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AND PROCESSING GROUND SYSTEMS IN THE 1980's

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1. INTRODUCTION

The Remote Sensing Program of INPE, which became more effective after the availability of data from the LANDSAT series of satellites since 1972, underwent a clear evolution on its perspectives, giving rise to a solid Brazilian experience in the field. This experience is represented both by the practical know-how and maturity of its specialists in the use of orbital remotely sensed data for various applications, and by their experience in the area of developing and establishing new receiving, recording and processing ground stations.

INPE used the experience gathered with the first Brazilian LANDSAT Station (since mid 1973 with LANDSAT-1, and from 1975 on with LANDSAT-2) to successfully specify, develop and implement, in 1978, the required modifications for receiving and processing data of the just launched LANDSAT-3. This satellite carried on board a new thermal channel for the MSS sensor, and an RBV camera system greatly different from its predecessors.

In late 1979, INPE conducted preliminary studies toward the definition and specification of a new system capable of receiving and processing the data which, in a near future, would be made available from a new generation of remote sensing spacecraft systems. This generation would be inaugurated with the next vehicle of the

LANDSAT series, LANDSAT-D, carrying on board, among others, the advanced "Thematic Mapper" instrument.

These studies gave rise to the "INPE LANDSAT-D Project" setting up several phased activities aiming the establishment of a new facility which would allow the Brazilian remote sensing user community to access the improved capabilities of the new instrument. Not only that but it would also fulfill the increasing requirements of such community in terms of timely, accurate and reliable data on earth resources. It was immediately recognized that the preceding INPE LANDSAT Station, yet fully operational concerning MSS data, would not be capable of receiving, recording or processing the data generated by the Thematic Mapper. In this manner a completely independent X-band reception and tracking capability would have to be added, as well as new demodulation and receiving equipment. Also, the substantially higher data rates assigned to the new instrument required a new high density digital tape recorder (HDDR) and an advanced format synchronizer. Finally, those higher data rates required more powerful equipment (HDDR, format synchronizer, demultiplexer, computer and film recorder) capable of generating high quality products in accordance with the much finer TM spatial and radiometric resolution and greater geometric fidelity.

The requirements of the growing user community called for the processing of satellite data in a comparably short time with respect to the dynamics of the phenomenon under investigation. Thus, accuracy, throughput and reliability aspects became the primary prerequisites for the new system, guiding, particularly, the selection of the data processing equipment through which the data would be converted into meaningful information suitable to a given application.

The flexibility aspect was also taken into special consideration. The system should be flexible both to operate and to be modified and/or upgraded, presenting an easier future

adaptability to other spacecraft and instruments as well as to the generation of new products.

Based on the above objectives (throughput, accuracy, reliability and flexibility) INPE decided to build the new Ground Station under a hybrid software-hardware approach.

To meet the throughput requirements, pipeline processing capabilities were inserted in the form of dedicated hardware chains able to handle raw data at real time rates, benefiting from the high speed correction capability proper of electron-beam type film recorders.

Accuracy requirements were considered in the design by the combination of both proven state-of-the-art equipment and careful system modelling and software design.

Reliability was pursued by the use of proven design hardware and the implementation of redundant data flows through the system, since the highly desirable hardware redundancy would be too costly for the available budget.

Flexibility was considered simultaneously from a modular equipment design concept and the addition of software-oriented processing functions (with computers performing the main tasks).

The effort along the project involved a significant contribution from INPE specialists, mainly in the system analysis, software development, hardware and software integration phases. A joint development program was indeed established with the foreign manufacturers of the hardware involved.

2. THE NEW GROUND STATION

The new ground station for TM data came to reality subdivided into two major subsystems: one, installed at INPE premises at Cuiabá, State of Mato Grosso, for receiving and recording the data; and the other, at the INPE Image Processing Facility at Cachoeira Paulista, State of São Paulo, for processing these data under a variety of ways to fulfill a given user requirement or to support specific applications.

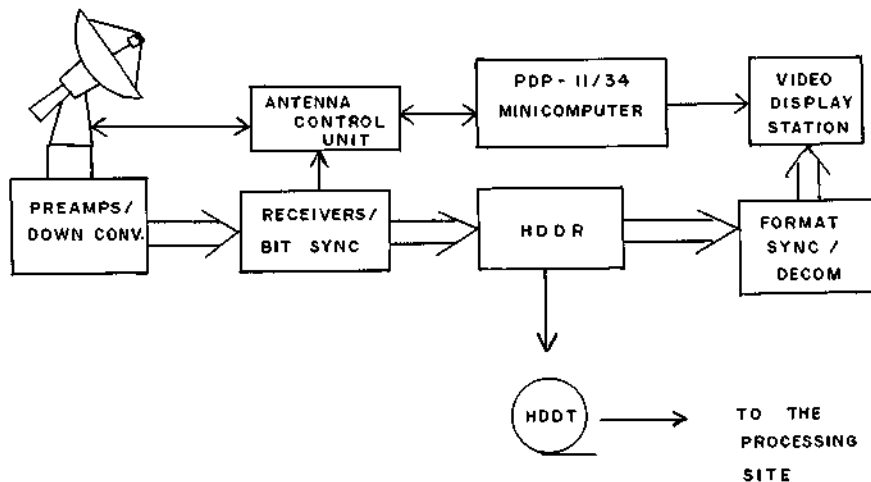


Figure 1 - Receiving and Recording Subsystems

At the receiving site (see Figure 1), the new 10-meter Cassegrain antenna is capable of both S- and X-band tracking and reception and can be connected to the receiver input of the old MSS/RBV system as a backup to the first antenna.

The ACU (Antenna Control Unit) provides autotrack and also accepts tracking commands, as a backup control mode, from the PDP-11/34 minicomputer that monitors continuously the antenna movement and takes over in case of autotrack loss. The assisted tracking software, that uses the antenna position readings during

autotrack operation, was designed and implemented by INPE. It showed superb performance in tests conducted disconnecting the tracking receiver inputs on the ACU, maintaining then the antenna pointed to the satellite, without loss of a single dB signal level, for more than one minute after the autotrack "loss".

The minicomputer is also used to generate antenna pointing data prior to the satellite passes based on the orbital elements received through telex.

Recorded TM data can be played back and monitored for quality and/or cloud cover at the black-and-white display after being format-synchronized and subsampled in the Format Sync/Decom (FSD). For doing that, the video station (a COMTAL Vision One/10) is downline loaded with a moving-window software from the PDP-11/34.

The station also receives and records the USB 8 Kbit/s channel of ancillary data, which include the platform attitude and position information required for annotating the imagery and referring it to a geographical frame of reference such as the UTM (Universal Transversal Mercator) or SOM (Space Oblique Mercator) projection planes. These 8 Kbit/s ancillary data are mainly used for MSS processing but can be treated as a partial backup for the PCO (Payload Correction Data) embedded on the 84.9 Mbit/s TM data stream.

The Receiving and Recording Subsystem became fully operational in early 1983 allowing acquisition, in a regular basis, of the MSS data transmitted at that time by LANDSAT-4. Direct readout of Thematic Mapper data was precluded due to the unexpected early failure of transmission capability of that spacecraft.

In April 1984, after the successful launch of the LANDSAT-5 satellite (which occurred on March 1st, 1984) and as soon as NASA started X-band transmissions to ground stations outside the U.S., INPE initiated the regular acquisition of Thematic Mapper data over Brazil.

Presently the station is acquiring MSS data from both LANDSAT-4 and 5 satellites and Thematic Mapper data from LANDSAT-5. Acquisition of a maximum of three passes a day is possible from either satellite.

The recorded HDDTs are airmailed to the processing site approximately once a week.

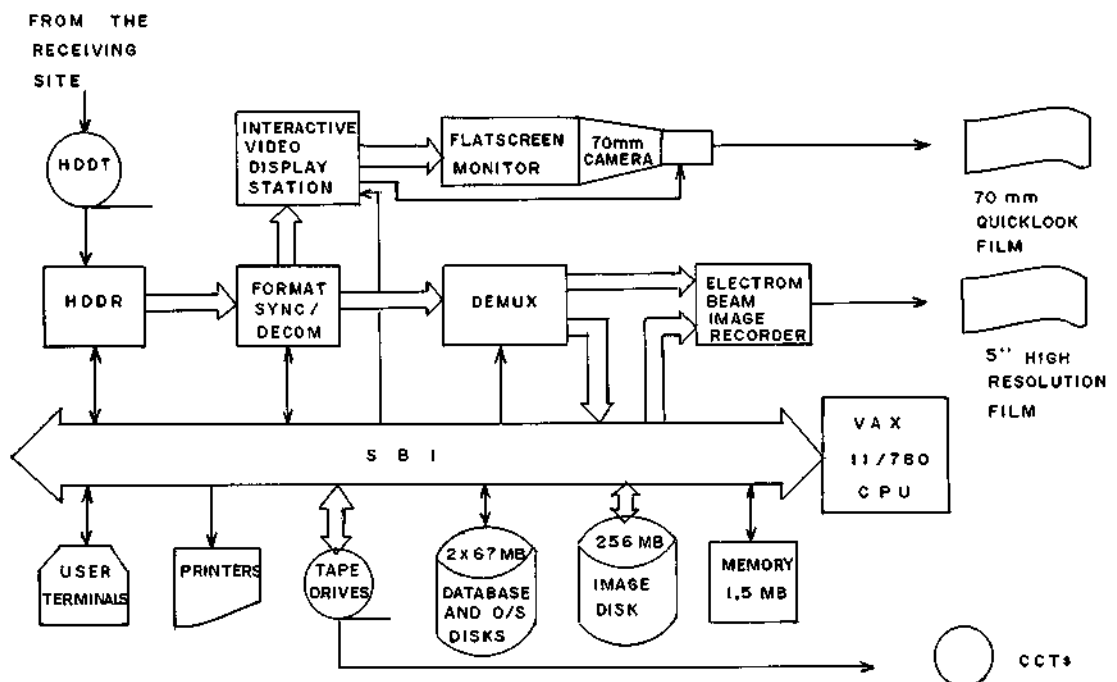


Figure 2 - Processing Subsystem.

At the processing site (see Figure 2), TM data are played back and can be routed through the FSD and the microprocessor-controlled Demultiplexer either directly to the Electron Beam Image Recorder (EBR), at real time rate, or at reduced rate to the image disk. Images on disk can be then output onto CCT without further processing or undergo operator-assisted enhancements for subsequent custom image generation onto the EBR.

As a preliminary step, all tapes received at the processing site are processed in what is called the "Initialization" pass, in which each tape is fully read and the auxiliary data (ephemeris, attitude, etc) are read into the computer so that the database is updated to include the new satellite passes. The next step is the "Quick-Look" pass, where the tape is once again read and subsampled video data is displayed at the interactive video display station (a COMTAL vision One/20 with color capability) already framed in accordance with the WRS, and pictured at a 70 mm camera coupled to a flatscreen monitor slaved to the display.

Every image produced onto film is recorded in the database to support future image searches or catalogs.

The image Processing Subsystem, completed and shipped to Brazil in October 1983, was acceptance-tested by the end of January 1984. In April 1984, under test basis, the processing station initiated the generation of Thematic Mapper products. NASA, at Goddard Space Flight Center, conducted, during the first three months of operation, the performance analysis of the new satellite and sensors, evaluating the post-launch calibration and compliance with overall specifications. INPE is expecting to start delivering TM products under regular basis as soon as the revised calibration data is issued and the software tuned accordingly. This shall be completed before the end of 1984.

3. OTHER DEVELOPMENTS

It is also significant to mention the efforts developed during 1983 and more intensively during this year of 1984 to establish a "Digital Cartographic System", based upon Landsat data, capable of generating geometric corrected geographically referenced digital imagery, immediately applicable in the production of planimetric maps. This system will be located at INPE's image processing facilities in Cachoeira. Most of the work is being done in the software area using the existing facilities.

In its first version the system will be able to treat only MSS imagery. TM data will follow in a very near future.

This new system will make possible creating digital mosaics of neighboring satellite scenes within any given spectral band, and temporal subpixel registration of scenes acquired in different dates over the same area. Once georeferenced to an a priori selected cartographic projection, the digital imagery will be able to support another ongoing project, a Brazilian Geographic Information System.

4. THE STEPPING STONES TO FUTURE DEVELOPMENT

The participation in the system design and analysis, together with the sharing of the software development effort with the supplier of the system, was fundamental in giving INPE the ability to modify, improve and expand it as needed.

This ability was first put to test in the process of adapting the System, delivered with several unsuspected compromises with the LANDSAT-4 characteristics, to the event of LANDSAT-5, in fact the first to be directly received at INPE and to be processed in real-life environment.

In the management software, several extensions were made, markedly the inclusion of the photolab and shipping steps in the scope of the order handling (only the generation of the film originals and CCTs were managed by the contracted software).

In general, the "burn-in" phase of bug detection and correction in both hardware and software has been incomparably smoother than the one experienced with the old MSS/RBV processing system, received in 1974 almost as a turn-key black box. Nevertheless, the experience gained in operating and enhancing it along all these years has proved fruitful. It enabled INPE to reach a

status of co-participant in the design and implementation of the second Brazilian ground processing system.

The next goal to be achieved will be to perform the function of system integrator, a necessary and important step towards the preparation for the Brazilian Complete Space Mission (MECB), proposed by the Brazilian Commission on Space Activities - COBAE* and approved by the Brazilian Government, where both ground and space segments will be designed and built in Brazil by INPE with the help of the Brazilian industry. The scope of this mission is to:

- Give the country the possibility of placing in orbit satellites to accomplish application programs of national interest, such as: meteorology, geological mapping, agriculture, forestry, environmental studies and land use.
- Achieve competence to project, manufacture and carry out a complete space program, not only regarding the satellites themselves, but also the launching vehicles.
- Train and familiarize a large team of specialists in a long, time-consuming project, involving high technological sophistication.
- Associate the research and development teams with selected Brazilian industries, in order to spread the knowledge acquired.
- Obtain the necessary technological capability, in planning such a large scale program and in using, effectively, the Brazilian industrial potentialities.

* COBAE is the governmental agency responsible for the coordination of space activities in Brazil.

Presently, INPE's attention is directed to the French satellite SPOT, which will be the first one featuring the imaging principle to be futurely employed in the Brazilian Remote Sensing satellites (Charge-Coupled Detector arrays in push-broom configuration). In integrating the ground processing system to handle SPOT data (in fact, an extension to the existing TM system), INPE intends to develop deeper knowledge and experience among its technical personnel. This will help facing the broader challenge of building not only the ground data processing, but also the control center for the first mission of the MECB (the data collection platform satellites) in the late eighties. This first mission will pave the way to the Remote Sensing series to follow in the early nineties.

The SPOT ground data processing system will include, in the receiving site, a new receiver/demodulator, bit synchronizers and an adaptation of the HDDR, besides test equipment and simulators.

At the processing site, the same HDDR adaptation will have to be carried out: a new Format Synchronizer/Decommutator will be added, as well as a SPOT data simulator, both to be compatible with the existing equipment on the TM input chain. To enhance system performance and avoid that geometric and radiometric corrections for SPOT data overload the system, an array processor will be integrated into it with the purpose of supporting these tasks. Also, to allow working with more than one scene at a time when processing stereo pairs, the image disk capacity will be augmented by adding a second drive.

INPE will design the software modifications and extensions, including the database and management functions, with the supplier of the Format Synchronizer/Decommutator furnishing the data formats affecting the input modules and handlers, as well as the detailed satellite technical characteristics.

The implementation and tests of the SPOT software will be totally carried out by INPE, along with the systems integration activities.

Still during the Brazilian SPOT ground station integration timeframe, design specifications for the Ground Segment of MECB's first mission will start being produced. They will include Brazilian-made equipment and systems as far as possible, profiting already from the effort spent in the last years by the Brazilian government in general, and INPE in particular, to incentivate Brazilian companies in developing state-of-the-art technologies and know-how.

The Ground Segment of the MECB will include three ground tracking/receiving and command stations spread over Brazil (one in the north, at Alcântara; one in the center, at Cuiabá; and one in the southeast region, at Cachoeira Paulista), as well as processing facilities for the DCP mission (first and second MECB satellites) and the Remote Sensing mission (third and fourth MECB satellites). All these facilities will be linked through a nationwide communications network. The major step towards the preparation of the satellites for the Brazilian Complete Space Mission is the expected flight on NASA's Space Shuttle of a Brazilian Remote Sensing Experiment - BRESEX - in 1987*. A ground segment will also be installed to process the data obtained in this experiment.

* For more information see: N.J. Parada, "Brazilian Remote Sensing Shuttle Experiment (BRESEX): Characteristics and Future Utilization on Satellites", Panel Discussion on Planned Future Earth Observation Space Systems, 18th ERIM Symposium on Remote Sensing of the Environment, 1-5 October 1984, Paris, France.

5. OTHER PROGRAMS

The development of the MOS (Marine Observation Satellite), MEOSS (Multispectral Electro Optical Stereo Scanner), ERS-1 (ESA Remote Sensing) and RADARSAT programs, as well as the Space Shuttle imaging experiments such as SIR-A and -B and the Metric Camera, and the future utilization of the US Space Shuttle are being closely followed by INPE, due to the possibilities they open in the promising field of multisensor applications. Even not considering developing direct reception capability for all these experiments, INPE is aware that Remote Sensing from space marked a milestone in the history of mankind. Being connected to those programs represents to INPE, as a Space Research Institute, a commitment to its role as a bridge between space technology and the social and economical developments of the human being.

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