	-	173	-	-	-	190	-	-	-	-	281	398
9	122	123	348	9	-	121	-	-	-	111	-	-	-	-	348	241
10	136	137	348	-	-	-	-	-	-	-	-	-	-	-	348	-
11	150	151	348	-	-	-	-	-	-	-	-	-	-	-	348	-
12	164	165	430	-	-	-	-	-	-	-	-	-	-	-	430	-
13	178	179	465	-	-	-	-	-	-	-	-	-	-	-	465	-
14	192	193	520	-	-	-	-	-	-	-	-	-	-	-	520	-
15	206	207	550	-	-	-	-	-	--	-	-	-	19	-	569	-
16	216	217	516	-	--	-	-	-	-	-	8	-	78	-	602	-
17	234	235	465	-	-	-	35	-	-	-	35	-	85	-	620	-
18	248	249	396	-	-	-	202	-	-	-	56	-	-	-	654	-
			4874	1559											5392	4969

8.3 - Magnetic Tape Requirements

The magnetic tapes for the tape recorder AMPEX FR 1928 are provided in 9,200 feet reels (280 m) or, in terms of recording time, 1.840 seconds.

The magnetic tapes for the tape recorder RCA TR 70-CVR-3E are provided in reels of 1,200, 2,400, 3,600, 4,800 or 5,600 feet lengths or, in terms of recording time, 738, 1,476, 2,214, 2,952, 3,444 seconds at a speed of 19.5 inch p.s.

The calculation of the number of tapes was made considering the recording in only one reel of the largest number of consecutive passages possible.

This method is illustrated in Table 8.2 for the AMPEX FR 1928 or equivalent. The recording time for passage 11 on the first day and 25 on second day are added. The total time of recording for continental coverage of these 2 passages is of 1,366 seconds, with 474 seconds of tape unused.

Table 8.3 shows the number of tapes necessary for the tape recorder RCA TR 70-CVR-3E or equivalent in a period of 18 days.The method used for calculation of tapes for the RCA TR 70-CVR-3E or equivalent is the same used in the calculation of number of tapes for the AMPEX FR 1928 or equivalent, with the later condition that the amount of unused tape be at a minimum. If for example:

(day, passages)	Recording time	Whole reel time	Non used time
(1,11) + (2,25) + (3,39)	2056 sec	2214 sec	158 sec
(1,11) + (2,25) + (3,39) + + (4,53) + (5,67)	3318 sec	3444 sec	126 sec

Using a 3,600 foot reel (2214 sec.) one can record 3 passages; the non used time of the tape corresponds to 158 sec. Using a 5,600 foot reel (3444 sec.) one can record 5 passages; the non used time of the tape corresponds to 126 sec. The method used of minimum time of non used tape chooses the 3444 sec. reel.

Table 8.2 and 8.3 show the total number of non used tapes in seconds/reel.

Table 8.4 shows the number of reels for the two tape recorders for the cycle of 18 days. Table 8.5 shows the cost of magnetic tapes for the period of 18 days.

The total coverage cost (continental sea) will be approximately the double of the cost shown in Table 8.5.

8.4 - Estimate of the quantity of photographs

The data recorded in the recording system of the tracking and receiving station will be processed and transformed in photographs later.

We will give an estimate of the final quantity of photographs that the system will provide.

Based on the data of table 8.1, the number of scenes (185 Km x 185 Km), which the station will receive per cycle (18 days) were calculated for the continental coverage of Brazil and total continental coverage (Brazil and other South American countries). It was considered that 30% of the images would not be utilized due to the excessive coverage of clouds. From the 70% left 10 preliminary copies will be prepared (we consider 10 users) in black and white paper and transparency. From these images it was considered that 20% would be composed of colors.From the preliminary images (bulk), it was considered that 30% will be transformed in precision images and copied for 10 users. It was considered that all precision images will be composed of colors. Tables 8.6, 8.7, and 8.8 illustrate these considerations and calculations.

With the estimate mentioned above the total amount of photographs provided to the users per day is shown in Table 8.9.

Tables 8.10 and 8.11 show the photographic processing costs per day for Brazil and for total continental coverage.

Table 8.12 shows the total annual cost for the indicated coverages.

The Brazilian User will demand annually 75% of preliminary images and 25% of precision ones; the color images, preliminary and precision, represent 9% of the image total.

Table 8.2 - Requirement for Magnetic Tape - Recording Time AMPEX FR 1928

TOTAL LAND COVERAGE			BRAZIL ONLY		
(DAY; PASS Nº)	RECORDING TIME SEC.	UNUSED TAPE SECS/REEL	(DAY, PASS Nº)	RECORDING TIME SEC.	UNUSED TAPE SECS/REEL
(1,11) + (2,25)	1366	474	(1,11) + (2,25)+		
(3,39) + (4,53)	1343	497	+(3,39)+ (4,53)+		
(5,67) + (6,80) + (6,81)+			+(5,67)+(6,80)+	1722	118
+ (7,94) + (7,95)	1828	12	+(6,81)+(7,94)+		
(8,108) + (8,109) + (9,122)+			+(7,95)		
+ (9,123) +(10,136)	1616	224	(8,108)+(8,109)		
(11,150) + (12,164) +			+(9,122)+(9,123)	1799	41
+ (13,178) + (14,192)	1763	77	+(10,136)+		
(15,206) + (16,216) +			+(11,150)+		
+ (17, 234)	1791	49	+(12, 164)		
(18, 248)	654	1186			
			(13,178)+(14,192)+	1535	305
			+(15,206)		
			(16,216)+(17,234)+	1377	463
			+(18,248)		
TOTAL:	10361	2519		6433	927

Table 8.3 - Requirement for Magnetic Tape - Recording Time
RCA TR 70-CVR-3E

TOTAL LAND COVERAGE				BRAZIL ONLY			
(DAY, PASS Nº)	RECORDING TIME SECS.	REEL LENGTH SECS.	UNUSED TAPE SECS/REEL	(DAY, PASS Nº)	RECORDING TIME SECS.	REEL LENGTH SECS.	UNUSED TAPE SECS/REEL
(1,11) + (2,25) +(3,39) + +(4,53) + (5,67)	3318	3444	126	(1,11) + (2,25)	661	738	77
(6,80) + (6,81) + (7,94) + +(7,95) + (8,108) +(8,109)+ +(9,122)+(9,123)+(10,136)	2835	2952	117	(3,39) + (4,53) + (5,67) + + (6,80)	707	738	31
(11,150)+(12,164)+(13,178)+ +(14,192)+(15,206)+(16,216)	2934	2952	18	(6,81) + (7,94) + (7,95) + + (8,108) + (8,109)	670	738	68
(17,234) + (18,248)	1274	1476	202	(9,122) + (9,123) +(10,136)	705	738	33
				(11,150)+(12,164)+(13,178)+ +(14,192)+(15,206)+(16,216)+ +(17,234)	3294	3444	150
				(18,248)	396	738	342
TOTAL	10361		463		6433		701

Table 8.4 - Tape Reel Requirements

	TAPE REEL REQUIREMENTS	
	AMPEX FR 1928	RCA TR-70
TOTAL LAND COVERAGE	7 reels of 9200 feet	1 reel 2400 feet 2 reels 4800 feet 1 reel 5600 feet
BRAZIL ONLY	4 reels of 9200 feet	5 reels of 1200 feet 1 reel 4800 feet

Table 8.5 - Magnetic Tape Cost

	AMPEX	RCA	TOTAL US$ (18 days)	ANNUAL COST* US$
TOTAL LAND COVERAGE	7 reels of 9200 feet US$ 2200	1 reel (2400 feet):US$ 110 2 reels (4800 feet):US$ 440 1 reel (5600 feet):US$ 256 US$ 806	US$ 3006	US$ 61000
BRAZIL ONLY	4 reels of 9200 feet US$ 1250	5 reel (1200 feet):US$ 275 1 reel (4800 feet):US$ 220 US$ 495	US$ 1745	US$ 36000

* Is assumed that all the available data is recorded and preserved

Table 8.6 - Amount of Images Received in the Station

	BRAZIL		TOTAL CONTINENTAL COVERAGE	
	RBV	MSS	RBV	MSS
Time/days	6433	6433	10.361	10.361
Scenes/18 days	257	257	414	414
Scenes/day	14	14	23	23
Images/day	42(3x14)	56(4x14)	69(3x23)	92(4x23)
Scenes without excessive cloud cover/day (70 % of the total)	10	10	16	16
Images without excessive cloud cover/day (70 % of the total)	30(3x10)	40(4x10)	48(3x16)	64(4x16)

Table 8.7 - Photo Copies of the Preliminary Images ("BULK")

	BRAZIL		TOTAL CONTINENTAL COVERAGE	
	RBV	MSS	RBV	MSS
Black and White prints	300 (30x10)	400 (40x10)	480 (48x10)	640
Black and White transparencies	300 (30x10)	400 (40x10)	480 (48x10)	640
Color prints (20 % of the total)	20 (20% of 10x10)	20 (20% of 10x10)	40 (20% of 16x10)	40
Color transparencies (20 % of the total)	20 (20 % of 10x10)	20 (20 % of 10x10)	40 (20 % of 16x10)	40
TOTAL	640	840	1040	1360

Table 8.8 - Photo Copies of the Precision Images

	BRAZIL		TOTAL CONTINENTAL COVERAGE	
	RBV	MSS	RBV	MSS
Black and white prints	90 (30% de 300)	120 (30% of 400)	150	200
Black and white transparencies	90 (30% de 300)	120 (30% of 400)	150	200
Color prints (100 % of the total)	30	30	50	50
Color transparencies (100 % of the total)	30	30	50	50
TOTAL	240	300	400	500

Table 8.9 - Total Photos Produced per day

	BRAZIL	TOTAL CONTINENTAL COVERAGE
Preliminary (bulk) photos	1.480	2.400
Precision Photos	540	900
TOTAL	2.020	3.300

Table 8.10 - Photo Processing Cost Per day for Brazil

Preliminary (bulk) Processing	US$
Film of 70 mm	5.0
Processing of 98 images/day	13.0
700 black and white prints copies	150.0
700 black and white transparencies copies	150.0
40 color print copies	14.0
40 color transparencies copies	14.0
TOTAL/DAY	346.0

Precision Processing	US$
Film of 70 mm	2.0
Processing of 21 images/day	3.0
210 black and white print copies	45.0
210 black and white transparencies copies	45.0
60 color print copies	21.0
60 color transparency copies	21.0
TOTAL/DAY	137.0

Table 8.11 - Photo Processing Cost Per day for Continental Coverage

Preliminary (bulk) Processing	US$
Film of 70 mm	9.0
Processing of 161 images/day	20.0
1120 black and white print copies	242.0
1120 black and white transparency copies	242.0
80 color print copies	28.0
80 color transparency	28.0
TOTAL/DAY	569.0
Precision Processing	
Film 70 mm	3.0
Processing of 35 images/day	4.0
350 black and white print copies	54.0
350 black and white transparency copies	54.0
100 color print copies	35.0
100 color transparency copies	35.0
TOTAL/DAY	185.0

Table 8.12 - Photo Processing Annual Cost

	BRAZIL	TOTAL CONTINENTAL COVERAGE
Preliminary (bulk) Processing	US$ 126,290	US$ 207,685
Precision processing	US$ 50,005	US$ 67,525
TOTAL	US$ 176,295	US$ 275,205

CHAPTER 9

GROUND STATION COST

We will analyze the cost for the implantation of an ground station to receive and process the information transmitted by ERTS satellite. The implantation could be done in parts, starting with the Tracking and Receiving Station and later with the first part of the station (Tracking and Receiving) it would be possible to track the satellite, receive information, and record it in magnetic tapes. These tapes would then be sent to NASA, where they would be processed at NDPF (NASA Data Processing Facility) and would be later returned to Brazil.

To avoid the necessity of sending the magnetic tapes to the United States, we would have to buy, simultaneously with the tracking and receiving station, the second part of the ground station, which refers to the image processing; this would make the treatment of the magnetic tapes previously recorded at the Tracking and Receiving Station possible here in Brazil.

We will present separately the cost of the Tracking and Receiving Station and the Image Processing Station with the respective operational costs.

9.1 - Tracking and Receiving Station

The Tracking and Receiving Station is a station where we would receive RBV information, MSS and the real time PCM telemetry, recorded in magnetic tapes. The cost of the basic components of this station would be approximately those shown in table 9.1.

Table 9.1 - Cost of the Components of the Tracking and Receiving Station

COMPONENTS	PRICE (US$)
1. Pedestal, 30 feet parabolic reflector,feeder, base extension, tracking receiver, tracking programmer, servo amplifiers, power amplifier, tracking converter, scan code generator,cables, multicoupler, down converter, RF patch-panel, antenna control.	250.000
2. Parametric amplifier(uncooled)	15.000
3. Receivers for MSS and RBV	20.000
4. Receiver for USB and PM subcarrier demodulator	18.000
5. Signal conditioner and MSS demultiplexer	100.000
6. Video processer and synchronism separator (VPASS)	100.000
7. Test equipment	40.000
8. Timing station	5.000
9. Tape recorder AMPEX FR 1928	70.000
10. Tape recorder RCA TR 70-CVR-3E	200.000
11. Quick-look monitor for RBV	90.000
12. Bit synchronizer for PCM telemetry	60.000
13. Building (300 m^2)	50.000
TOTAL	1.000.000

Table 9.2 - Annual cost of operation and maintenance of the Tracking and Receiving Station

COMPONENTS	PRICE (US$)
1. Magnetic tapes (in the assumption that all recorded tapes are kept at INPE)	60.000
2. Personnel	
1 electronic engineer	
2 electronic technicians for maintenance	
4 operators	30.000
3. Replacement material	50.000
TOTAL	140.000

Table 9.2 shows the operational and maintenance cost of the Tracking and Receiving Station.

The total price of this station could be reduced to approximately US$ 100.000 if we change the "Quick-look monitor" (item 11) for a simple oscilloscope and eliminate the purchase of test equipament (item 7).

If we changed the tape recorder of parallel recording, AMPEX-FR-1928, for a tape recorder of series recording, for example the TR70-CVR-3E modified, the price of the station would increase by approximately US$ 50.000.

So that the system could become completely reliable, it would be interesting to purchase some reserve units.

There is the possibility that this station would expand by the purchase of equipment for receiving other signals transmitted in the USB channel. These other signals would be the DCS (Data Collection System) and the stored PCM telemetry. This expansion could possibly be in the purchase of a digital tape recorder for example the AMPEX FR-2000. The accomplischment of this expansion would increase the price of the station in approximately US$ 150.000 irrespective of the price of the DCS (Data Collection Platforms) and sensors correlate to these platforms.

There is also the possibility that the expansion could be to receive meteorological satellites in the band S, such as Tiros N and SMS/GOES. For this, three receivers are enough.

9.2 - Image Processing Station

This processing station permits the complete processing of RBV, MSS and USB signals (telemetry PCM and DCS) in Brazil; they have capacity to generate the preliminary and precision images for RBV and MSS and the CCT (computer Compatible Tapes) for MSS besides performing multispectral analyses.

Figure 9.1 shows the configuration of this complete processing station; it is noteworthy that the processing for precision images is obtained with manual determination of local errors in all photographs, one by one; it is also noteworthy that in this figure the DCS processing, the generator of CCT tapes and the multispectral analyses are not shown.

The proposed station may be schematically separated in terms of cost,as table 9.3 shows.

Table 9.3 - Cost of image processing station

ITEMS	PRICE (US$)
1. Electron Beam Recorder (with controls)	200.000
2. RBV and MSS preliminary processing (bulk)....	1.200.000
3. RBV and MSS precision processing	800.000
4. CCT tapes for MSS	100.000
5. DCS processing	200.000
6. Multispectral analysis	250.000
total	2.750.000

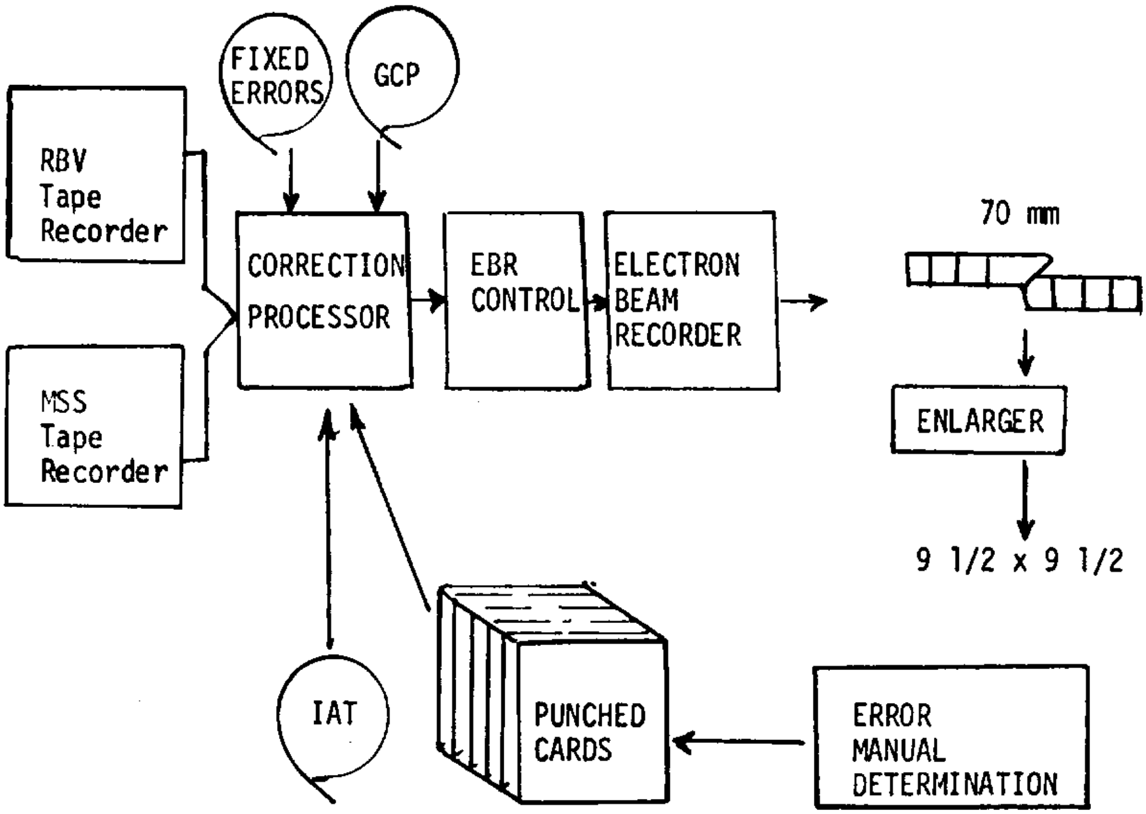


Fig. 9.1 - Image Processing Station

It should be noted that the processor is included in the item concerning the preliminary processing; it should be also noted that in this item the price for generation of IAT tapes (Image Annotation Tape) and "Fixed Errors" tapes is not included in this item because it was considered that NASA will provide Brazil with these tapes for preliminary corrections and annotations.

The generation of these two tapes is already included in item 3; i.e., to go from the preliminary processing to precision processing with generation of IAT and "Fixed Error" tapes, there would be an increase of approximately US$ 800.000.

The sophistication grades of the system may be considered as:

SPECIFICATIONS	PRICE (US$)
1º) Images without corrections and annotations ..	200.000
2º) Preliminary images annotated, with IAT and "Fixed Error" tapes provided by NASA.........	1.400.000
3º) Preliminary and precision images annotated, with IAT and "Fixed Errors" tapes generated at INPE	2.200.000
4º) Item 3º) more generation of CCT tapes for MSS	2.300.000
5º) Item 4º) more DCS processing	2.500.000
6º) Item 5º) more multispectral analyses	2.750.000

It should be noted that the tape recorders utilized to reproduce the tapes recorded in the Tracking and Receiving Station for subsequent processing are not estimated here, since the tracking and processing stations are considered to be in the same place. If this is not possible, the cost of the processing station would increase by the price of the tape recorders (US$ 270.000).

Table 9.3 shows the annual cost of operation and maintenance of the Image Processing Station, including the photographic processing.

Table 9.4 - Annual cost of operation and maintenance of Image Proces$ing Station

DISCRIMINATION	PRICE US$
1. Computer compatible tapes	20.000
2. Personnel	
-3 engineers	
-2 maintenance technicians	
-8 operators	60.000
3. Replacement material	100.000
4. Photographic processing	176.000
TOTAL	356.000

9.3 - Summary of the Station Total Cost

The cost of the Tracking and Receiving Station Shown in Table 9.1 (US$ 1.000.000) would be increased by US$ 150.000 (to make possible the receiving of DCS signals and storing of PCM telemetry not estimated in Table 9.1) and another US$ 50.000 for the acquisition of some reserve units which be almost indispensable. Then the cost of the Tracking and Receiving Station would be US$ 1.200.000. The operational cost for a year would be US$ 140.00, as shown in Table 9.2.

The cost of the investment for the acquisition of the Image Processing Station would be increesed by US $ 270.000, correponding to additional tape recorders; this would result in a total of US$ 3.020.000. The operational cost for a year would be US$ 356.000, as shown in table 9.4.

Summarizing, we would then have the total cost of the investment and operation for a year:

PURCHASE INVESTMENT	PRICE (US$)
1. Tracking and Receiving Station	1.200.000
2. Image Processing Station	3.020.000
	4.220.000
ANNUAL OPERATION	
1. Tracking and Receiving Station	140.000
2. Image Processing Station	356.000
	496.000

Then, the investment in the purchase of the equipment in Cruzeiros, considering the presente rate of exchange for the dollar ... (Cr$ 5.845) will be Cr$ 24.665.900,00.

The disbursement of this amount of money occurs in accordance with the Chronogram of Fig. 9.2; it allows for 25% of the total at the signing of the contract with the firms; 15% of the total at the end of the second, third and fourth months after the signing of the contract; 20% of the total at the shipping of the equipment; 10% of the total at the end of the installation.

It is convenient to remember that the firms proposing to sell the equipment for the station are interested in trying to get international financing.

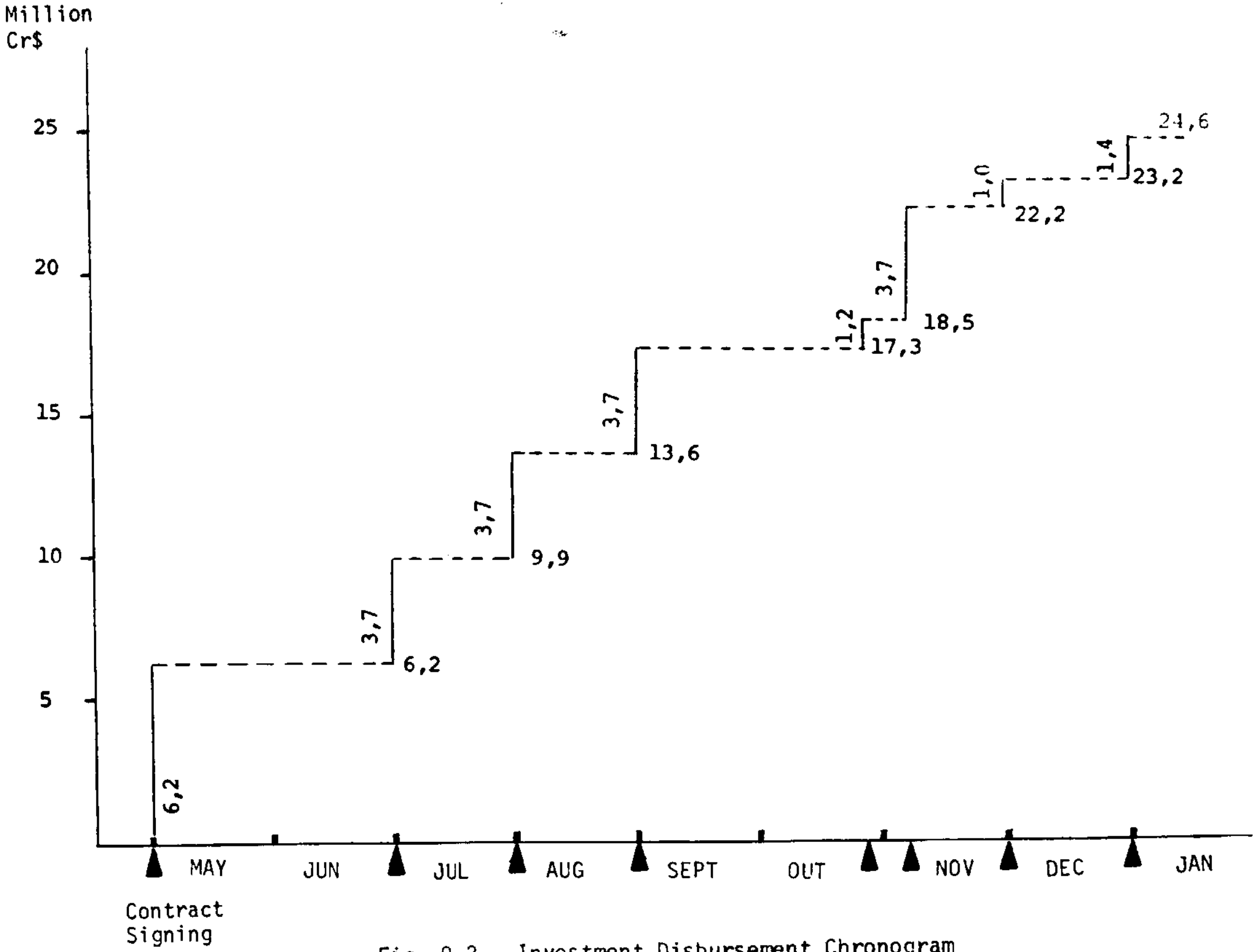


Fig. 9.2 - Investment Disbursement Chronogram

CHAPTER 10

STATION IMPLANTATION

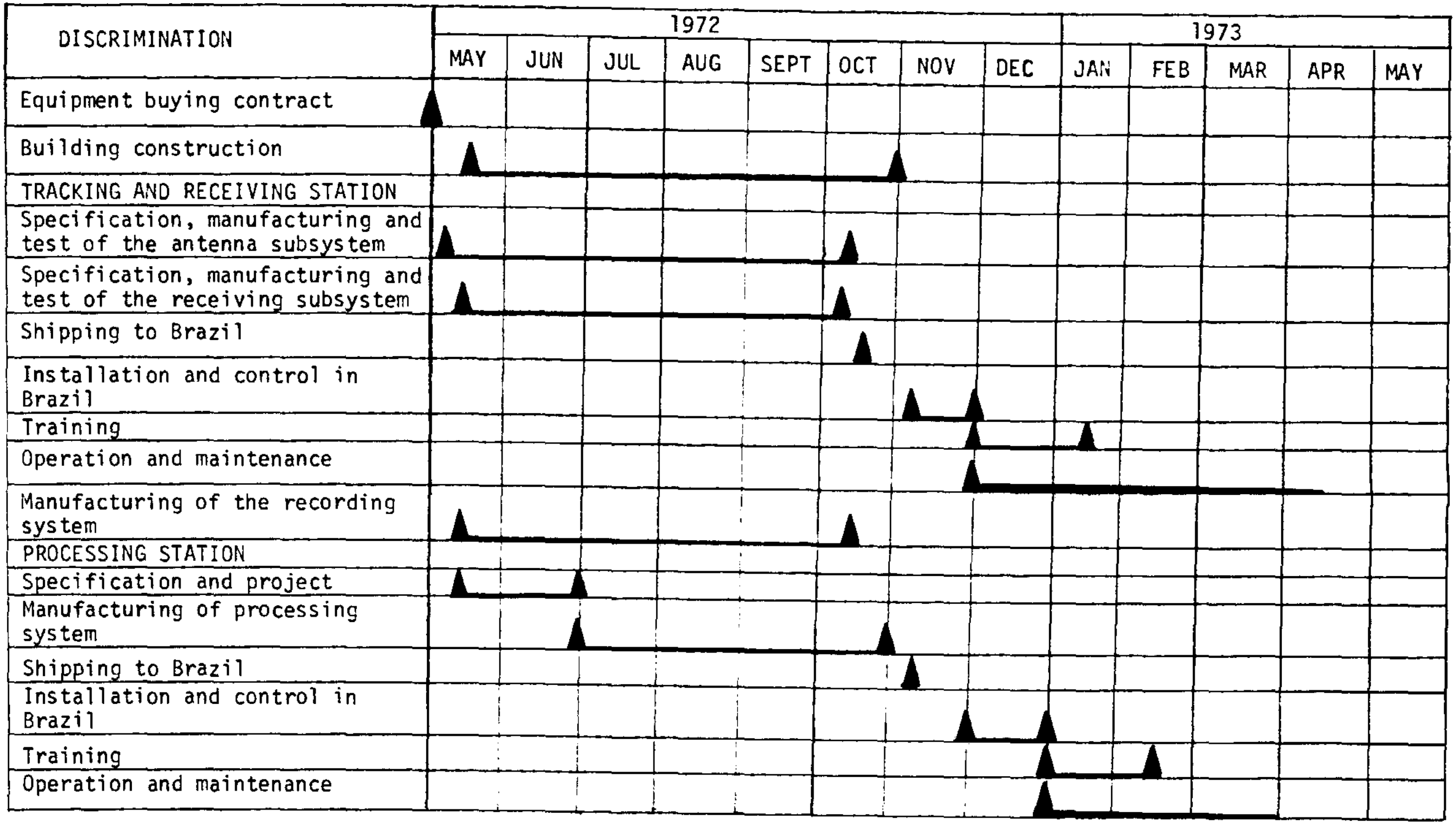
CHRONOGRAM

The launching of the satellite ERTS-A is forecasted to take place in the week of June 22,1972. If the order is made in May, the receiving and recording part will go into operation in November 1972, and the image processing part two months later.

Satellites for exploration of the Earth resources such as the EOS and possibly other ERTS will secure continuity of the program.

Table 10.1 shows the chronogram for the implantation of the stations; this table shows that the building where the station will be installed must be concluded by early November 1972.

Table 10.1 - Station Implantation Chronogram



DISCRIMINATION	1972								1973				
	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Equipment buying contract	▲												
Building construction	▲	━	━	━	━	▲							
TRACKING AND RECEIVING STATION													
Specification, manufacturing and test of the antenna subsystem	▲	━	━	━	━	▲							
Specification, manufacturing and test of the receiving subsystem	▲	━	━	━	━	▲							
Shipping to Brazil						▲							
Installation and control in Brazil							▲ ▲						
Training							▲	━	▲				
Operation and maintenance							▲	━	━	━	━	━	
Manufacturing of the recording system	▲	━	━	━	━	▲							
PROCESSING STATION													
Specification and project	▲	▲											
Manufacturing of processing system		▲	━	━	━	▲							
Shipping to Brazil							▲						
Installation and control in Brazil							▲	▲					
Training								▲	━	▲			
Operation and maintenance								▲	━	━	━		

CHAPTER 11

CONCLUSION

It is hoped that the previous chapters have made it clear that the installation of the mentioned station in Brazil will represent a priceless technique in the surveying and preservation of the resources of the country.

INPE's effort to provide Brazil with such a station is of relevant importance mainly in the part concerning the solution of fundamental problems of the country, such as those enumerated in Chapter 1.

The INPE proposed station in its complete version will permit Brazil to receive data from all the national territory and transform them in a group of seven photographs in the spectral bandwidth of the visible and near infrared; these photos could be distributed to all Brazilian entities interested; this group of 7 images (3 provided by the television system and 4 by the scanner system) is renewed every 18 days, due to the repetitive coverage of the satellite. This station in its more complete version would cost Cr$ 24.650.000,00.

Brazil's participation in the ERTS program and consecutively in the future program of exploration and surveying of Earth resources, using orbital platforms, will result in enormous benefits to the country by relatively low costs as compared to other methods of surveying.

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APPENDIX A

SENSING EQUIPMENT OF THE AMERICAN ORBITAL STATION

(SKYLAB)

Some of the sensing equipment to be used in the experiments for observation of the Earth include:

i) Multispectral photographic equipment (S-190)

This experiment uses six 70 mm high precision cameras with matching between the distortion and lenses of focal distance of 15.2 cm (21.2^0 field of view through planes) giving an area coverage of 163 x 163 km (88 x 88 nautical miles) and a photo scale of 1:2,800,00 . The lenses are aligned and mounted in a panel of simple lenses with its parallel optical axes less than a minute of arc. Images will be registered within 5 mirrors of error. The cameras are equipped with synchronous obturators, offset for the movement of the spacecraft. It is expected that the system reaches a resolution (film-lens) of more than 100 lines per milimeter, in color. The effective ground resolution may be approximately 30 meters. The system is designed for the following spectral combination of wave/film length:

0.5 to 0.6 microns - Pan X black and white film
0.6 to 0.7 microns - Pan X black and white film
0.7 to 0.8 microns - Black and white infrared film
0.8 to 0.9 microns - Black and white infrared film
0.5 to 0.88 microns - Color infrared
0.4 to 0.7 microns - Color Hi-Res

The spectral band covered by mission S-190 in general corresponds to the spectrum coverage designed for multispectral scanners and "Return Beam Vidicon" (RBV) of the ERTS. Similar sensors will be used in airplanes to permit the correlation of simultaneous observations of the "SKYLAB", ERTS, aerial and terrestrial.

ii) Multispectral Scanner (S-192)

This sensor will provide radiation values in several spectral bands through scanners with angle of 10° to produce strips of 78 km. Each strip will have an instantaneous field of view of 80 m^2. The spectral bands are approximately:

1) 0.410 to 0.460 microns
2) 0.460 to 0.510 microns
3) 0.520 to 0.556 microns
4) 0.565 to 0.609 microns
5) 0.620 to 0.670 microns
6) 0.680 to 0.762 microns
7) 0.783 to 0.888 microns
8) 0.980 to 1.080 microns
9) 1.090 to 1.190 microns
10)1.200 to 1.300 microns
11) 1.550 to 1.750 microns
12) 12.100 to 2.350 microns
13) 10.200 to 12.500 microns

iii) The set of cameras considered for the "SKYLAB" consists of a modified camera Hycon KA-74. This equipment has a lens with focal distance of 18 miles long and produces images of 4.1/2 x 4.1/2 inches in film rolls of 5 inches width. The equipment was qualified for use in manned satellites but, although it might be used for vertical and oblique photos, it is not a mapping camera.

The equipment being considered for the possible future flights of the "SKYLAB" II or III includes a camera for ground mapping with a focal length of 12 inches, with film format of 9 x 14.1/2 inches, for which lenses giving adequate aperture may be obtained: a camera of stellar altitude with focal length of 6 inches using 70 mm film, a laser altimeter and a camera of focal lenght of 12 inches with film format of 9 x 18 inches. A panoramic camera of the lunar program may be used, too. This camera has lenses focal length of 24 inches, 108^0 for scanning, casement of 4.1/2 x 45 inches, aperture F3.5 and is capable of producing 1.650 exposures. It is considered that photos from this camera would give details of mapping in the scale of 1:50.000 and 1:25.000. Copiers of rectification and transformation which duplicate essentially the geometry of the adopted system are being developed.