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16.Summary/Notes

This report briefly describes the activities of INPE related with Space Science, Space Technology and Space Applications and its main concerns about the role that international cooperation should play in those areas.

17.Remarks

INDEX

CHAPTER I

INTRODUCTION

The Institute for Space Research (Instituto de Pesquisas Espaciais - INPE) is the main civilian organization devoted to space activities. INPE was created in 1971 to succeed the National Space Activities Committee, (Comissão Nacional de Atividades Espaciais - CNAE) which existed from August, 1961. The Institute is affiliated to the National Council for the Development of Science and Technology (Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq). However, policy decisions regarding the activities to be held at the Institute are established by the Brazilian Committee on Space Activities (Comissão Brasileira de Atividades Espaciais - COBAE) at ministerial level.

Currently, all the activities at the Institute can be considered within the framework of peaceful use of the outer space. The activities carried on may be well classified among the three existing areas:

- *Space* and *Atmospheric Sciences*
- *Space Applications*
- *Technology* and *Space Systems*

The headquater of the Institute for Space Research is located at São José dos Campos, (SP), with additional facilities in Cachoeira Paulista (SP), Cuiabá (MT), Natal (RN), Fortaleza (CE), Atibaia (SP) and São Paulo (SP). Research is carried on mainly at São José dos Campos, Atibaia and São Paulo, while the other sites are more dedicated to data acquisition and processing.

In order to accomplish its goals, the Institute maintains and supports a graduate program which has formed specialized personnel for its own programs, as well for several other governmental institutions.

Graduate courses are offered in the São José dos Campos facilities in the areas of Space Science, Meteorology, Systems Analysis and Applications, Computer Science, Electronics and Telecommunications and Remote Sensing. All of these courses are accredited by the Ministry of Education.

The Institute has graduated in the last three years near a 100 students at the master's degree level, while some 200 students are currently enrolled.

CHAPTER II

SPACE SCIENCE

2.1 - INTRODUCTION

Since CNAE set up in 1961, Space Science has been an area to which a great deal of effort has been given. It played an important role in the establishment of the existing national competence in space activities and even today it occupies a relevant place in the roll of disciplines where scientific interest exists in the country.

Ground-based experiments and sounding rocket measurements performed "in situ" and the interpretation of the corresponding data have guided, during many years, the activities performed by the Brazilian scientists in the area. Later, a stratospheric balloon program was established in cooperation with several foreign institutions. Today, INPE operates two national facilities (which are also used by foreign and international organizations): the Itapetinga Radio-Astronomy Center (located at Atibaia, SP) and the Stratospheric Balloon Launching Center (located at Cachoeira Paulista, SP), and important research programs are based on them. Scientific payloads using Brazilian or foreign sounding rockets are launched from the Barreira do Inferno Rocket Launching Center, operated by the Brazilian Air Force in Natal (RN). Because Brazil has not yet launched its own scientific satellites, research using satellite data is performed under international cooperation.

Below, a brief description is given of the areas where activities are being carried out at INPE.

2.2 - HIGH ENERGY ASTROPHYSICS

The program of high energy Astrophysics in INPE is essentially confined to experiments in X-ray, low energy gamma-ray, ultraviolet and infrared observations of extraterrestrial sources. The detection of these radiations is very important to understand the high energy interactions taking place in many astrophysical sources such as compact binary systems, supernovae, novae, active galactic nuclei, pulsars, interstellar and intergalactic media.

Since 1971, INPE has been constructing and testing detectors and launching them on balloons to measure X-rays from 0.03 to 0.30 MeV and gamma rays from 0.3 to 20 MeV originating in Earth's atmosphere and in extraterrestrial sources. At present, telescopes to measure these radiations are being developed with advanced technology utilizing germanium-lithium diodes, hyperpure germanium and sodium iodide scintillators as active anticoincidence detectors which can give high spectral resolution in energy.

Balloon payloads up to 1 ton are launched from Cachoeira Paulista, SP (22^{o} 70'S, 45^{o}W). A main telemetry station located at São José dos Campos, SP (23^{o} 23'S, 45^{o} 85'W) and a ground-mobile station located in a chosen point of the trajectory of the balloon receive the data transmitted to the ground allowing flights up to 30 hours duration. The data are later analysed using the computer facilities at INPE.

Today, the main projects are:

- Project GELI: designed to detect cosmic gamma-ray line emissions (0.05-8 MeV) with high energy resolution telescopes of high flux sensitivity ($\leq 10^{-4}$ photons/cm^2 - s). These telescopes use Ge(Li) diodes as main detectors surronded by NaI (Tl) scintillators as active anticoincidence detectors. Their field of view is $\simeq$ 25º FWHM at 0.511 MeV.

- Project SOURCE: consists of a new type of gamma-ray telescope, which uses a passive shield to anti-collimate the main detector. It uses two NaI (Tl) crystals separated along the axis of the telescope. The angular field of view for this telescope is 30º FWHM at 1 MeV and the sensitivity for a point source is 2.4 x 10^{-3} photons/cm^2-s at 0.662 MeV, in its present configuration.

- Project FUVE: envisages the study of galactic and extragalactic sources in the middle ultraviolet (2000Å - 3000Å) and for infrared (> 50 μm) radiation. A telescope with a 45 cm paraboloid as its primary mirror is being developed to observe stellar objects such as transient X-ray sources, close binary systems and BL Lacertae objects which may give UV radiation of the order of 10^{-12} erg/cm^2-s-Å.

2.3 - RADIO-ASTRONOMY AND SOLAR PHYSICS

The experimental facilities existing at the Itapetinga Radio-Astronomy Observatory (Atibaia, SP), which comprise today an antenna of 45 ft diameter and radiometers in the millimeter range, are being heavily utilized and are being further improved. New radiometers are being developed in order to cover the utilizable range of the big antenna (up to 100 GHz). The technique of VLBI interferometry will also be used, first with the construction and installation of a VLBI terminal MK II (cooperation with Haystack Observatory, USA) and later with the extention to a national scale. International VLBI for geodynamics studies is also being considered with the use of a MK III terminal located in different continents. A feasibility study is presently under way for a new millimeter antenna with coherent radiometer to be used up to 300 GHz and, depending on the funds available, its construction and installation will be carried out in the 82/85 period.

The research activities are mainly related to the interstellar medium and the study of extragalactic objects, quasars and peculiar galaxies.

In solar physics the activities are principally concentrated in the study of solar plasma in active regions and effective participation in the Solar Maximum Mission (NASA international program and SMY Coordination), through the high sensitivity data collected from the millimeter antenna, mainly during the two year period 81/82. To study solar X-rays, a codified imagery screen (to be flown with national sounding rockets) is being considered and a detector system (to be flown on board stratospheric balloons in 1982) is being developed.

Routine measurements of solar activities at 7 GHz and lower ionosphere VLF propagation monitoring are being also carried out at Itapetinga.

2.4 - GEOMAGNETISM

The geomagnetic research conducted at INPE comprises investigations on equatorial electrojet currents in the E region of the ionosphere, precipitation of charged particles from the inner Van Allen radiation belts into the atmosphere of the South Atlantic Magnetic Anomaly and electromagnetic induction in the earth.

The experimental work carried out is listed below:

- Continuous recording of D, H and Z components of the geomagnetic field at Eusebio (3.87^{o} S, 38^{o} 43'W) and Cachoeira Paulista (22.7^{o} S, 45^{o} 00'W), using flux-gate magnetometers.

- Measurements of electric field and Bremsstrahlung X-ray produced by the precipitation of charged particles in the atmosphere of the South Atlantic Magnetic Anomaly through balloon borne experiments, launched in the period November-December each year.

- Micropulsations in the geomagnetic field intensity recorded at Cachoeira Paulista.

- Magnetotelluric field measurements in the period range 200 seconds to 24 hours at Eusebio and Cachoeira Paulista.

In addition to the data from the experiments described above, extensive use is made of the magnetic data obtained from the World Data Center (Boulder, U.S.A.) and from NASA.

2.5 - IONOSPHERE

The interest of the Institute in this area is concerned mainly with the problems peculiar to the equatorial and low latitude ionosphere which covers a wide area of Brazil. One of the important areas of current interest is the dynamics of the equatorial ionosphere and its influence on the generation and morphology of the ionospheric fine structure, or irregularities, that affect transionospheric telecommunication systems in a significant way.

Ionosphere-magnetosphere interaction is relatively more pronounced in the low latitude region over Brazil than in other low latitude regions of the earth owing to the presence of the magnetic field anomaly close to the south Atlantic coast of Brazil. Therefore, the investigation of the aeronomic effects of energetic radiation belt particle precipitation constitute another major area of investigation. Research is also carried out in the areas of D and E region ion chemistry, minor constituents, stratosphere-ionosphere coupling, and atmospheric gravity wave propagation.

Several ground based instruments are being operated routinely by the Institute at different locations in Brazil. Two ionosondes (at Cachoeira Paulista and at Fortaleza) are used to obtain ionospheric parameters and to study the effects of particle precipitation, sporadic E, spread F, equatorial ionospheric irregularities, ionospheric bubbles, TIDs, etc. Two VHF Faraday rotation polarimeters (at Cachoeira Paulista and at São José dos Campos) are being used to study the dynamics of the equatorial and tropical ionospheric F region. Two VLF phase tracking receivers in São José dos

Campos and Atibaia and three riometers in Cachoeira Paulista and Blumenau are used to study particle precipitation in the South Atlantic Geomagnetic Anomaly. In the near future it is intended to develop VHF coherent radar and spaced receiver system for measuring the structure and dynamics of the equatorial electrojet and spread F irregularities. The construction of rocket payloads for "in situ" measurement of the ionospheric parameters has recently started.

2.6 - UPPER ATMOSPHERE

The activities of the Institute are concentrated in the areas of the composition, dynamics and photo-chemistry of the stratosphere, mesosphere and lower thermosphere, specifically including experimental studies of stratospheric aerosols, sodium distribution in the mesosphere and the chemiluminescent emissions of atomic oxygen, hydroxil and sodium. The results are interpreted in therms of the photochemistry and dynamics of the atmosphere.

The studies of the upper atmosphere at INPE are mainly based on experimental observation using the optical techniques of laser radar and photometry of atmospheric emissions. The INPE laser radar permits the study of the spatial distribution of aerosol particles and sodium. A technique is being developed to permit the measurement of mesospheric temperature. A number of photometers, developed in the Institute's laboratories, are used to measure the spatial and temporal variations of emmissions from the upper atmosphere. The existing photometers are used to measure the OI 5577, OI 6300, OH (9,4), OH (8,3), OI 7744 and Na 580 emissions, and photometers to measure the O_2 atmospheric and Herzberg bands, and a number of emmissions excited by the precipitation of energetic neutral particles from the radiation belts, have recently been put into operation. A photometer equipped with a Fabri Perot interferometer is under development to measure temperatures and winds in the F region of the ionosphere.

Recent results include: a study of the 24 hour variation in atmospheric sodium, showing that a vertical oscillation produced by the solar semi-diurnal tide is the major source of this variation; a theoretical study of the photochemistry of sodium in the middle atmosphere, showing among other things the importance of reactions involving hydrogen, a study of F region disturbances, showing that their southward propagation characteristics are consistent with their being caused by field-aligned ionospheric "bubbles" produced by the Rayleigh-Taylor instability; the measurement of stratospheric and mesospheric winds by laser radar; a study of the excitation mechanisms of the hydroxyl radical in the middle atmosphere, showing that photometric measurements are inconsistent with a single mechanism, and that a double mechanism is required to explain the observed distribution of population rates between the various vibrational levels; the demonstration of a technique to measure F-region peak height and electron density by means of photometric observations.

2.7 - PLASMA PHYSICS

The study of the propagation and interaction of waves in plasmas and the evolution of instabilities is very important for the understanding of phenomena occuring in space plasmas, such as the ionosphere, solar wind, stellar atmosphere, etc. The existing and planned experimental facilities will allow the diagnosis and simulation of space plasmas in the laboratory. These facilities will also be used in the study of processes which occur in laboratory plasmas of possible importance to controlled thermonuclear fusion. The areas of interest are: nonlinear wave propagation in quiescent plasmas; RF heating of magnetically confined plasmas and energy transport in laser-produced plasmas. In parallel with the implementation of basic plasma research, technological aspects are under consideration, such as the development of equipment for the diagnosis of plasmas and the construction of ion microthrusters for satellite orbital and attitude control.

CHAPTER III

SPACE TECHNOLOGY

3.1 - INTRODUCTION

Brazil has demonstrated great interest in space applications such as telecommunications, meteorology, and remote sensing of earth resources by satellite since early in the space age. This interest was justified by the prospect of being able to collect inexpensive, reliable data of various types over the vastness of its territory and to provide integrating communications among remote regions. In effect, Brazilian participation in experimental and operational international space applications programs has steadily increased over the last two decades and is now quite significant in world terms.

In the area of space technology, substantial progress has taken place in recent years in the development of earth stations for point-to-point telecommunications by satellite and for the reception and processing of signals from meteorological and remote sensing satellites. Stratospheric balloon and sounding rocket payloads have also been developed and used in a number of earth-oriented applications, as well as in scientific experiments.

The importance played by the existing space applications programs and the degree of maturity reached by Brazilian research and development institutions involved in space activities, on the one hand, and the increasing technological requirements of national development in this and related areas, on the other, have suggested the development of Brazilian applications satellites specifically designed for national needs.

Design, development, integration, testing, qualification, and operation of satellites in orbit: these are space technology goals

to be attained by INPE and Brazilian industry by the end of the current decade, in the framework of the Brazilian space program. The program calls for a first satellite carrying a repeater for data originated from ground-based environmental data collecting plataforms (DCPs), and a second satellite for remote sensing in optical frequencies. These relatively small satellites (each with mass under 200 kg) shall be placed in circular orbits at altitudes not exceeding 800 km.

A brief description of the activities on Space Technology and related areas is given below.

3.2 - SATELLITE TECHNOLOGY

Activities in the satellite program are concentrated in the following areas: spacecraft structure and thermal control; solar power generation, conditioning, and distribution; on-board data handling; telecommunications; attitude and trajectory control; spacecraft payload functions; spacecraft integration and testing, including simulated environment tests; and ground-based tracking, telemetry, and control (TTC) and data handling operations. Particularly important are those activities related to the qualification of components and subsystems of utilization in space, which will envolve preliminary experiment on board stratospheric balloons, sounding rockets, and possibly, orbital space vehicles such as NASA's Space Shuttle.

Other types of satellites are envisaged to be developed in the future on the basis of the experience obtained from these first missions. A number of ground facilities required by the first two satellites will remain available beyond the completion of the program here described.

The following paragraphs contain a brief description of each of the forementioned areas of activity for the Brazilian satellite program.

- Spacecraft structure and thermal control

Work in this area includes structural analysis and design for the two types of satellite under study, with consideration of forces and moments that act on the spacecraft during launch and in orbit. The requirements for dynamic stability will be determined in each case. Similar analysis, design, and choice of materials are necessary for the passive thermal control system of each satellite.

- Solar power generation, conditioning, and distribution

Power supply subsystems for the satellite are being designed from the basic data of orbital mechanics (which define illumination by the sun) and power requirements from each on-board subsystem in each phase of the orbit. Model simulation and hardware development will follow.

- On-board data handling

The on-board computer subsystem will be based on a distributed processing concept. Besides general supervision involving data acquisition and distribution in the spacecraft and routing of most telecommand and telemetry messages, this subsystem is in charge of performing control and data management algorithms, as in the attitude control function required for the remote sensing satellite. The on-board computers will be fully interactive with its ground-based counterparts and a standard space communications protocol will be required for this purpose.

- Telecommunications

The on-board telecommunication subsystem considered here is responsible for general housekeeping functions of telecommand reception and telemetry transmission, besides serving as a repeater for tracking signals. As in the case of other subsystems, specification, design, and laboratory development will be carried out to obtain prototypes that can be integrated and tested with the various spacecraft models.

- Attitude and trajectory control

Modelling and analysis of the motion of the satellite in low Earth orbit, with the preparation of algorithms and computer programs for trajectory estimation and guidance, are the principal activities already in progress in this area. The data collecting satellite will carry a passive attitude control system (using Earth's gravity gradient) and will not require trajectory control beyond the launch phase. The remote sensing satellite will be equipped with active on-board systems for attitude and orbit control, given that the mission requires accurate pointing of an optical instrument and continued operation in heliosynchronous orbit.

- Spacecraft payload functions

Each satellite will carry a specialized mission-oriented payload. In the case of the data collecting satellite, this is an UHF to S-band transponder that relays DCP data received from the earth back to one or two receiving earth stations. The mission-oriented payload for the remote sensing satellite is an optical system with charge-coupled device sensors and associated hardware for high-speed data conversion, formatting, modulation and transmission to the earth. Both payloads share antennas with the above described telecommunications subsystem, but are otherwise independent from it.

- Spacecraft integration and testing

Integration and testing of subsystem and, at the final stage, of the complete spacecraft, consist in the methodical sequence of steps which culminate with the assembly of a properly operating ensemble for the mission envisaged. Test instrumentation and procedures will be required for both satellites, and extensive computer programming will be developed for the simulation of integrated spacecraft in orbit. Adequate facilities for the more elaborate simulated-environment tests, not yet available in Brazil, shall also be required by the satellite program. Existing facilities in INPE are sufficient for testing certain sub-assemblies in conditions similar to those of the upper atmosphere.

- Ground-based TTC and data handling operations

A very substantial part of the effort in the satellite program is devoted to the ground segment, which includes a main station and a backup station for tracking, telemetry, and command operations in all phases of satellite life. A control center will be responsible for all routine housekeeping operations, as well as special manoeuvers. A terrestrial data communication network and a processing and distribuition center for mission-related data (DCP or remote sensing) are equally important constituents of the ground segment.

3.3 - SYSTEMS ENGINEERING

The main objective of Systems Engineering is to develop a well-defined body of knowledge and techniques that can be used in the analysis of complex systems. Research in Systems Engineering includes the development of methodology for economic analysis of space projects, particularly cost-benefit analysis of space projects, economic analysis of the Brazilian satellite program and economic

analysis of the profitability of transference of technology derived from space activities.

Another research area is related to the planning, management and control of projects, involving the use of optimization methods, modelling techniques, and operations research and systems engineering methodology. Studies thus far have developed methodology and techniques of project planning and control, in the development of forecastind and estimation methods applied to remote sensing, meteorology and crop forecasting, and in operations research techniques, mainly in systems optmization and modelling.

Also, methologies of urban-regional planning were developed through the use of data interpretation from remote sensing and systems engineering concepts. LANDSAT imagery is used in the study of the limitation of urban systems dynamics, in the interpretation of the evolution of urban space in the cities by means of statistical techniques and information provided by remote sensing, and in the transference of know-how to other Brazilian or foreing research institutes.

3.4 - COMPUTER SCIENCE AND INFORMATICS

This program develops software packages needed for the execution of research and technology activities of the Institute. Three main research lines were estabilished: image processing and pattern recognition, with application to remote sensing and meteorological satellites imagery; artificial intelligence and programming languages, with the development of language translators and studies in man-machine interfaces applicable to space activities; and application software development for special needs of INPE, with emphasis on software engineering techniques, reliabity, portability and maintainability.

Thus, the continuity of the various activities of the research team will increase proficiency in the following areas: image pre-processing, image classification, pattern recognition; man-machine interfaces, computer decision-making, heuristic search methods; compilers, interpreters and translators, real time languages, data compression, computer graphics, data bases; software engineering tools - program testing, debugging and documentation; and in applications such as computer-aided project planning and control, software for mission control, spare systems data management, and software for remote sensing and meteorology.

3.5 - MATERIAL SCIENCE AND TECHNOLOGY

The aim of this program is to develop solid state devices based on the photovoltaic effect and to study the physics associated with their functioning and properties, always paying attention to the needs of the other projects of the Institute.

Ongoing research includes monocristalline silicon solar cells, ternary semiconductor infrared detectors, physics of MOS devices, physics of doped semiconductors (e.g. Si:P), and disorderd materials.

Besides basic research in the areas, it is expected that important technologies will be dominated in the fabrication of solar cells of polycristalline silicon and infrared detectors.

3.6 - SENSOR SYSTEMS

The principal goal is the develpment of sensor elements and complete sensor systems of interest for the Institute.

The initial emphasis has gone to the infrared, but other spectral regions will be considered, according to the evolving needs

of other activities in the Institute. The infrared detectors realized so far will be improved by the inclusion of a pre-amplifier stage integrated on the same substrate (SiC) as the detector. Cryogenic quantum detectors will also be built with ternary alloys grown in the Institute.

A high resolution multispectral camera intended for remote sensing satellites will be developed using electronic scanning on one axis with CCD detectors. The first prototype will be tested on INPE's Bandeirante aircraft, and possibly in stratospheric balloons. The prototipe digital solar detectors thus far developed will be improved for use on the attitude measurement of satellites. Preliminary tests will be carried out on stratospheric balloons.

The sensor systems already constructed will be improved, including a nitrogen laser UV fluorescence measuring system to detect oil on the surfaces of the ocean. Besides this, new sensor systems will be developed and tested. These include a high resolution and high precision radiometer to be used in the Bandeirante aircraft, to measure temperatures of the ground below (0.2 rd. resolution, or 10 m at 2 km altitude), a scanner imaging device for the thermal infrared to be used on the Bandeirante spacecraft, a microwave radiometer and a high resolution telescope to be loaded on a stratospheric balloon for infrared astronomy studies.

3.7 - COMBUSTION

These activities include basic and technological research in combustion processes, propulsion, flame acoustics and ionization, burning of biomass and alternative fuels.

In the area of propulsion, small cold gas and hydrazine decomposition engines are being realized. Hypergolic bipropellent, ionic and jet pulsed microengines will be developed, all to be used

in attitude control of orbiting satellites. Continuation will be given to ongoing studies of ignition techniques for conventional internal combustion engines, by use of a high power spark, to improve burning conditions so as to increase efficiency and to lower pollution.

Concerning flame acoustics and ionization, studies are being made of instabilities in the combustion of solid propellents, which will be extended to liquid propellents and to electromagnetic effects on the instability of combustion of weakly ionized gases.

Burning of biomass and alternative fuels are being investigated by means of a fluidized bed combustor, searching for maximum efficiency in the burning of mineral coal, and determining the rate of production of biogas, starting from varios types of biomass at room temperature or under controlled conditions in anaerobic digestors.

3.8 - SPACE GEODESY

Research in space geodesy at the Institute uses artificial satellite tracking for the determination of geodesic coordinates of points, in gathering of space vehicles orbital data and in the modelling of the geopotencial above the Brazilian territory. The geodesic coordinates determination is partly done in conjunction with LANDSAT image retrieval for cartographic application and uses INPE Doppler tracking station. Orbital data are obtained from the Doppler station and the Laser tracking station in operation (Natal, RN, in cooperation with the Smithsonian Institution, USA); a new Laser tracking station, for the same purpose, functioning in another region of Brazil, is under consideration. These data will be handled for artificial satellites orbit determination and the improvement of satellite motion models. Besides that, the data will be used to obtain geopotential parameters jointly with gravimetric data. In order to accomplish Brazilian satellite tracking and guidance, for the forecast and precise orbit determination, the complete knowledge of the

geopotential in the region of the space above the Brazilian territory is needed.

3.9 - DIGITAL AND ANALOG SYSTEMS

This program is engaged in the development of reliable analog and digital processing systems, including two data networks, one for support in space missions and another for date collection and distribution.

Data processing hardware and software under development are: on-board data handling systems for spacecraft and aircraft, programmable data collection plataforms, image processing systems, and an incremental computer. A new on-board computer (called ASTRO B/2) is being developed for stratospheric ballon missions and remote sensing missions using an airplane. On the ground, computers of another series (ASTRO S) and some of their peripherals are being designed and programmed to be used to receive telemetry and send telecommand data, in the configuration of the nodes of the projected data network. As to the acquisition, processing and transmission of images and similar data, microprogrammed minicomputers with a 16 -bit word length are being developed (hardware, firmware, and software). These computers (designated ASTRO M and ASTRO P include a floating-point arithmetic unit, which shall be capable of operating in the nodes of high-speed data communication networks. Finally, the incremental computer under development (ASTRO L) is of the array type. This computer will be capable of parallel multiprocessing with up to 63 processing units (besides the control and supervision units), and one of its typical applications will be in the number crunching for solving systems of differential equations. It should be emphasized that the various ASTRO computers results from design, development as well as programming work perfomed in INPE as a purely Brazilian effort.

A similar observation applies to work under way in connection with data communication networks. Here, the objective is developing pilot network, as well as a future operational network for use in connection with the first Brazilian satellite missions. Various types of equipment for data network applications have already been built as prototypes in INPE's laboratories, among which programmable and non-programmable teletype terminals, multiple cassette-tape digital memory controller (including tape transport), acoustic couplers and low-speed data modems; and programmable units for data collection platforms (DCPs) to be used with geostationary satellites.

3.10 - TELECOMMNICATION BY SATELLITE

In order to develop in the future a technology of geostationary telecommunication satellites, INPE will soon undertake preliminary system studies, with an emphasis in on-board telecommunication subsystems (antennas, feeds, filters, transponders, and related equipment). The subsystems will later undergo laboratory development of an exploration nature, so as to verify functional performance of each prototype, with little concern during the phase for the stringent requirements of operations in space (mass and volume limitation, long-term realiability, and compatibility with the environment of outer space). It is believed that in the latter half of the decade it will be possible to participate in the actual development of space-qualified hardware for geostationary telecommunication satellites.

Concerning the ground segment for telecommunication by satellite, there is an on-going program that is developing small earth stations for thin-route narrowband communications (voice, data and telegraphy). The first laboratory prototype, for communication in the 6 and 4 GHz bands, is due to be completed in 1981. Later versions will operate in the 14 and 12 GHz bands.

Studies concerning the propagation of radio waves with frequencies above 10 GHz in the space above Brazil are also due to proceed. Knowledge of propagation characteristic in those frequencies is extremely important, especially in equatorial and tropical climates, because of their future use in operational telecommunication satellite systems. Measurements will be carried out by means of experimental earth stations and, in some cases, radio telescopes.

3.11 - CONCLUDING REMARKS

Space connected efforts in Brazil provide a new goal stimulating the improvement of standards of excellence in research and development, with a corresponding increase in the existing industrial capacity.

Furthermore, the program provides a challenging and exciting common application for scientists and engineers to develop a variety of otherwise weakly interconnected efforts, in a supporting and mutually stimulation context. This is particularly the case of those areas where development tends to be slow which might well be neglected without the coherent motivation normally associated with a large program, because they are too small to warrant independent investment in infraestructure.

Similarly, certain ground based applications are considered to be too distant into future by prospective funding agencies unless the space program requires similar hardware or software. One of the more spetacular spin-offs was created by the development of solar cells some two decades ago. On a different scale, the same is happening in the present Brazilian effort concerning all sorts of photovoltaic device, in imaging systems and in applications of combustion studies to the search of alternative energy sources.

CHAPTER IV

SPACE APPLICATIONS

4.1 - INTRODUCTION

The effort on Space Science in Brazil was followed in the last decade by a large and important program on Space applications, especially in the areas of remote sensing and meteorology. Territory integration and the necessity of obtaining low-cost reliable periodic information about it were the key factors responsible for the massive utilization of data collected and/or transmitted by the so-called application satellites in the areas mentioned above.

The Brazilian territory is not yet well known, mainly with respect to its natural resources. With an area of a little over 8,500,000 square kilometers, it presents large regions of difficult acess and low population density (for example, the Amazon Forest occupies a surface of about half of it), making hard, if not impossible, to study it by conventional methods. The dynamical character of the processes that contribute to the social and/or economical development of the country and/or to its security asks for a data collection systems that presents four basic ingredients: can be applied for the whole territory; has a low cost/benefit ratio; has an almost real-time data utilization character and can be used many times (periodically, if possible).

Consequently, Earth observation satellites which allows the periodic survey of large areas very rapidly and at relatively low cost became an effective tool for Brazil to increase the knowledge about its renewable and non-renewable resources, its weather and climate and to monitor the modifications that take place on its environment.

The present situation about Space Applications in Brazil can be summarized as follow:

- there are facilities for the reception, processing and dissemination of data collected by all existing remote sensing and meteorological satellites;

- a significant effort has being devoted to the development of methodologies for the application of those data in the survey and monitoring of natural resources (mineral, agronomical, forest, hydric, oceanographic) and land use, observation of the environment, map and thematic cartography, regional and urban planning, pollution, disaster forecast and monitoring, weather and climate forecast, crop survey, management of atmospheric resources, among others; special emphasy is given to projects related to national priorities which today include Agriculture and Energy;

- the know-how needed for the design and construction of satellite ground receiving and processing systems has being acquired;

- the results already obtained have shown that the economic return to the country has completely justified the investment made.

Next, a brief description of the activities in the areas of satellites remote sensing and meteorology is presented.

4.2 - RECEPTION, PROCESSING AND DISSEMINATION OF IMAGES AND DATA FROM METEOROLOGICAL SATELLITES

Today, at the Institute it is possible to receive satellite imagery of high and low resolution in at least two channels

(visible and infrared), radiation data for the determination of vertical temperature profiles, as well as of water vapor content, WEFAX broadcasting of messages, maps and images, and relaying of data collected by remote plaftorms (ARGOS and GOES systems). With the use of specific receiving and processing stations developed and operated by the Institute, data are being received from all satellites accessible from the Brazilian territory (geosynchronous satellites SMS/GOES and sun-synchronous satellites of the TIROS-N family). The activities in this field started in 1967 with the design and construction of an APT station for the reception of low resolution visible imagery; this prototype was then given to private industry. Over 20 units were built and installed at several institutions in the country and have been systematically upgraded (some of them, for example, received an S-Band adaptation kit, designed and built at the Institute in 1979, which allows for the direct reception of WEFAX signals transmitted by the geoestationary satellites). A VHRR/VTPR receiving station was also developed for the NOAA satellites. The high resolution images (900 meters on the ground) in two channels (visible and thermal infrared) were found mainly useful applications in both meteorology and oceanography. A receiving station for the SMS/GOES satellite was later developed and integrated. Data in the infrared (1978) and in the visible channel (1980) are produced by a laser beam recorder. The upgrading of the VHRR/VTPR station in 1980 enabled it to receive the AVHRR/TOVS signal, including images in four channels.

The Institute is presently providing images to several users (including operational centers) in the form of paper copy or through transmission by telephone lines.

4.3 - METEOROLOGICAL INSTRUMENTATION

Besides the vast experience in the design, construction and integration of station for the reception and processing of data from meteorological satellites (APT, VHRR/VTPR, SMS/GOES, WEFAX), another effort was done in the development of new systems devoted

to the extraction of information from them in quasi real time, with the use of computers and man-machine interactive systems. The Image Storage and Display Unit, designed and built at the Institute, is the first step towards the development of an Interactive Image Processing System to be accomplished.

In the area of Satellite Data Collection Platforms (DCP), an ARGOS/DCP prototype (to be used with the low-orbiting TIROS/N type satellites) is presently undergoing final tests. Ten units will be built for the pilot ARGOS/DCP network. The required software for the reception and decoding of the ARGOS signals has been developed. The DCP's are compatible with those which will be used by the Data Collection Brazilian Satellites to be built in cooperation with the national private industry. Two prototypes are being developed for use with the SMS/GOES satellites, one being a dedicated unit for certain sensors, and the other a programable unit. After their industrialization, they will integrate the GOES/DCP network (Ten initial dedicated platforms are envisaged).

4.4 - METEOROLOGICAL APPLICATIONS

Technique and models are being developed for the management of atmospheric resources and their application in the areas of agriculture, environment and energy. This objective is pursued through the systematic investigation of the mechanisms of interaction between the atmosphere and human activities, as well as through the development of the necessary systems for the processing of meteorological information, especially from satellites.

In particular, the implementation of a system for the reception of meteorological satellites and the development of associated processing systems have laid the foundation for the effective application of satellite information to the management of atmospheric resources. The accumulated experience in the processing of conventional data is also relevant.

The results already obtained in studies of physical processes in the planetary boundary layer are specially significant from the point of view of application in the areas of agriculture and environment.

The inclusion of the area of Cloud Physics, although new in the organization, is based upon experience brought from other centers.

4.5 - DYNAMIC METEOROLOGY

The objective in this area is to understand the basic phenomena which control the dinamic behaviour of the atmosphere, especially over Brazil, with emphasis on the use of general circulation models.

The fact that the socio-economic planning of the country is so vulnerable with respect to meteorological phenomena and adverse climatic conditions stresses the importance and the real need to understand the complex thermo-hydrodynamic system of the atmosphere.

One approach to the study of the structure and the dynamic behaviour of the atmosphere is through numerical modelling, by making use of numerical weather prediction and general circulation models. These models should be able to reproduce the physical and dynamic phenomena responsible for the evolution of the states of weather and climate.

In addition, synoptic-climatological studies are essential in the establishment of cause-effect relationships associated with weather and climate variations, as well as to validate the numerical models. Due to the observational nature of these studies, special attention must be paid to the aspects of acquisition, processing and storage of meteorological information, both conventional and from satellites.

In the area of modelling, four specific numerical models have been developed and tested with simulated and real data.

In spite of the fact that the knowledge is still small in the country, in the area of climate modelling, significant progress has been made and it is contemplated that the main stream of activities here will consist of the use of general circulation models for simulation studies and validation of climatic hypotheses. In particular, an experiment has been performed in cooperation with the U.S. NASA - Goddard Laboratory for Atmospheric Sciences, with the use of the GLAS general circulation model. This study highlighted the influence of sea surface anomalies in the North and South Atlantic upon the occurence of severe drought in Northeastern Brazil.

4.6 - IMAGE PRODUCTION

The Institute participates in the LANDSAT program and has a well established tracking, receiving, processing and distribution system. The tracking and receiving station is located at Cuiabá - MT, this allowing the coverage of great part of the South America; the processing station and dissemination center are located at Cachoeira Paulista, SP. INPE offers its users several LANDSAT products, such as black and white and color MSS images, as well as computer compatible tapes (CCT). Paper products range in scale from 1:3,704,000 to 1:250,000 for MSS or to 1:100,000 for RBV. The receiving and processing system is being upgraded so as to receive and process MSS and thematic mapper data from LANDSAT D as well as SPOT data. There is also two-engine "Bandeirante" aircraft equipped with several sensors (RC-10, I^2S, PRT-r, HASSELBLAD), other field equipment (ISCO, EGT) and two automatic image analysis systems: a GE-IMAGE-100 (Multiespectral Image Analyser) and a Bendix MDAS (Multiespectral Data Analyser System). Several algorithms for machine classification and image enhancement are available. Some specific routines as MAXVER (Maximum likelihood) classifier and digital filterings were developed and implemented by INPE's technical staff.

User service centers, located in different cities, are normally in operation providing to the user community the necessary assistance.

The large amount of data and the facilities available have allowed the development of a great number of new application methodologies in many areas of importance for the country.

4.7 - MINERAL RESOURCES

Application of remote sensing techniques in the survey and control of potential mineral deposits has being a constant preocupation in the program. For that purpose, there has been an attempt to study the spectral characteristics of lithologic units, such as: experimental evaluation of geological information contained in several spectral bands; correlation of geological, geobotanical, geophysical and geochemical data with remote sensing data for mapping surface reflections of deep-seated structures, spectral characterization of lithological units, mineralizad zones and hydrothermally altered rocks; evaluation of geothermal resources with "in situ" thermometric determinations; discrimination of mineral deposits in humid tropical forests; analysis of greisen zones in several granitoid terrains; mineral-bearing structures survey in several geological environments; structural studies of sedimentary basins, basement, and impact structures; delimitation of mineral zones utilizing classification and enhancement techniques; morpho-structrural studies of sedimentary basins for prospecting hydrocarbon deposits and aquifers; studies of physical parameters of lithologic units such as, thermal inertia, temperature and moisture.

4.8 - AGRONOMY AND FORESTRY

Activities in these areas include: crop identification and area estimate; characterization; mapping, inventory, management and monitoring of natural and artificial forest lands; cartography and study of soil spectral characteristics.

Studies of crop identification and area estimate have been carried out for many crops, like sugar-cane, wheat, soybean and corn.

Methods for the evaluation and monitoring of natural vegetation, and reforestation using LANDSAT data have being developed. Results for the Amazon deforestation, national park monitoring and reforestation with pinus and eucalyptus have shown that remote sensing is an efficient and important tool. Today, national-wide programs are being established in those areas.

Large soil groups can be mapped using LANDSATdata in the visual and near-infrared channels. Besides this, a study is now under way on the spectral characteristics of soil in the thermal region.

4.9 - OCEAN RESOURCES

Meteorological satellites (SMS-2, NOAA-6, TIROS-N) and LANDSAT data have been used in the development of fishing charts, studies of the dynamics of oceanographic phenomena, and control of sea-water pollution.

Fishing charts are produced using temperatures of the sea surface provided by the satellite imagery, and oceanographic and fishing data. These charts provide important information about the best fishing areas for pelagic species such as sardines and tuna. At present the activities converge to the establishment of an operational methodology for the generation and transfer of the charts to the users. Detection and monitoring of upwelling in the Cabo Frio region and the dynamics of the Brazilian and Malvinas Currents in the western South Atlantic Ocean are being under study.

4.10 - ENVIRONMENTAL ANALYSIS

Applications of remote sensing data in the analysis and monitoring of environment, specially in the field of Geomorphology and land use have been developed.

The main objectives of the research projects are: to study the relationship between land use and silting problems in man-made reservoirs using MSS-LANDSAT data; to study the correlations between land use types and gully erosion of soils; to establish a methodology to use all available remote sensing data to study the relationship between human activities and the morphogenesis of small river basins; to analyse the effects of topography on the spectral response of different soil types; to develop a methodology to monitor areas polluted by coal-mining activities; to monitor metropolitan areas by means of the analysis of population increase and urban land use changes.

4.11 - IMAGE PROCESSING AND RECOGNITION

This program includes the development of algorithms, programs and documentation for: image enhancement, using histogram transformations, homomorphic and Wiener filtering, and mappings from the spectral to the color space; image geometric registry, using correlation measure; feature selection, using Fischer separating planes; and image classification using aggregation, texture and context. These activities are part of those of the Computer Science and Informatics Program, described elsewhere in this document.

4.12 - CROP FORECASTING

A Crop Forecasting System using Earth Observation Satellite is being developed through the combination of activities of three areas: Remote Sensing, Meteorology and Systems Engineering. This program uses, primarily, remote sensing data obtained from earth resources satellites to furnish basic information for the determination of area under cultivation, crop characteristics and phytossanitary

aspects. Meteorological satellites are also used to obtain meteorological data which are necessary in the crop productivity model, in combination with historical data. Major crops, such as sugar-cane, soybean and wheat occupying the southern states of Brazil (São Paulo, Paranã, Santa Catarina e Rio Grande do Sul) were selected for study.

4.13 - CARTOGRAPHY

As Brazil is a very large country with some regions still very poorly mapped, a governmental program has been established with the objective of having the country fully mapped in the scale of 1:250,000 by the end of the year 1983. Studies were carried out in order to use remote sensing data to support the job.

Improvements were made towards enhancing the geometric quality of LANDSAT images. Internal accuracies came down to the range of 100 to 150 meters, allowing the images to be used directly as planimetric base for the charts. Successful pilot projects were established to produce 1:250,00 Topographic Image Maps and 1:250,000 Aeronautical charts.

4.14 - CONCLUDING REMARKS

Research and technological development on Space Applications have been carried out in Brazil for more than one decade. The experience acquired during that period has confirmed that the benefits provided by this new technology are enormous, helping the governmental and private sectors of the society to established efficient planning, policy and decision making.

Significant results have been obtained with the use of remote sensing techniques in a wide range of applications. Soil mapping, survey of potential areas for agricultural expansion, crop identification and area estimation, crop forecasting, mineral and oil exploration, monitoring and evaluation of reforestation, natural

vegetation mapping and deforestation, cartographic applications, fishing charts and land use are some important examples which are nowadays reaching an operational stage.

Since the beginning of the Satellite Remote Sensing Program in 1973, the number of images produced and the number of users have grown steadily. In terms of image production, Brazil is second in the world (near 20,000 images produced last year) and the number of users (mostly institutions) has crossed the 1,300 mark (more than 1,000 are Brazilian).

Today, remote sensing is a reality in Brazil. Due to the spetacular utilization of remote sensing satellite data, two further steps were already taken by the Brazilian Government.

The first one is the decision to upgrade the existing LANDSAT reception and processing stations to receive and process MSS and Thematic data from LANDSAT-D satellite as well as SPOT data. The second is related to the project, construction, integration and operation (all done by INPE with the effective participation of Brazilian industries) of two remote sensing satellites, which will be launched by a Brazilian launcher in the 1987 - 1990 period.

The meteorological satellite data, besides its use in many important conventional meteorological applications, allow for the realization of basic research in numerical modeling of the atmosphere, thus improving weather and climate forecasting and simulation of climate variations. It is important to observe that meteorological satellite data have a great importance for South America, as they are the important source of information about the oceans, which play an important role in the meteorologic and climate characteristics of that region.

In all cases, the transference to the user community of the know-how, technology and related methodology developed in a given application is a constant preocupation in the process. Besides offering on-the-job training, especialized seminars and graduate courses, the participation of the user institution in the methodology development phase is always forced for the transfer to be more effective.

CHAPTER V

INTERNATIONAL COOPERATION

The existence of Earth observation satellites has openned new possibilities of knowing better, monitoring and exploiting our planet. They are important tools for the development of countries like Brazil, which present large territory with important areas of difficult access and low population density and have agriculture and energy as national priorities.

The continuation of the free (no-cost) reception of meteorological satellite data by all interested countries is a policy that is strongly recommended.

However, a trend to transform the low-cost reception of remote sensing satellites data into a profite commercial business has been observed. If this is confirmed, the utilization of the data by developing countries will be seriously jeopardized. In that case, precautions must be taken by United Nations in order to prevent the establishment of operational systems in a commercial basis or, if not possible, at least to force the countries that own the satellite to make available to the users community, at a reasonable price, the remote sensing data gathered.