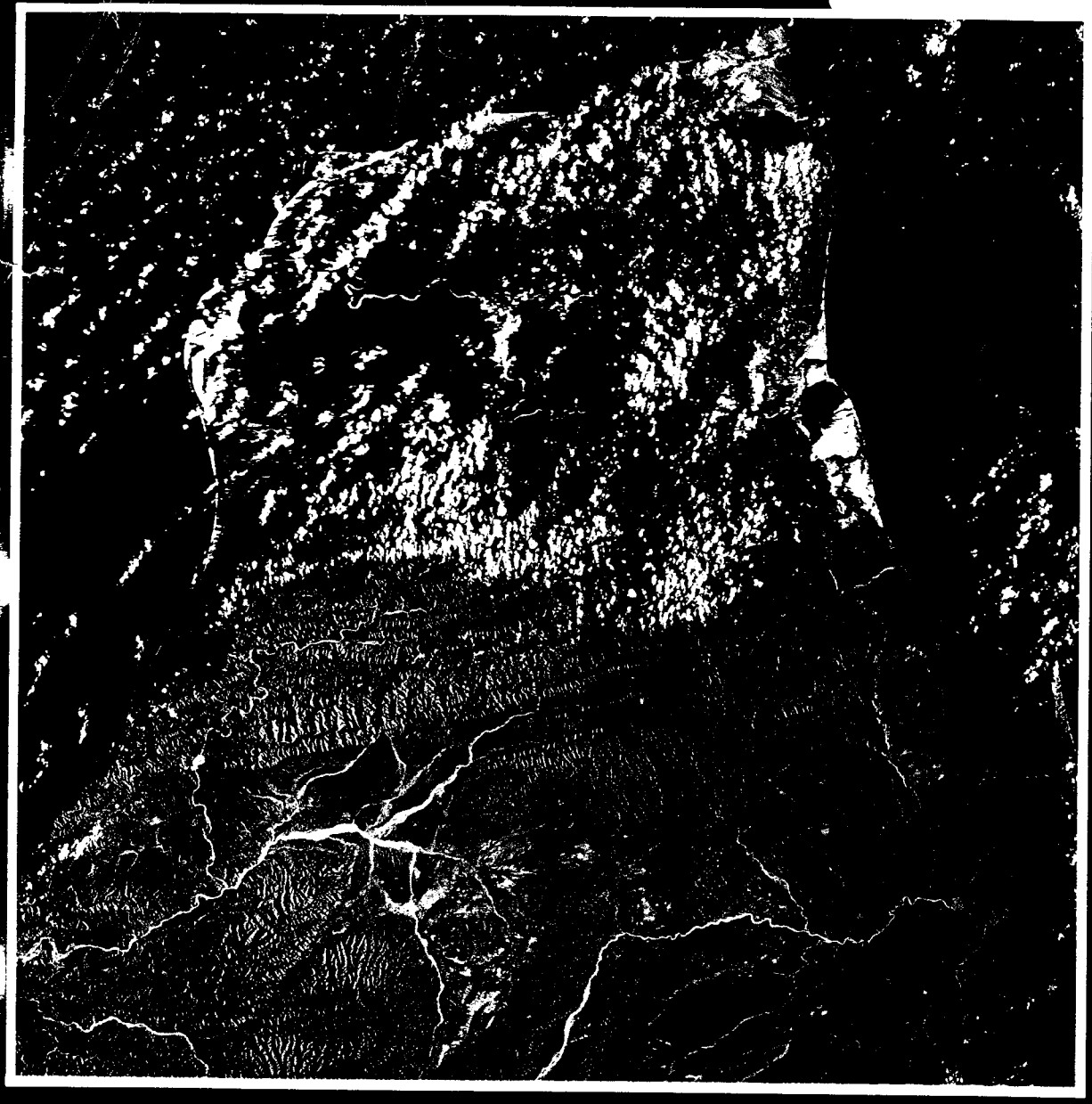
Remote Sensing for Development



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Part II

The Brazilian Satellite Remote Sensing Program

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Abstract

Almost twenty years after the first time Remote Sensing was mentioned in Brazil, a reflection upon the results achieved and a planning for the future are due, in harmony with the aims and priorities of the new Brazilian Administration. Conscious of this spirit, INPE has revised its ongoing projects and established a new, goal-oriented organization structure. After one year of work, some achievements are already available and are presented in this paper. The analysis of these preliminary results, in conjunction with the governmental priorities and the knowledge of the state-of-the-art at international level will surely guide Government actions in years to come.

1. Introduction

Nearly twenty years have passed since the expression *Remote Sensing* was first used in Brazil in the way it is known today. So, it seems proper to review the obtained results, some of its consequences - both positive and negative - and to plan for the future; this planning done through the setting of goals matched with the new priorities established by the Brazilian Government.

During this time two different (but complementary) actions were developed in Brazil on the Government Level: the RADAMBRASIL Project and the *Satellite Remote Sensing Program.*

The RADAMBRASIL Project was supposed to perform the *Land Resources Integrated Survey* of an area of 1.500.000 km^2 in the Amazonic Region, within the zone of influence of the *Trans-Amazon Highway* (a 2.075 km long road parallel to the Amazon River). However the surveyed area was gradually increased and, by 1975 it covered the whole 8.500.000 km^2 of the Brazilian Territory, thus becoming the world's largest airborne radar data coverage project (side looking radar). This work generated 38 reports with excellent thematic maps (in the 1 : 1.000.000 scale) and their availability has been an important asset for the Government Planners both on the Federal and State levels.

This event generated a most important byproduct which was the training of hundreds of technicians on the handling and assessment of non-conventional images. Until then, the Brazilian technical people were used to the handling of aerophotography only.

Today, both the data generated by the RADAMBRASIL project and a fairly large number of specialists can be found in the IBGE Foundation, in Rio de Janeiro (*Instituto Brasileiro de Geografia e Estatística*, the Brazilian Institute for Geography and Statistics).

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Meanwhile, the *Satellite Remote Sensing Programm*, headed by INPE, has followed other tracks. First, it was essential to prepare people for the then unknown techniques (even on the international level) of satellite generated data handling. Recall that the first natural resources monitoring satellite (then labeled ERTS-1) was launched by NASA (USA) only in July 1972!

In those days, however, communication satellites were already being used worldwide and were beginning their commercial phase. Hence several Brazilian technicians were sent abroad to seek specialization at every level (i. e. from short on the job training courses all the way to MSc's and PhD's).

Further, it was enough just to look at the characteristics of Brazil, to guess that the country would become very shortly an important user of the data generated by those satellites.

The large territorial area, the sparse knowledge of her natural resources, the need of checking on the progress of Big Projects going on in remote areas, the economic interest on the results of the agricultural policy, all this plus the cost involved in obtaining data on the above factors by the traditional methods, led Brazil to install in 1972 (right after USA and Canada) a complete *Landsat Satellite Ground Station*.

This allowed the direct access to a large amount of data not only on the complete Brazilian territory but also on several other neighbor countries, thanks to the strategic position of the *Cuiabá Receiving Station*.

Hence INPE technicians have acquired during these past years considerable experience in the process of developing techniques and in the identification of problems which can be either solved or mitigated with the use of satellite images. Meanwhile INPE also trained (offering courses of specialization in several levels and graduate courses, MSc level) hundreds of people from the Government, Universities and Private Industries.

The experience in maintaining and operating sophisticated receiving equipment led INPE to become also an R & D center able to develop fairly complex units mainly in the areas of receiving and data processing stations as well as *Image Analysis Systems*. Nowadays the Industry, strengthened by the Government Policies is able to make and sell abroad competitively, not only items but systems developed by INPE.

Unfortunately the Economic Crisis which hit Brazil in the last few years was specially rough on the Country's R & D Centers, INPE among them. The lack of financial support and the struggle for survival led INPE (and some other important Government R & D Centers too) to invade an area which traditionally belonged to the private industry which was that of bidding for the execution of conventional, non R & D Projects.

However, the new Government, installed in March 1985, granted the opportunity to review every policy in the Country. Thus the *Remote Sensing* subject was also analysed. Meanwhile, a simple inspection of what is happening in the Western Countries lead the observer to conclude that the Satellite Remote Sensing activities are going now through the transition from a well proved technology to a commercial venture with a very high probability of success. Just like the Telecommunication Satellites Networks during the early seventies, the mid eighties in the future will be known as the turning point for the satellite Remote Sensing technology. Hence, why not to consider these facts in the new policy for the Remote Sensing in Brazil?

The private sector for aerophotogrammetry still hesitant on space applications would invest in the area if supported by a clear, positive, government policy on the subject.

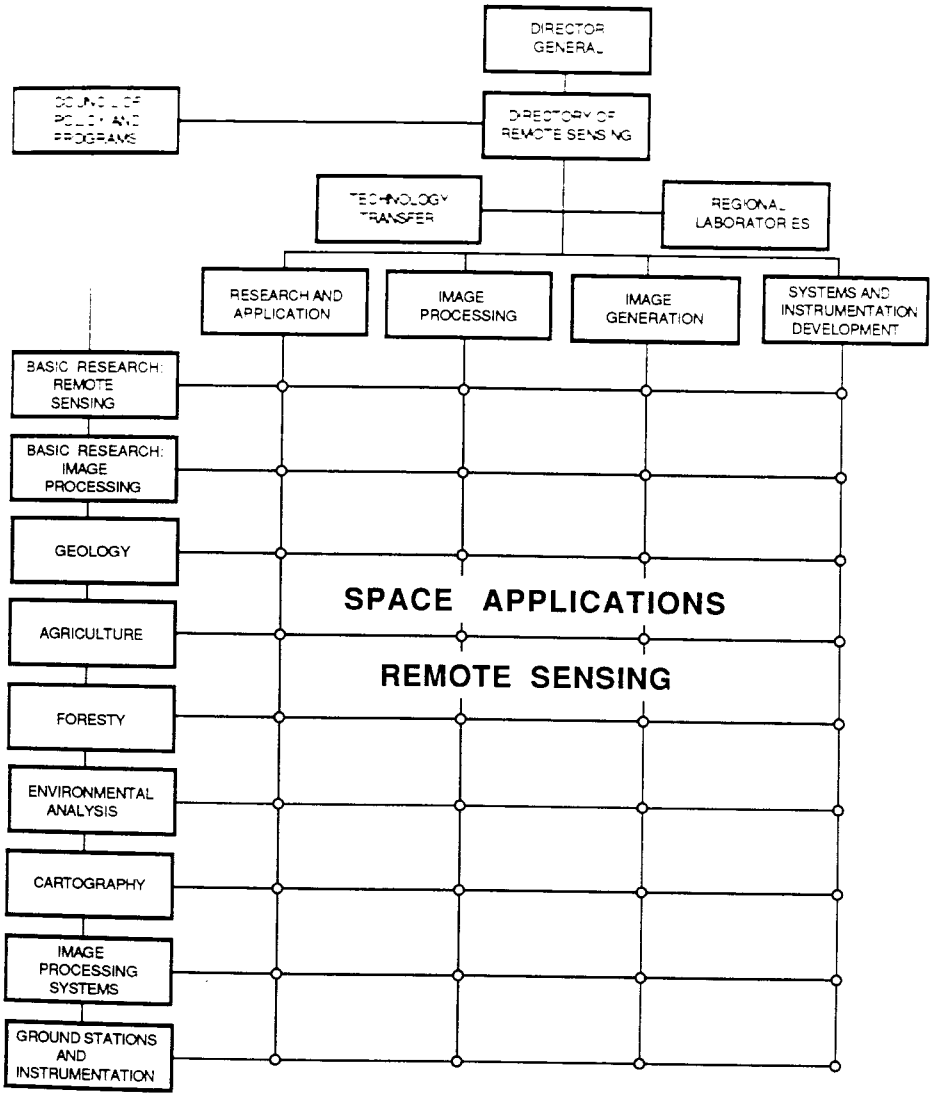
Based on these facts and trends INPE has reshaped its own policy and structure in the Area of Remote Sensing, as it will be shown later on.

The *Brazilian Satellite Remote Sensing Program* deals with the receiving, processing, storing and dissemination of images; with the developing of application techniques and its transfer to the interested sectors; with the development of systems and related instrumen-

tation; and last but not least, with the maintenance of the human resources in the area on the desired level.

2. Remote Sensing Organizational Structure at INPE

This area is led by a Directorate assisted by a Council on Policies and Programs and a Coordinator on Technology Transfer. It operated in a matrix where the Programs (and their Projects) occupy the rows. The human and material resources for the support on these programs/projects come from Departments (columns) as shown below.



The objectives of these departments are:

- *Research and Applications*

Qualified people in different areas such as Geology, Agronomy, Forestry, Cartography, Geography, Urban Studies, Engineering, Statistics etc. The qualification has been acquired through graduate work at INPE and other institutions in the Country and abroad. The Department has field radiometers, laboratories and operational equipment for both visual and digital analysis and interpretation.

- *Image Analysis*

Engineers and Systems Analysts specialized in digital processing, modelling and simulation techniques. The department has laboratories for the development of interactive image analysis and interpretation systems.

- *Systems and Instrumentation*

Engineers and systems analysis specialized in RF, process control, real-time techniques, data communication links, etc. The department has laboratories for the development and integration of satellite data receiving and processing stations and related equipment.

- *Image Generation*

Operational systems for receiving, recording, processing and storing of signals (image and other data) from Remote Sensing and Meteorological Satellites such as LANDSAT (MSS and TM), GOES and TIROS-N. This Department also handles the data from INPE's airborne remote sensing platform (Bandeirante aircraft).

- *Technology Transfer*

- User's assistance and orientation service with a specialized team. Units (ATUS - User Attendance Service) in Natal, Manaus, Brasilia, Rio, São José dos Campos and Cachoeira Paulista.
- Training for professionals in the need of familiarization with the remote sensing techniques.
- Graduate courses in the area with regular courses in Remote Sensing and Image Analysis, beginning February each year and leading to an MSc Degree (2–3 years on the average).
- International Cooperation in Remote Sensing, including participation in and/or coordination of training courses, projects, experiments or joint activities with other Countries and International Agencies. To the present INPE has cooperate with Argentina, Bolivia, Canada, Chile, China, Colombia, DRG, Ecuador, France, FRG, Great Britain, Iraq, Japan, Panama, Paraguay, Peru, Uruguay, USA, ESA, FAO, UN, UNESCO, World Bank and the Interamerican Development Bank.

3. Remote Sensing Programs

3.1 Environmental Analysis

This program includes projects on Remote Sensing Environmental Data Gathering Techniques and systems using orbital and airborne imagery.

The Program includes:

a) *Environmental Geomorphology* - Coastal systems erosion and equilibrium;
b) *Hydric Systems* - Handling, water quality and availability;
c) *Land Use* - soil occupation;
d) *Urban areas* - growth and use.

Since July 1985 this program has developed the following projects:

- Cubatão (with CETESB, the state of São Paulo Environment Authority): Mapping of the vegetal cover of the Quilombo and Mage river valleys to evaluate vegetation degradation and recuperation rates using IR and color airborne images in the 1 : 25.000 scale. The work is done and the technique is available for the user.
- IRRIGA (with DAEE, the state of *São Paulo Water Resources Authority*): Viability studies on the LANDSAT-TM sensor use in irrigated areas identification and map production. Test area is Bragança Paulista.
- ASSENTAMENTO (with INCRA, the *National Land Reform Institute*): Identification of possible areas for use in the National Program of Land Redistribution, employing LANDSAT Imagery. Six test areas covering 96 counties were selected in the state of Rio Grande do Sul, in a total area of 6.000.000 ha. The project has been completed.
- São José dos Campos (with the São José dos Campos county authority): A Development of Techniques for updating the land use of that county, employing airborne and LANDSAT-TM images. The project will be finished by December 1986.
- IRRIGA II (with the *National Irrigation Program* and the *Ministry of Transportation*): Consulting services in the mapping of a 3.000.000 km² area for actual Land use, in a scale compatible with the use of the Landsat-TM Imagery. The project is to be completed early 1987.
- EROSÃO (with the state of *São Paulo Water Resources Department* (DAEE), the *Technology Institute* (IPT) and IAC - *The City of Campinas Agronomic Institute*): The use of orbital imagery to establish diagnostic maps on Land use and erosion for the state of São Paulo, scale 1 : 250.000.
- INUNDA (with SUDENE, the *Northeast Development Agency*): Use of LANDSAT data to monitor areas with flood risks. It will begin shortly.

3.2 Program of Geology

Remote Sensing is an adequate techniques for mining and energy (i. e. oil and gas) surveys through the analysis of the land surface. Hence this Program has projects on:

a) *Mineral and Energetic Research* - Mineral and oil deposit studies through Remote Sensing, for the establishment of prospecting models;

b) *Geological Mapping* - identification of lithostatigraphic units and structural analysis in different scales seeking the definition of evolutionary models;

c) *Engineering and Hydrogeology* - Remote Sensing application on geothechnical and hydrogeological problems.

The Program of geology involves the following projects since July 1985:

- CRATON: Geological, Structural and Geotectonic Integration Studies of the southern edge of the craton of the São Francisco River through the use of Remote Sensing, geophysical and field surveys.
- SERGIPE (with INEP - Planning agency of the state of Sergipe): Employment of Remote Sensig Techniques for morphostructural study of underground water in anomalous regions in the state of Sergipe.
- TEBAS (with Petrobras - The *Brazilian Oil State Co.*): Development and/or adapting orbital remote sensing techniques to evaluate the tectonics in areas of interest for hydrocarbon prospecting.
- CERG (with CBPM The *Bahia Mineral Research Co.*): Evaluate Computer treated LANDSAT-TM data in order to detect spectral standards in Grossans areas and lithology connected to sulfide deposits in the North of the state of Bahia.

3.3 Program of Forestry

Research and Development of Remote Sensing techniques for application in Forestry: Vegetation Mapping, Forest management and inventory, timber volume estimates, evaluation and monitoring of deforested areas (fires, plagues, droughts etc.). This program is developing the following projects since July 1985:

- QUEIMA: Evaluation of burnt areas in the *Brasilia National Park* and the monitoring of the Forest regeneration, through the use of LANDSAT-TM Imagery. The Project has been concluded.
- ANOVEG: Studies on the evaluation of orbital Remote Sensing Data in the detection of vegetal anomalies in the Alto-Xingu Region. Airborne and field work have confirmed the expected results.
- URUGUAI (with Uruguayan Government/UNIDO): Forestal Resources Survey of Uruguay using LANDSAT-TM Imagery, scale 1 : 1.000.000. Project expected to end later this year.

3.4 Program of Agriculture

The use of Remote Sensing techniques to carry out Projects on crop survey and yield of areas of utmost importance for the National Economy. In this framework INPE has done work on wheat, soyabean, corn, rice, etc. Tilled areas estimates are done through visual and/or automatic interpretation of satellite or airborne imagery thus setting up integral or sample mapping of desired region. These techniques can also be used to estimate the losses caused by plagues, deseases and periodic events such as frost or drought.

Yield estimates are obtained through modeling with data from orbital remote sensing and conventional Meteorological Stations. Hence this program has developed since July 1985 the following projects:

- SOLONU (with the *Ministry of Agriculture*): Evaluation of the growth of tilled areas in the state of Mato Grosso in the 1984/1985 and 1985/1986 periods.
- IRECÊ (with the *Bank of Brazil*): Use of Remote Sensing technique to help the Rural Credit fiscalization Process. The test area was chosen to be the IRECÊ county in the state of Bahia (beans, corn and Castor Oil Plant). The project has been concluded and its results made available to the *Bank of Brazil* to be used countrywise.
- CANASATE (with SERPRO: the Federal Data Processing Service) Sugarcane farms inventory and mapping on national level, employing orbital and airborne remote sinsing techniques.
- MAISAT (with the Province of Corrientes - Argentina): Irrigated rice areas inventory and mapping through the use of LANDSAT-TM Imagery.
- SIAG (with IBGE, the *Brazilian Institute of Geography and Statistics*): Establishment of a reliable operational system on Agricultural and Livestock Information, using orbital remote sensing and based on Probabilistic Methods applicable in the whole National Territory. Its first phase, covering the state of Paraná will be completed by April 1987.
- ESTIMA (with the *Bank of Brazil*): Developing of yield Modelling for sugarcane, wheat and soyabeans.
- FISATE (with the *Bank of Brazil*): Improvement of orbital Remote Sensing techniques in the Agricultural Credit Fiscalisation Process.

3.5 Image Analysis Systems Program

INPE has made an effort to develop in the last few years, a family of image analysis systems. These systems, based on Brazilian made micro computers, are used in the analysis of Natural Resources mainly, although their frames allow the use in other areas such as in Metallurgy, Meteorology and Medicine.

This Program also works in the field of geographic information systems, incorporating satellite imagery.

The equipment which are of interest to the user community are transferred to the Industry for production and commercialization. Hence this program includes the following projects, since July 1985:

- SITIM: Family of *Image Analysis Systems* under different architectures, each with a given cost-performance ratio. This development includes Brazilian made hardware and application software for several areas (remote sensing, meteorology and image analysis). The first member of this family, SITIM-150, is available in the market and two more versions (SITIM-250 and SITIM-250) are being developed.
- SGI: Development of *Geographical Information System*, using hardware and software both made in Brazil. This system will be able to handle, in an integrated mode, Satellite Imagery, Thematic Maps, Conventional Topographic Maps, Statistical Data, terrain digital Models, etc., all set around a SITIM type of Environment. The first software package is nearly completed.

3.6 Ground Stations and Instrumentation Program

INPE acquired its first satellite receiving and data processing station in 1972 just after the launching of the LANDSAT-1 satellite. Since then INPE technicians have been updating the station to handle data from new satellites, besides keeping up with its operational needs and improving its efficiency.

The knowledge absorbed in this process led INPE into an effective participation in 1980, in the design and development of a ground station for the Thematic Mapper Sensor.

INPE has been also developing equipment for Meteorological Satellite Stations and for *Data Collection Platforms* (DCP's). Hence this Program has been developing, since July 1985, the following Projects:

- GOES-AAA: Development of a system to process data transmited by the new GOES satellite. The prototype is ready and the Industry will begin production early next year.
- TIROS-N: Facilities for high resolution, digital, geometrically and radiometrically corrected imagery Production for INPE's Meteorological TIROS-N Station.
- DCP: Data Collection Plattforms for polar orbiting and Geostationary Meteorological Satellites. In the past INPE developed a DCP for the ARGOS system which is being industrialized in the Country. Shortly a DCP for the GOES system will also be available as well as an ARGOS low-cost receiving station, in VHF.
- SPOT (with the CNES/SPOT Image Co.): Development of hardware and software for use in the LANDSAT-TM Station to receive and process SPOT data. The first phase will provide receiving and recording capabilities and will be ready before July 1987. Data processing on the levels SPOT 0, 1 A and 1 B will be possible by December 1987. Agreements between CNES (France) and COBAE (Brasil) and the contract between INPE and SPOT Image will be signed shortly.

3.7 Program of Cartography

Since 1980 INPE has been concentrating in this area its efforts in the problem of developing techniques for geometric correction of orbital imagery.

The treatment of these images using control points and advanced sensors allowed INPE to direct its cartographic activities towards:

a) production of planimetric image-charts with future inclusion of altimetric information;
b) production of thematic maps in different scales and
c) updating of conventional topographic maps.

This program is developing since July 1985 the following project:

- CARTA-IMAGEM with DSG - The *Army Cartographic Service*): Use of LANDSAT-MSS and TM data to generate cartographic products (such as planimetric image-maps).

3.8 Research Program in Image Analysis

Since 1975 INPE has been doing research on the subject in order to support the Institute activities, which include orbital and airborne imagery, graduate courses and training in the area. Efforts are concentrated in enhancing, filtering, classification, registration, geometric correction and image analysis techniques. Hence this Program has two projects:

- PREPRO: LANDSAT Imagery preprocessing techniques and wind fields detection in Meteorological GOES Images. It is plannend next to develop preprocessing techniques for the SPOT-HRV sensor.
- ANIMA: Research on Image Analysis Methods using theories on Pattern Recognition, Image Processing and Mathematical Morphology for applications in Remote Sensing, Metallography, Medical Images, Cytology, Non-Destructive Testing etc. This project has been assisted by several organizations such as PETROBRÁS, INCOR and the *University of Erlangen* (in Nuremberg).

3.9 Remote Sensing Research Program

The purpose of this program is to increase the knowledge about remote sensing data and possible correlations with terrain features. The activities include studying the parameters which can influence the data acquisition and registration techniques such as atmospheric effects, spectral radiometric properties, sensor specifications, etc. This program includes two projects since July, 1985:

- LATER: Spectral discrimination of Laterite in the Paramirin Valley through field and laboratory data correlated with enhanced LANDSAT-TM imagery.
- CES (with the *Mauá Institute of Technology* and the *Lavras School of Agriculture* both in the State of Minas Gerais): 10 GHZ Radiometer Performance check-out.

This radiometer has been developed at INPE for Land Spectral Characterization.

NOTE: This Program has two more research projects, one in Agriculture, the other in Geology, dealing with the evaluation of the SPOT data over the Brazilian Territory.

4. The Future

The number of images produced and the user community has been steadily growing since the beginning of the program. Brazil has an outstanding position among the countries

operating the LANDSAT System. The data base includes nowadays nearly 200.000 LANDSAT images. The number of Users (mostly Institutions) exceeds 1.500, many of them being from outside Brazil.

The growing use of Remote Sensing Data in the Country led the Government in 1979 to update the existing Ground Stations to collect data from the new LANDSAT series. Today INPE receives, processes and distributes LANDSAT 5 data from the *Thematic Mapper* (TM) and the *Multispectral Scanner* Subsystem (MSS). It is getting ready to use data from the French Satellite SPOT-1. Another step taken by the Government related to the Remote Sensing Program was the official approval of the so called *Brazilian Complete Space Mission* (MECB).

MECB has the objective of designing, building, integrating, testing, launching and operating four national application satellites - two for Data Collection and two for Remote Sensing. The launcher is being developed in Brazil by the IAE - *Institute of Space Activities* (Ministry of Aeronautics). The expected date for the first satellite launching is February, 1989. The first two satellites, i.e. the Data Collection ones, will use the DCP's (Data Collection Platforms) which is an economically viable option for national applications. The greatest advantage of the telemetry via satellite is that costs are not too high and are not related to the distance involved.

The *Remote Sensing Satellite* whose Launching is foreseen to occur in 1993, will relay information on natural resources evaluation, using an onboard *Multispectral Earth Observation Camera*. This will enable the country to achieve its own data bank at low cost and on nearly real time.

Nowadays as it has been already mentioned the Policy among the Western Countries is the transference to Private sector of the space technologies which have been fully tested and approved after years of operation. Hence, as it happened to the telecommunication satellites, the LANDSAT system after fourteen years of operation is beginning to be thought of as a commercial item. This means that very shortly its users will have to pay normal prices for services here-to-fore rendered at a symbolic rate. Similarly the French Government operates the SPOT system, in a commercial basis, through the SPOT-Image Co.

Thus it is imperative that Brazil possess its own satellites.

A satellite configuration is chosen to attend the aims of its owners. In a domestic satellite, the spectral bands and the channels of the observation camera are established as a function of the parameters the country wants to observe, measure or collect. This action will allow the establishment of long range economical and social programs.

Still in the International Scenario, an ever growing number of new satellites and data acquisition systems will be placed in orbit, so that Natural Resources Surveying Processes and Environmental Monitoring Techniques will become more and more simple, precise and less expensive.

So it is time to plan ahead, thinking in terms of the Future.

Brazil has today thousands of LANDSAT images of its Territory and its complete Radar Coverage (SLAR) is available. Besides, it has data gathering and processing facilities which can be upgraded at reduced costs to handle future satellites data. More important, it has quite a reasonable number of skilled technicians who can make adequate use of the available technologies.

Among the New Government highest priorities in the *Social Welfare Plan* it can be mentioned the Programs for Food Distribution, Urban Development, Land Reform, Irrigation and the *Northeast Development Project* as those which can benefit from the use of Remote Sensing Technology. In fact, INPE is already working in nearly everyone of them.

However, it is high time to bring in the private Industry. Our Electronics and Informatics Industries are capable to produce the items required by the remote sensing specialist. Besides, the Airsurvey Companies can also be present in the Commercialization of Data,

thus improving the overall efficiency and yielding better service to the Users community. The Government would stay in the area of the Research of new technologies, improving the existing facilities (e. g. installing Regional Remote Sensing Laboratories), training personnel and warranting the data access to new satellites and systems of interest.

This way it will be laid the foundations which will allow the Brazilian Society to have an effective participation in defining future Space Missions either national or international.

Finally, as everybody here knows, space means development. Its adequate use will be crucial for the social and economic welfare of Brazil.