COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1972/15

THE UNITED NATIONS PANEL MEETING ON THE ESTABLISHMENT AND IMPLEMENTATION OF RESEARCH PROGRAMMES IN REMOTE SENSING

BRAZIL, NOVEMBER - DECEMBER 1971

by

C. Maffi

Record 1972/15

THE UNITED NATIONS PANEL MEETING ON THE ESTABLISHMENT AND IMPLEMENTATION OF RESEARCH PROGRAMMES IN REMOTE SENSING

BRAZIL, NOVEMBER - DECEMBER 1971

by

C. Maffi

CONTENTS

SUMMARY

The work of the Panel consisted in a study of the remote sensing experiences of Brazil, Canada, India, and Mexico.

This paper contains a detailed description of the Brazilian organization and equipment, some examples of the Brazilian activity and an outline of the Brazilian proposals to NASA for participation in the Natural Resources Technology Satellites (ERTS) and SKYLAB programmes.

The Canadian, Indian, and Mexican programmes are briefly described.

It is concluded that the exploration of natural resources by means of remote sensing techniques is best done if the activities are co-ordinated, under a multi-disciplinary programme, by a National Remote Sensing Centre. The National Centre could be assisted by Regional Interpretation Centres under the control of local administrations. A tentative programme for the establishment of such an organization is outlined.

The establishment of a research programme in automatic processing of remote sensing data by BMR is suggested.

INTRODUCTION

The United Nations Technical Panels on Remote Sensing were instituted early in 1971, in response to the recommendations expressed by the Scientific and Technical Sub-Committee of the U.N. Committee on the Peaceful Uses of Outer Space. They are intended to be a means of studying the development of remote sensing techniques, and of providing the U.N. Member States with information and recommendations on the use of such techniques.

The first Panel was convened in the United States from 3 to 14 May 1971. It was mainly devoted to the observation of remote sensing activities in progress in the United States. A second meeting, which took the form of a Technical Consultation on remote sensing applications to the management of food and agriculture, was held in Rome, in co-operation with FAO, from 13 to 17 September 1971.

The third meeting, described below, was held in Brazil from 29 November to 10 December 1971. The purpose was to study the organization and administration of a programme of remote sensing of natural resources and to prepare a report for submission to the U.N. Scientific and Technical Sub-Committee. To achieve its purpose, the Panel investigated in detail the Brazilian programme of remote sensing and, to a lesser degree, the Canadian, Indian, and Mexican programmes.

The information contained in this report is derived from the sessions of the Panel, from papers presented to the Panel, and from discussions with other delegates as well as with Brazilian experts.

WORK OF THE PANEL

The meeting was held at INPE (National Institute for Space Research) in São José dos Campos, State of São Paulo. 136 delegates attended, 83 of them from the host country and 53 from 16 Nations, the U.N. Secretariat, other international organizations and specialized agencies.

The Panel elected R.J. Imawan of Indonesia as Chairman. A group of delegates from Argentina, Australia, Brazil, India, Nigeria, and USSR was elected to draft the Official Report of the Meeting.

Simultaneous translation facilities were available to the delegates and a closed-circuit TV system permitted an audience to follow the work of the Panel. 38 papers, out of the 43 presented to the Panel, were read and discussed. Annex 1 of this report is a list of papers deposited in the BMR Library.

In response to a request by the Panel, the delegates of Argentina, Australia (see Annex 2), Germany, Indonesia, Italy, and Peru presented brief accounts on remote sensing activities in their countries. Since these accounts had to be prepared at short notice, they were given an informal character and excluded from the Official Report of the Meeting.

To illustrate the Brazilian programme, visits were made to the INPE campus and aircraft, to the Geoscience and Oceanographic Institutes of the University of São Paulo, to the Agronomical Institute of Campinas, and to the Department of Mineral Production and Naval Research Institute of Rio de Janeiro.

The next Panel on remote sensing will meet when more information is available, probably at the end of 1972; Argentina put forward its candidature as host country.

Many delegates showed interest in Australian activity in remote sensing and some of them expressed the hope that Australia will host one of the future Meetings.

THE BRAZILIAN PROGRAMME

1 - GENERAL INFORMATION

The organization responsible for remote sensing in Brazil is INPE, which operates in collaboration with other national agencies. Within the Brazilian Government 5-year plans, INPE is in charge of investigating solutions to problems in the fields of Natural Resources, Meteorology, Communications, Education, and Transfer of Technologies and Systems to other user agencies. Annex 3 shows the framework of a programme for the implementation of remote sensing activity based on Brazilian experience and proposed by INPE.

Specialized training of Brazilian personnel in remote sensing techniques started a few years ago, when 14 professional people from various disciplines were sent to U.S. Universities, under NASA auspices. Physicists, geologists, agronomists, foresters and oceanographers were included. When they returned to Brazil, they were entrusted with the instruction of other personnel, the development of programmes, and the design and acquisition of equipment.

At present there are over 600 personnel working full-time at INPE. About 350 of them are professional staff employed in research work. There is also a varying number (about 50 at present) of part-time consultants. Some 40 INPE graduate students are in U.S. and European Universities, working for their Ph.D's.

Post-graduate courses on the application of remote sensing techniques are available to Brazilian students. From next year these courses (in Portuguese and English) will be available also to foreign students, and scholarships will be offered to other developing countries. The teachers will be from INPE and from U.S. universities.

Some of the papers presented during the Meeting demonstrated that the Brazilians have already achieved very satisfactory results in remote sensing applications. During a conversation with INPE personnel I learned that the benefits obtained during three years' operation have permitted the administration to recover part of the cost of sending people abroad for training and of equipping the Institute.

INPE places great emphasis on the improvement and expansion of existing laboratory facilities in the field of electronics, optics, pattern recognition, etc. The aim is to enter into a phase of quantitative analysis and of experimental repeatability. Programmes for the automatic interpretation of remote sensing imagery by electronic computers are being developed in view of the enormous quantity of data that will soon become available, particularly with the launching by NASA of the Earth Resources Technology Satellites (ERTS) and of SKYLAB.

For the storage of data in a small space and for their quick retrieval, INPE is now organizing its own data bank. Not only raw and processed remote sensing data, but also any other type of information, including library references, will be processed into computer-compatible form and stored on magnetic tapes.

2 - INPE REMOTE SENSING EQUIPMENT

2.1 - AIRBORNE EQUIPMENT:

2.1.1 - Photographic cameras:

Wild RC-8 Metric Camera
Wild RC-10 Metric Camera
Multispectral Cluster composed of four Hasselblad cameras, mod. 500 EL/70, each equipped with 50, 80, 250 and 500 mm focal-length lenses.

2.1.2 - Synchro Unit:

Developed by INPE, has the function of operating the metric and multispectral cameras singly or in any combination.

2.1.3 - Dual-channel Bendix Thermal Scanner mod. LN-3:

The first channel works in the UV-visible-near IR region, with the possibility of using filters to operate in a narrow band. The second works in the mid-far IR region and is equipped with filters in the 1 - 2.7, 4 - 5.5 and 8 - 14 micron bands. The output can be recorded on tape or displayed on film in photograph-like form.

2.1.4 - Radiometer PRT-5:

Detects electromagnetic radiation in the 8 - 14 micron band. The field of view is 0.03 rad. The temperature range is -20°C to +75°C with an accuracy of 0.5°C at extreme temperatures and of 0.1°C at 25°C. The output can be read from a graph and recorded on magnetic tape.

2.1.5 - Automatic data correlator ADAS:

Generates a time signal that is recorded simultaneously by all systems and permits an accurate correlation of data.

2.1.6 - Positioning system of the aircraft:

The system provides a continuous and accurate record of the position of the aircraft in relation to ground points. It includes the following instruments:

Doppler Radar System Bendix mod. DRA-12C: provides information on the aircraft ground speed and drift angle,, at 0.2 second intervals.

Radar Altimeter Bendix mod. AN/APN-184: gives a continuous record of the aircraft altitude above the ground.

Compass System Bendix mod. DR-60: gives a continuous record of the aircraft flight direction.

Time Code Generator CGS mod. SP-300B: records in binary decimal code information on the exact flight time between preselected points.

2.1.7 - Signal Monitoring System:

Consists of a Junction Box and an Oscilloscope. The Junction Box makes the output from the sensors and auxiliary equipment compatible with the Signal Recording System (see forward) and permits a control of the output signal levels. The Oscilloscope displays on a screen the output signals from up to four sensors; to facilitate the operation of signal level control, any signal can be stored on the screen for more than an hour.

2.1.8 - Signal Recording System Ampex mod. AR-1600:

Simultaneously records on analog magnetic tape the signals from all sensors and auxiliary instruments. It has 14 tracks, 2 recording modes (direct and frequency-modulated) and 6 tape speeds.

2.2 - MAIN GROUND EQUIPMENT:

2.2.1 - Photographic processing laboratory for B & W and colour photography.

2.2.2 - Return Beam Vidicon TV Camera and Video Converter:

Used to scan photos and record the image on magnetic tape.

2.2.3 - Recorder Reproducer Ampex mod. FR-1900:

Reproduces the signals of the remote sensors and auxiliary equipment of the aircraft, from the 14-track tape, for digitization and computer processing.

2.2.4 - Computers Hewlett Packard 2116B, Burroughs 3500 and Burroughs 6700:

Digitize and process data from all the sensors and auxiliary equipment.

2.2.5 - Spectrophotometers Perkin-Elmer mod. 450 and 700; Spectroradiometer ISCO:

Are utilized to measure the reflectance, transmittance and absorption, in different spectral bands, of mineral and vegetation samples; the signatures obtained are used as patterns for the automatic processing of remote sensing data.

2.2.6 - Radiometer PRT-5:

Is used on the ground to obtain sample temperatures and to measure, in conjunction with the one installed on the aircraft (see paragraph 2.1.4), atmospheric parameters.

2.2.7 - Meteorological instruments.

Figure 1 is a flow-chart of the INPE data processing system.

3 - INPE ACTIVITY

Fundamental Research and Applied Research are the two sectors into which INPE is grouped. The first deals with scientific projects and absorbs from 20 to 30 percent of the Institute's resources. The second sector receives the larger share of the resources and aims at early and important contributions to national development.

The projects under development at INPE are:

3.1 - Fundamental Research:

3.1.1 - Project MATE: study of the geomagnetic field with emphasis on its variations and micro-pulsations.

3.1.2 - Project MIRO: subdivided into two sectors. The first studies absorption of cosmic noise by the upper atmosphere. The second sector measures parameters of the natural atmosphere between the heights of 30 and 90 Km.

3.1.3 - Project TELA: dedicated to the construction of payloads for stratospheric balloons, including several types of detectors and telemetry equipment, for the study of precipitation of charged particles in the region of the South Atlantic Magnetic Anomaly.

3.1.4 - Project OBRA: study of atmospheric noises caused by electrical discharges which interfere with radiocommunications in the VLF and HF bands.

3.1.5 - Project SAFO: research in the high atmosphere using rocket-borne payloads, with the co-operation of foreign agencies and the Brazilian Ministry of Aeronautics.

3.1.6 - Project RASA: measurement of ionosphere electron content through Faraday and Doppler effects. Also scintillation measurements of signals emitted by satellites. Generally speaking, this project studies the structure and morphology of the ionosphere and their variations.

3.1.7 - Project RADA/SOL: aims at the observation of solar explosions and flares by continuous photography in the H-alfa region, for analysis and exchange of data with other solar observatories.

3.1.8 - Project SONDA: for ionospheric sounding with variable frequency transceivers; the analysis of the resulting ionograms is a great help to communciations in the HF band.

3.1.9 - Project BEMA: study of the propagation of VLF radiation from terrestrial stations and from sounding rockets.

3.1.10 - Project LUME: observation and analysis of luminescence in the upper atmosphere.

3.1.11 - Project EXAMETNET: meteorological investigation using sounding rockets to gather data on temperature, pressure and winds at altitudes higher than those reached by balloons.

3.2 - Applied Research:

3.2.1 - Project MESA: meteorological studies using satellite-made and automatically transmitted pictures which yield cloud cover and temperature information. This project includes design and improvement of equipment for the reception and processing of pictures transmitted by U.S. meteorological satellites. Several receiving stations designed by INPE and built by Brazilian industry are in use throughout the country.

3.2.2 - Project SACI: feasibility study of a Brazilian geostationary satellite designed to relay TV programmes to improve the capabilities of the country educational system.
A pilot study will be carried out next year: a NASA

telecommunication satellite will be used to broadcast programmes to 50 schools in northeast Brazil. If this experiment is successful, the Brazilian satellite will be launched in 1976 and guided into a stationary orbit approximately 35,000 Km above the equator in northern Brazil.
A TV studio is being set up at INPE and watching centres for school children will be organized in the less developed regions of the country.

3.2.3 - Project SERE: utilization of remote sensors for the survey of natural resources in the fields of geology, hydrology, agriculture, oceanography and forestry, and for the survey of urban development, transport routes, pollution, etc.
The project consists of four phases, three of which have already been accomplished:
Phase A consisted in training, under NASA auspices, the initial group of fourteen specialists from INPE and other organizations, such as the Ministry of the Navy, the Ministry of Mines and Energy, the Ministry of Agriculture, etc.
Phase B consisted in the selection and development of test sites for the phase C flights.
Phase C consisted of overflights of the test sites by an instrumented NASA aircraft. The following instruments were used: Wild RC-8 camera; four-lens multispectral camera; side-looking radar; two-channel infrared scanner; automatic data correlator.
Phase D consists of operational flights of Brazilian aircraft and of interpretation and correlation of data collected from the field, from the aircraft and, in future, from ERTS and SKYLAB.

3.2.4 - Project RADAM: the purpose is to provide basic information for the development of the Amazon region by means of remote sensing techniques. A detailed description of this project is given in Chapter 5.

4 - EXAMPLE OF A GEOLOGICAL STUDY

To give an idea of the equipment used and of the results achieved by the Brazilians, one of the missions connected with Project SERE is described in more detail.

Most of the information is drawn from the paper "Geological studies using data from NASA Mission 96" by L.H.A. de Azevedo; some data were obtained through personal communications.

4.1 - Area:

The Iron Quadrangle, State of Minas Gerais. Surface: 10 000 Km^2.

4.2 - Reasons for choice:

4.2.1 - Area of intense mineralization.

4.2.2 - Geology previously mapped at 1:25 000 scale.

4.2.3 - Favourable position in relation to the industrialized centres of the country.

4.3 - Sensors used:

4.3.1 - Radiometer PRT-5 (8 to 14 micron band).

4.3.2 - Multispectral camera with B & W film and Wratten filters No. 47 (blue), 57 (green), 25A (red) and 89B (infrared).

4.3.3 - RC-8 Camera with B & W, Ektacolor and IR colour films.

4.3.4 - Dual-channel thermal scanner (3.0 to 5.5 and 8.0 to 14.0 micron bands).

4.3.5 - Side looking radar (16.5 GHz).

4.4 - Objectives:

4.4.1 - Map soils, rocks, laterite.

4.4.2 - Delineate vegetation and outcrop patterns.

4.4.3 - Determine regional structure and lineaments.

4.4.4 - Determine whether iron ore deposits can be identified through variations in radiometric temperatures.

4.5 - Approach:

Three areas were chosen as test sites representative of the region, to develop interpretation keys. In these areas, ground information stations were set up for the collection of data to be correlated with those obtained by the aircraft. The interpretation was based on the assumption that each sensor by itself would provide information that, when coupled with data from other sensors, would give a larger probability of uniquely identifying a given geological feature.

4.6 - Results:

4.6.1 - RC-8 Camera: A comparative analysis was made of the response of each lithologic unit on the three types of film used.

The IR colour photographs were the most suitable for mapping the Iron Formation, which is identified by its low reflectivity and stunted vegetation. In the Ektacolor photographs, the predominance of green gives an appearance of homogeneity that makes it difficult to distinguish the Iron Formation. In the B & W photographs it is difficult to map the Iron Formation from variations of tone alone.

Quartzite in the area also is identified more easily in IR colour photography than in B & W and Ektacolor.

The other rock units in the area (schists and phyllites) are covered by fertile soil with thick vegetation which makes it difficult to use only tone or colour for geological interpretation. In this situation, the drainage pattern and the geomorphological features are the most important elements for lithologic identification.

4.6.2 - Multispectral Cameras: In the interpretation of the images, a spectrometer was used to determine optical densities. Some 2 100 optical density measurements were taken from each image, then the information was compared for the 4 channels. Differentiation based on variations of grey tones was successful, even though the instruments and measuring methods were not ideal. This technique looks promising for automatic analysis of the data by computers.

Comparison of the multispectral images showed that the IR channel is far superior to the others for the objectives of this study.

On the IR channel there is a marked tonal contrast between Iron Formation and gneiss and schist, and also between vegetation types.

On the blue channel there are few contrasts in the photographic patterns and almost all the photographs are light grey.

The green channel shows a small difference in optical density between Iron Formation and other units. On this channel the vegetation shows small contrasts in relation to the surrounding elements.

The red channel shows considerable contrast: a dark tone is consistently associated with vegetation.

Using the range of tones in three channels - the blue one being abandoned because it does not increase the amount of information - an attempt was made to differentiate the Iron Formation from the vegetation and from the soils produced by schists and gneiss, etc. by using a FORTRAN IV programme developed by INPE. Some 1 000 points were selected to check the computer interpretation against detailed lithological maps made in the field. The statistical pattern showed that the probability with which the computer accurately identified a target was: 62% for the Iron Formation, 74% for the vegetation and 85% for soil derived from schists and gneiss.

4.6.3 - Thermal scanner: The best results are those in the 8 - 14 micron interval. The 3.0 - 5.5 channel has less contrast and more noise and reveals less information than the 8 - 14 channel.
Maps of thermal anomalies were made by visual comparison with a ten-tone grey scale.
On post-sunset imagery, such anomalies could be identified with materials rich in iron with satisfactory precision: a field check showed that the identification was correct in 20 out of 24 cases (83%).
It was not possible to map the other rock units in the area because of the influence of one or more of the following: thick vegetation cover; few fresh rock outcrops; soils with similar thermal properties covering different rocks.

4.6.4 - Side-looking radar: a 1:360 000 scale mosaic was made and interpreted for geographic, lithological and structural features.
The geographical interpretation was difficult because of the small scale of the mosaic: only general features could be identified.
For the lithological interpretation, drainage-texture-tone associations were used to form a number of homogeneous groups; the groups were mapped on the mosaic, then checked against ground information. The group boundaries matched with satisfactory accuracy the lithological boundaries; one of the groups corresponded with the Iron Formation. The rugged topography of the area made lithological identification of other groups difficult: the geometry of the terrain produced a complex of shadows and specular reflections that masked other factors which also

influence radar return. The lithological characteristics would be more precise and obvious in areas of less relief. Factors such as the surface roughness and the dielectric constant have more influence on the return in flat than in steep terrain.
The structural interpretation was the most successful: the radar mosaic was found to yield more structural information than existing geological maps.

5 - PROJECT RADAM (RADAR FOR THE AMAZON REGION)

The information contained in this chapter is taken from the paper "Project RADAM of the Ministry of Mines and Energy" by J.M. de Moura, integrated with information supplied by RADAM Project personnel, in Rio de Janeiro.

The planning and co-ordination of the Project is the responsibility of the National Department of Mineral Production, an agency of the Ministry of Mines and Energy. INPE and several other agencies assist with personnel and equipment.

The initial plan involved the mapping of 1.5 million Km^2; then the Project was extended to cover 3.7 million Km^2, one third of which had been flown by December 1971. About 90 professional staff and more than 20 students are employed in image interpretation and field work. The budget of the project is 18 million U.S. dollars.

5.1 - Aircraft:

Twin-jet Caravelle, flying at 11 to 12 000 m above ground level.
Operative speed: 700 Km/hour.

5.2 - Sensors:

5.2.1 - Side-looking radar Goodyear mod. 102: it operates in the X-band (3 cm wavelength; 9 600 MHz frequency). The antenna is of the synthetic aperture type and can be switched to either side of the aircraft, to obtain images having the same look direction when the aircraft reverses its course. Horizontal polarization is used for transmission and reception. The spatial resolution is better than 20 m at any point. The depression angles of the scanner are between 13° and 45° from the horizon. The side swath in each run covers 37 Km in width.
From the imagery, 1:250 000 scale mosaics are produced; the scale is to be uniform to within 1%, throughout the whole mosaic.

5.2.2 - Zeiss metric camera: is equipped with a super-wide-angle lens to obtain 1:130 000 scale photographs. The film used is IR colour. The overlap along each run is 60%.

5.2.3 - Multispectral camera I^2S: is equipped with four independent synchronized lenses. B & W infrared film is used in conjunction with green, red, blue and infrared filters. The scale of the photos is 1:73 000.

5.2.4 - TV camera: produces a vertical record of the flight path on video magnetic tape.

5.3 - Flight mode:

The flights are carried out along north-south lines. All sensors are operated simultaneously. The season and the time of the day were chosen in order to obtain the best results from photography: it is estimated that, despite the tropical climate, about 50% of the photo-coverage should be cloud-free. The distance between aircraft runs was set at 23 Km, in order to obtain a 26% overlap between consecutive radar strips; thus the 1:130 000 scale photography has a small amount of side-lap, but the multispectral photography coverage is discontinuous. The rectilinearity and correct position of the flight lines are maximized by the use of suitable navigational equipment aboard the aircraft. Continuous tracking of the aircraft from ground stations, in addition to the images from the TV camera, provide data for the geometrical control of the radar mosaics.

5.4 - Interpretation:

The images are interpreted for geology, hydrology, geomorphology, vegetation and soils. The aim is to assess the potential of the region for the development of mineral resources, forest resources, hydroelectrical and fresh water resources, agriculture, transportation routes, etc.

From a preliminary analysis of the data, priority areas will be selected for more detailed surveys. These surveys will eventually lead to the selection of small areas in which development will be started.

The multispectral photography, which is now used as an aid in the interpretation of the radar imagery, will be the basis for a comparative analysis of the images to be obtained by ERTS A and B.

6 - THE BRAZILIAN PROGRAMME FOR ERTS AND SKYLAB EXPERIMENTS

The exploration of large areas which have never been surveyed before, the correction of existing maps and the selection of promising areas for further study are the main targets at which Brazil is aiming in its participation in the ERTS and SKYLAB experiments.

The results that have been achieved with the study of Gemini and Apollo images have encouraged Brazil in the preparation of its proposals to NASA. The approach will be multi-disciplinary; INPE will participate with its personnel and equipment, and will co-ordinate the efforts of other government agencies, universities and private organizations.

The programme was studied and discussed with great interest by the Panel. Its main features are outlined in the next paragraphs. Further information can be obtained from the following papers: "Brazilian program for geology using Earth Resouces Satellite data" by G. Amaral, and "Brazilian proposal for agricultural investigation using data from ERTS and SKYLAB" by L.A. Fobe.

6.1 - ERTS-A proposal:

Originally, two large areas were selected and proposed to NASA for ERTS-A coverage. The first area is in the Amazon region, the second one is the major mining, industrial and agricultural part of central-east Brazil.
Subsequently, after a consultation with NASA advisers, it was decided to propose the coverage of the whole country; the proposal was accepted in principle. For practical reasons, the territory was divided into seven areas, classified in order of priority.

6.2 - ERTS-B proposal:

The proposal for participation in the ERTS-B programme is being prepared. As the satellite will carry a thermal imaging system, priority will be given to areas in which mineral deposits associated with high thermal flow are known to exist.

6.3 - SKYLAB proposal:

For the SKYLAB experiment, Brazil has selected a number of test sites, in areas where important natural resources exploration is being carried out. As in SKYLAB the remote sensing experiments will be affected by severe time limitations, many test sites were selected with the purpose of giving NASA many different options for mission planning and execution. NASA accepted the proposal in principle.

6.4 - Methodology:

Test sites were selected for each of the disciplines involved - geology, hydrology, agriculture, forestry, geography, ecology, oceanography - where interesting features are present and ground information is already available. The satellite imagery will be firstly assessed over the test sites, then the interpretation will be extended to other areas.

For some of the test sites, repetitive coverage was requested: every two months for forestry and agriculture studies; every six months for the study of dynamic geological processes, such as fluvial and marine erosion and sedimentation, landslides, etc. The most suitable time of the year was selected for the coverage of each area.

On the test sites, data acquisition will be carried out simultaneously from four levels: data collected by the spacecraft will represent the first level; data collected by aircraft flying at high altitude will represent the second level; the third one will refer to data collected by aircraft flying at moderate to low altitude; the fourth level will include data collected from helicopters flying close to the ground data from the field and data from laboratory experiments.

6.5 - Data handling plan:

The first step will be the indexing and storage of all the material in the INPE data bank. During and after the investigation, processed data at various stages of elaboration will also be stored in the data Bank.

Since visual interpretation of the enormous amount of imagery that will be acquired would be impossible, automatic interpretation techniques will be used. The imagery will be scanned by a TV camera and the video signal will be recorded by an Ampex FR-1900 system. A Burroughs 3500, a Burroughs 6700 and a Hewlett Packard 2116B digital computers will be used to process the original data and to interpret them (see Figure 1). In the case of geology, the purpose will be to select distinct or anomalous areas; over these areas, visual interpretation will then be performed.

A particular application of the ERTS-A data will be the study of phenomena related to the dynamic history of the earth. This study will be carried out in connexion with the Brazilian participation in the Geodynamics Project which is sponsored by the International Council of Scientific Unions and is a continuation of the Upper Mantle Project, completed in 1970.

THE CANADIAN PROGRAMME

In 1969 the Canadian Cabinet Committee on Science and Technology set up an Interdepartmental Committee on Resource Satellites and Remote Sensing, with a Programme Planning Office to act as secretariat. This Planning Office set up 13 working groups composed of approximately 200 scientists from government agencies, universities and industries.

The working groups were asked to make recommendations for a national programme on remote sensing and on an organization to carry out the programme. They submitted their final reports in March 1971.

The Programme Planning Office was then replaced by a permanent organization, the Canadian Center for Remote Sensing. The working groups went out of existence and will soon be replaced by an organization to be called Canadian Advisory Committee on Remote Sensing. This committee will advise the Director of the Center on how best to use the remote sensing facilities to meet the most important national needs.

The elements of the national programme on remote sensing are:

1. The conversion of an existing radar station located at Prince Albert, Saskatchewan, into a receiving and recording station for ERTS data.
2. The institution of a Ground Data Handling facility at Ottawa which will be used for processing airborne data and for developing data-interpretation techniques. It will also be capable of producing photogrammetrically correct colour images from ERTS data.
3. The enlargement of the existing National Air Photo Library which will be responsible for receiving the ERTS and other remote sensing data for processing them in colour and black and white and for distributing them to users.
4. Aircraft Programme: in 1970 a limited airborne programme was conducted using a CF 100 high altitude aircraft belonging to the Department of National Defence. In 1971 the programme

was expanded by the addition of a DC-3 aircraft. In 1972 the programme will employ a CF 100, a FanJet Falcon and two DC-3 aircraft.

5. Sensor Development Program: universities and industries are being funded to develop new sensors. Ten sensors are now in the second year of development and three are nearly ready for airborne testing.

6. A Research Programme into the interpretation of remotely sensed data is just getting underway.

7. The establishment of Regional Interpretation Centers for conducting interpretation of available data within specified geographical areas. These Centers would be under Provincial control. The reason is that the end users of the data, as well as the persons who must make decisions based on the information thus provided, are located mainly within provincial administrations. In addition the best interpretations are likely to be made by workers who have local knowledge of an area. Because of the large amount of data that will be acquired, this decentralization is also required if bottlenecks in the flow of information are to be avoided.

8. The designation of ERTS test areas in Canada where interested agencies will undertake ground studies in conjunction with airborne and ERTS studies. Canada submitted to NASA a consolidated proposal describing 75 test areas where ground information is available and where in many cases, airborne work will be done during or before ERTS launch. The purpose is to evaluate the potential of ERTS imagery in the study of superficial geology, pedology, land classification and use, geography, ecology, forestry, hydrology, snowfall distribution, ice movements, cloud cover and pollution.

9. A symposium will be held in Ottawa in February 1972, at which the users will be presenting the initial results of their experiments.

THE INDIAN PROGRAMME

The remote sensing activity in India is co-ordinated by the Indian Space Research Organization, through its Remote Sensing Project. The headquarters of the Organization are at Ahmedabad.

The staff attached to the Remote Sensing Project consists of one Principal Investigator, two scientists and four engineers, in addition to administrative and support personnel.

Government agencies have for several years performed experiments in remote sensing: the Geological Survey, for mineral exploration; the Atomic Minerals Division, for radioactive minerals; the National Geophysical Research Institute, for the development of airborne instrumentation; the Indian Meteorological Department; and the Cartographic Survey of India.

In a country like India, with heavy dependence on food production, the Remote Sensing Project places great emphasis on agricultural studies, soil surveys, etc.; side benefits are also expected in such fields as fisheries development, forest inventory, hydrological surveys, etc.

Satisfactory results have been obtained in the early detection of crop diseases. For example, in 1970 an experiment was carried out, with the co-operation of NASA, on the detection of a virus disease that affects the coconut palm. A Hasselblad 70 mm camera with several film-filter combinations was flown on a helicopter at a speed of 100 km/hour at heights of 150 and 300 m above the ground. The best results were obtained with IR Ektachrome film:

1. Healthy coconut trees appeared red and could be distinguished from other types of trees, such as cashew trees (pink) and jack trees (brighter red than coconut trees).
2. Trees affected by the virus showed a low IR reflectance.
3. Some trees showed a slightly weak IR reflectance when their images were examined with a micro-densitometer; however in the field the same trees appeared healthy. When the juice extracted from their leaves was examined under an electron microscope, the presence of the virus was revealed.

The Indian remote sensing programme will soon be expanded. A group of experts will be trained abroad, then will be used to train local staff. Meanwhile, Indian representatives attend all congresses and symposia in which remote sensing and natural resources play an import role.

In order to have a reasonable but not too expensive capability, a four-lens camera and a thermal scanner will be acquired soon, together with photo-processing and photo-interpretation equipment. More sophisticated equipment, including a multi-channel scanner and computer facilities for data analysis, will be added at a later stage.

The future missions will be mainly concentrated on the following studies:

1. Crop classification, detection of crop stress and diseases.
2. Inventory of forest resources, detection of tree diseases.
3. Measurement of ocean surface temperatures.
4. Mapping of coastal features.
5. Assessment of flood or drought damage.
6. Detection of fresh water springs along the coast and in river valleys.
7. Detection of water discoloration due to river effluents, mud banks, plankton concentrations, etc.
8. Detection of pollution in rivers and inland watersheds.

The study of data from ERTS and SKYLAB will be a major activity of the Remote Sensing Project in the next five years. A proposal was submitted to NASA, to obtain data over the country in pictorial or in digitized form. The proposal was accepted in principle. While programmes are being prepared, one of the Project's scientists is being trained in computer data processing at Purdue University; other personnel will be trained as the programme takes shape.

A preliminary evaluation of satellite imagery for geological purposes is being carried out on pictures taken by a Nimbus satellite over the Thar Desert in northwest India. The pictures are being interpreted for geological structure and geomorphic expression.

THE MEXICAN PROGRAMME

For the co-ordination and development of research in the exploration and usage of outer space, the Mexican Secretary of Communications and Transport created, in 1962, the National Committee of Outer Space (CNEE).

In 1965, an agreement of technical co-operation was established between CNEE and NASA. One of the aspects of this co-operation is the promotion of research in remote sensing and its applications. The programme includes: the contribution by NASA in the training of Mexican specialists, the determination of the most suitable remote sensing techniques for earth resources exploration, and the development of compatible data handling systems to facilitate the exchange of information between Mexico and U.S.

For the purpose of adapting the remote sensing programme to national needs, an advisory committee was formed with representatives from user organizations: the Agriculture and Cattle Department, the Communications and Transport Department, the Marine Department, the Public Works Department, the National Patrimony Department, the Hydraulic Resources Department, the Federal Commission of Electricity, the National Nuclear Power Commission, the Mexican Oil Institute, the National Polytechnical Institute, the National Autonomous University, the Secretary of Defense and the Commission for the Study of National Territory.

In fulfillment of its attributions, CNEE promoted a four-step programme for the establishment of research in remote sensing:

Stage A: Preparation of detailed programmes, in collaboration with the U.S.; gathering and instruction of personnel.

Stage B: Institution of a Research Centre; selection of test sites; investigative flights by NASA aircraft.

Stage C: Flights by NASA aircraft.

Stage D: Acquisition by Mexico of an equipped aircraft; flights by Mexican aircraft.

Stage A ended in July 1968; the Mexican personnel were trained for six months in U.S. universities and at the Manned Spacecraft Center in Houston, Texas.

During Stgage B (July 1968 to April 1969), six test sites were selected. The NASA aircraft was equipped with two RC-8 cameras, a multiband cluster of four KA-62 cameras, a thermal scanner RS-14 (3.0 - 5.5 and 8 - 14 micron bands) and a Philco side-looking radar (16.5 GHz). The images were interpreted for geology, hydrology, agriculture, forestry and oceanography.

The main conclusions obtained from Stage B are:

1. From colour photographs at a scale larger than 1:30 000, information on geology, hydrology and land use was obtained more quickly and accurately than from panchromatic and from IR black and white photos.

2. For detailed engineering work (instability due to seepage, drainage problems) it is advisable to use IR colour photos at about 1:5 000 scale.

3. Both colour and IR colour photos give better results than any other type of photography in mineral exploration and soil studies; their use can reduce field work considerably.

4. Thermal imagery is excellent to contour surface humidity zones, to locate old river beds and to obtain hydrological information in general.

5. Radar imagery is ideal in regional studies to locate folds, faults and fractures, and to identify rock types and their state of fracturing and weathering, particularly where it would be difficult to take aerial photographs because of poor weather conditions. For mineral exploration the radar imagery has too small a scale, insufficient contrast and low resolution; however its interpretation confirmed the existence of a mineralized fault system.

One of the consequences of these conclusions has been that, from 1970, the Commission for the Study of the National Territory has abandoned the use of B & W photography at 1:25 000 scale and adopted colour photography at the same scale, to carry on its ten-year plan for the inventory of the natural resources of the whole country (approximately 2 million Km^2). Maps at 1:50 000 scale are being produced in four series: geology, soil use, potential soil use and soil fertility. The Commission is still using B & W photography at 1:50 000 scale for the production of its topographical series at 1:50 000 scale.

Stage C started in April 1969 and ended in 1970. The results were not communicated to the Panel.

The plans for Stage D are being prepared. The equipment will include: an aircraft, navigational instruments, a metric camera, a four-lens multispectral camera, a ground profile recorder, a thermal scanner and, possibly, side-looking radar, tape recorder and data processing equipment. Meanwhile CNEE is selecting the personnel required for the project, including pilots, navigators, photography technicians, systems analysts, etc.

For the ERTS-A programme, Mexico has requested from NASA the coverage of 14 test sites. The proposal was approved by NASA in principle.

The satellite imagery will be checked against the information previously obtained by means of field work and aircraft missions. The main fields of interest will be: geology, geomorphology, hydrology, agriculture, forestry, pedology, urbanism, communication routes studies, oceanography and geography.

CONCLUSIONS AND RECOMMENDATIONS

1. Remote sensing technology is still in a phase of early development. However the results achieved so far are promising and show that worthwhile economical benefits can be obtained even while experiments are being carried out.

2. Airborne and, probably, satellite-borne remote sensing are best suited for countries that have a low population-to-area ratio, such as Australia.

3. To concentrate skills and efforts, to avoid duplication and to make the best use of equipment, the exploration of natural resources by means of remote sensing should be done in accordance with a national multi-disciplinary programme.

4. From the experience of Brazil, Canada and other countries, it can be deduced that a national programme could be developed in the following way:

   a. Preparation of an initial nucleus of specialists selected from the various disciplines involved (physicists with experience in electromagnetic radiation, geologists, geophysicists, pedologists, hydrologists, oceanographers, etc.).

      Their instruction could be carried out in specialized universities, for example at Michigan University for remote sensing in general, at the University of California for remote sensing in forestry, geology and agriculture, at Purdue for automatic data processing, at the University of Kansas for radar applications in geology, geography and agriculture, at the Colorado School of Mines for remote sensing in geology, etc. However in certain instances it might be more economical to employ teachers from the specialized universities for short periods.

      The initial nucleus of specialists should then start to prepare programmes and to train other personnel.

b. Establishment of a National Remote Sensing Centre equipped with data-gathering, processing and storage facilities.

Visual interpretation is still a very important source of of information. However, automatic interpretation is likely to become more and more necessary with the rapidly growing quantity of remote sensing data that will be available in the near future, particularly when earth resources satellites will be operative.

Since the equipment for automatic data processing is very expensive, the Centre could start its activity by using existing facilities. For example, in Brazil INPE is using the electronic equipment of its meteorological station for digitizing and interpreting remote sensing data.

Storage of data in computer-compatible form would be necessary to save space and retrieval time.

The National Remote Sensing Centre should operate as a consulting body for other users, such as government agencies, universities, mining companies, etc.

c. Establishment of decentralized Interpretation Centres, under the control of local administrations. Following the Candadian example, these Centres would be responsible for collecting ground data, conducting interpretation and distributing information on a local basis. They would benefit by the services of the National Centre and feed back information to it.

5. The development of a programme of remote sensing for natural resources on a national scale can proceed by steps, following the technological progress and taking advantage of local experiences as well as those of other countries.

6. In the mean time, BMR could consider the opportunity of starting experiments on automatic data processing, in the context of its remote sensing programme. The Geophysical Branch has a small computer, similar to HP 2116 B; the services of a large computer, similar to B 6700, can be hired from CSIRO at 160 dollars per hour. What we would need to acquire is a portable Vidicon camera, a Video Converter and a suitable tape recorder. The computer programmes could be written by officers within the Geological Branch or, perhaps, they could be obtained from other organizations, such as INPE.

7. A relationship for the exchange of technical information could be established between BMR and INPE, through each's own Libraries or directly by interested Sections.

ACKNOWLEDGEMENT

I wish to express my gratitude to the Director of INPE Dr F. de Mendonça and to his staff, in particular to Mr A.G. de Souza, for providing me with valuable information on the organization and activities of INPE.

ANNEX 1

PAPERS DISCUSSED BY THE PANEL AND AVAILABLE FROM THE BMR LIBRARY

1 A.H. ABDEL GHANI - Peaceful uses of outer space.

2 H.J. RICCIARDI - Welcoming address.

3 J. HANESSIAN Jr. - Technology transfer to the less developed countries.

4 E.B. TERRACINE, F. DE MENDONÇA, J.B. MACHADO - The Brazilian remote sensing applications program on natural resources survey.

5 J.M. DE MOURA - Project RADAM (Radar for Amazon) of the Ministry of Mines and Energy.

6 R.H. MOTA, B.C. RUIZ - The role of Mexico in the sensing techniques for the evaluation of natural resources - The Mexican remote sensing program and some results of Mission 91.

7 G. AMARAL - Brazilian program for geology using ERTS data.

8 E.A. GODBY- The Canadian remote sensing program.

9 E.G. DE ALMEIDA - Oceanography - Brazilian proposal for oceanographic studies using data from ERTS and SKYLAB.

10 S. DE PAULA PEREIRA - Remote sensors and data acquisition system of INPE aircraft.

11 A.V. PADILHA - The Brazilian program for remote sensing application in mineral resources research using aircraft.

12 L.A. FOBE' - The Brazilian program on the application of remote sensing to soil resources by aircraft system.

13 R.H. MOTA, B.C. RUIZ - Participation of Mexico in the program of Earth Resources Technological Satellites (ERTS).

14 R.H. HOFFER - The importance of ground truth data in remote sensing.

15 T.A. HARIHARAN - The Indian remote sensing application programme.

16 S. ANDREWS - The co-operative Brazil/United States remote sensing applications programme.

17 L.H.A. DE AZEVEDO - Geological studies using data from NASA Mission 96.

18 E.G. DE ALMEIDA, A. DE SILVEIRA MASCARENHAS - Oceanographic studies using data from NASA Mission 96.

19 C.V. BARBIERI PALESTINO, G.T. BATISTA, H. OKAWA - Preliminary results of INPE participation in the RADAM Project.

20 L. LUBY, A. TEBALDI TARDIN - Agronomic and forestry studies in the area of Altamira in the Amazon region.

21 A.C. TARDIN, J.D. DE ARAUJO, M.K. NOSSEIR, A.G. DE SOUZA - Aircraft data uses to map cover types, soil conditions and land use at Lafaiete, central Brazil (preliminary results).

22 A.G. DE SOUZA COELHO - Aerial images screening for photo-interpretation purposes.

23 A.G. COELHO - Statistic study of colour variation in remote sensing data.

24 L.A. MILANI MARTINIS, S.K. YAMAGATA - INPE participation in RADAM Project - Preliminary results of the Teresina Mission, Mineral Resources Group - Geologic evaluation of radar imagery from Teresina Quadrangle.

25 P.P. MARTINIS Jr., A.V. PADILHA - Remote sensing of mineral resources in Lafaiete - Preliminary results.

26 P.P. MARTINIS Jr., L.R. SILVA - Analyse de superficie de tendance appliquée aux données densitométriques - Une étude hydrographique (Application of trend surface analysis to densitometric data - An hydrographical study).

27 R.P. ALDERICO Jr. - INPE remote sensing equipment.

28 E.G. DE ALMEIDA - Project SERE, Oceanography - A proposed ERTS experiment.

29 J. DORNBACH - Project SERE.

30 J.B. MACHADO - Remote sensing of unexplored regions.

31 J. PAMALAZA, P.N. LAVI ZAMBRANO - Application of remote sensing techniques in the study of the Rio Santa Basin (in Spanish).

ANNEX 2

TEXT OF THE SPEECH ON REMOTE SENSING ACTIVITY IN AUSTRALIA
delivered to the Panel Meeting on December 2, 1971

Mr Chairman, Ladies and Gentlemen,

Firstly I shall give some information on the present status of airphoto coverage in Australia. Then I shall outline some of our research projects in the field of remote sensing. And finally I shall briefly describe our proposals to NASA for the ERTS and SKYLAB projects and our data handling programme.

Australia is almost entirely covered by black and white photography at 1:50 000 scale. New RC-9 photography at 1:85 000 scale covers at present about 75% of the nation and will soon be completed. Colour photography is becoming more and more popular in photogeological work; we foresee that it will soon substitute black and white photography, at least for detailed interpretation in mineral exploration. The scale most commonly used for this last purpose is 1:25 000.

As far as remote sensing is concerned, I shall be able to give you only a few examples of what the Bureau of Mineral Resources has done. Many other organizations, such as the Commonwealth Scientific and Industrial Organization and the Universities, are doing a lot of work in this field, but my knowledge of their activity is not deep enough to give a precise account of it. So, please, don't take my description as a picture of all the Australian activities in remote sensing.

Multispectral photography was firstly tried out by BMR over areas of Victoria and Western Australia. In Victoria it provided data for the detection of salt contamination in a dense irrigation area. In Western Australia several film-filter combinations and detailed airborne magnetometry were used with the purpose of detecting geological structure in an area of poor outcrop and deep weathering; the evaluation of this project is still under way.

Side-looking radar was flown over the highlands of Papua New Guinea, which, as you probably know, have many features in common with the mountain areas of the Amazon region. The interpretation of the imagery was carried out, then we checked it against conventional photo-interpretation and in the field. It proved of great value for mapping structural data and for the differentiation of some rock types, such as limestones, volcanic rocks and ultramafic rocks.

A thermal infrared scanner, the Daedalus, was flown over areas of volcanic activity in the Talasea Peninsula of the New Britain Island. The system proved quite successful for the detection of hot spots and in pin-pointing spring effluents along the coastline.

The Daedalus line-scan was also flown over an area of the Bowen Basin, in Queensland, with the purpose of detecting coal deposits covered by residual soil. The full evaluation of the imagery is still to be done, however a preliminary appraisal showed that coal deposits with a soil cover less than 2 m thick might appear as cold areas in post-sunset imagery.

These are only a few, but typical examples of the BMR experiments in remote sensing.

As far as the ERTS and SKYLAB projects are concerned, you can see on the screen a map of Australia, in which our test sites have been plotted. The blank boxes are the sites of our original proposal to NASA. A great deal of ground truth is available over these areas from many agencies, each one for its own discipline: geology, forestry, land management, and so on. On the basis of the positions of these test sites, we selected 6 corridors across the country and proposed to NASA to provide us either with the whole coverage of the corridors, or with the coverage of only the test sites along the corridors. The first proposal was accepted, in principle.

A 7th corridor across Western Australia was proposed at a later date. I don't know if this has been accepted, yet.

The dotted boxes on the map indicate subsequent requests by government agencies and Universities, which we received when the ERTS project became better known in Australia. We proposed the coverage of these areas to NASA only a few weeks ago and a decision had not yet been taken when I left Canberra.

The diagonal lines on the map represent two possible paths of SKYLAB; we proposed to have either of them covered and this proposal was accepted by NASA, in principle.

Now, what will Australia do in connexion with the ERTS and SKYLAB projects?

Our programme is still under study. What is certain at this stage is that we shall carry out ground observations and possibly aircraft missions before and during satellite overpasses. At the time in which ERTS data will be available, we expect to have suitable laboratory facilities. The imagery will be assessed over the test sites, then its interpretation will be extended over less known areas. All the agencies involved are expected to collaborate with each other in the interpretation and, of course, all results will be available to interested parties.

Let me spend these last seconds to congratulate our Brazilian friends for what they have achieved. I was deeply impressed by what I have seen, including last night's demonstration of their enthusiasm and vitality. I wish you a successful conclusion of your efforts.

ANNEX 3

FRAMEWORK OF A PROGRAMME FOR THE IMPLEMENTATION OF REMOTE SENSING ACTIVITY BASED ON BRAZILIAN EXPERIENCE AND PROPOSED BY INPE

	IMMEDIATE MEASURES	INTERIM	PERMANENT
PERSONNEL	Select and train initial nucleus of interdisciplinary, inter-agency personnel.	Train larger group using personnel of initial nucleus.	Maintain interdisciplinary force adequate both for day-to-day tasks and for the investigation and the improvement of existing techniques.
EQUIPMENT	Based on most pressing needs, decide on what equipment to acquire first. Consider entering into agreements for the use of equipment of other countries.	Increase types of equipment so as to gradually improve capability.	Have comprehensive programme of surveying and secure equipment adequate to the execution of programme.
ORGANIZATION	Nominate a capable individual, directly under a cabinet member, to head the remote sensing group.	Establish co-operative programmes for the obtention and utilization of data of interest.	Establish own programmes and expand scope of activities as dictated by the country's needs.

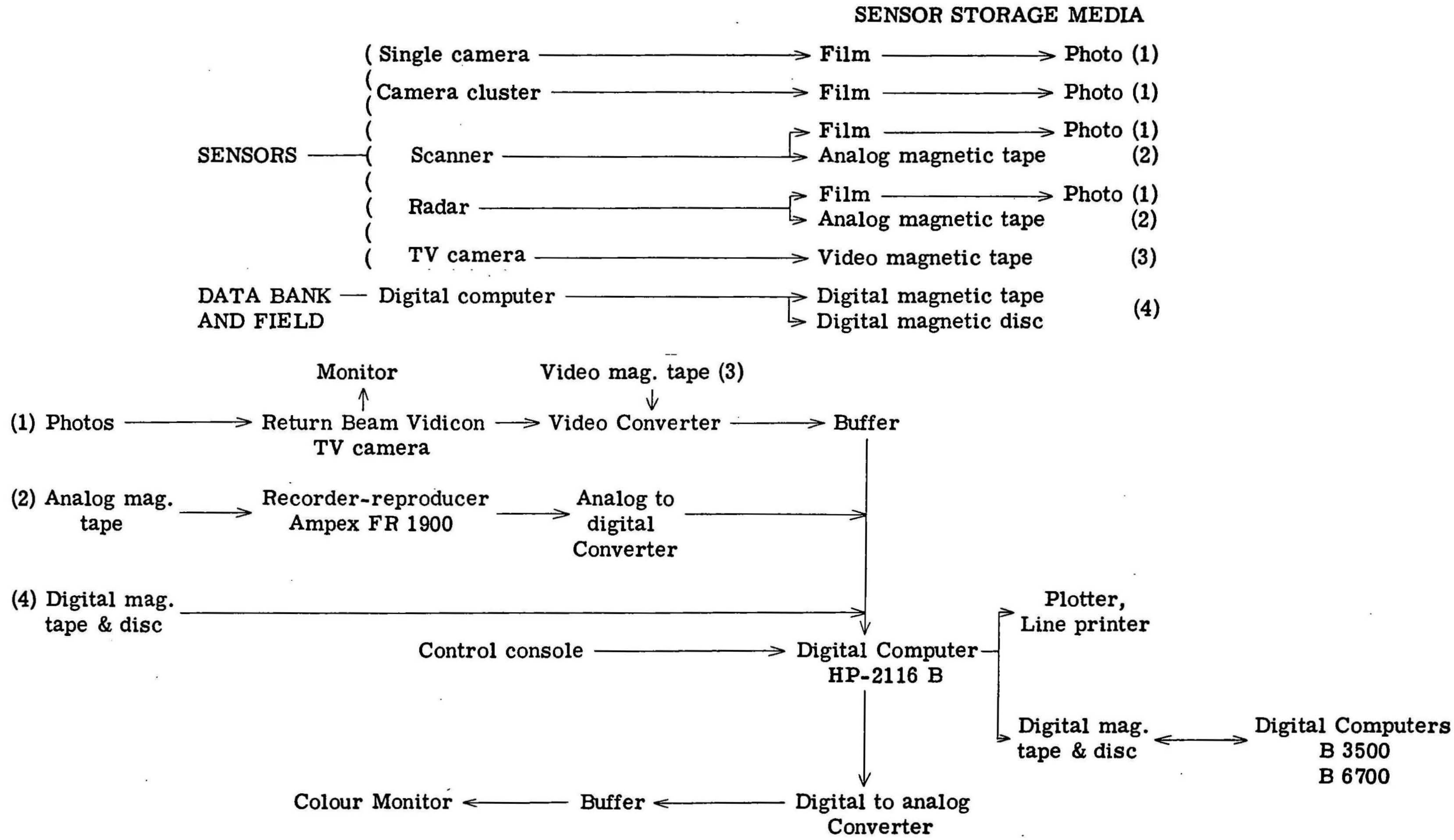

FIG. 1 - INPE DATA-PROCESSING SYSTEM