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14. Abstract/Notes

This report presents the result of the initial data collecting phase (Preliminary Phase) to determine interconnection options between the REDACE System ("Sistema de Rede de Dados para Controle Espacial") of INPE and the "Réseau de Stations 2 GHz" of CNES. The final objective to be attained with this continuing work is the cross-support for Space Missions between CNES and INPE.

15. Remarks *This report is the result of a cooperative work executed by the technical staffs of INPE/ETE/ECA and CNES/CST/ESO in a final review completed in Toulouse, France, on Dec.'1986.*

RESUMO

Este relatório apresenta o resultado da fase inicial de levantamento de dados (Fase Preliminar), que tem como objetivo a determinação das opções de interconexão entre o Sistema REDACE ("Sistema de Rede de Dados para Controle Espacial") do INPE e a "Rede de Estações 2 GHz" do CNES. O objetivo final deste trabalho, em andamento, é o de viabilizar o apoio cruzado entre o CNES e o INPE em Missões Espaciais.

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1. INTRODUCTION

The Brazilian Institute for Space Research - INPE (Instituto de Pesquisas Espaciais) develops its Data Network for Space Controle, the so-called REDACE System (Sistema de Rede de Dados para Controle Espacial). Gateways for data communications with external data networks are being considered in the development of the REDACE System. These gateways are expected to provide cross-support in space missions between INPE and other space agencies (Bergamini,1984).

In particular, this project presents the various options for connections between the"Rêseau de Stations 2 GHz"(CNES,1984a) of the Centre National d'Études Spatiales - CNES and the REDACE System of INPE. The facilities of the "Rêseau de Stations 2 GHz" are composed of earth stations, a data communication network, the so-called "Systême de Transmission de Donnêes Digitales - STDD" (CNES,1984a) and several control centers:

- CCS Centre de Contrôle Spêcialisê (dedicated control center);
- COR Centre d'Opêrations Rêseau (network operations control center);
- COO Centre d'Orbitographie Opêrationnelle (operational orbit computation center);
- SDM - Service de Dêtermination des Manoeuvres (maneuver determination service).

The effective implementation of this project is expected to observe the following five phases: 1) Preliminary Phase; 2) Evaluation Phase; 3) Decision Phase; 4) Development Phase; 5) Operation Phase.

The Preliminary Phase of this project comprises the study of the characteristics of both data networks (INPE and CNES) and their options for data communication interfacing. This report represents the result of this phase of the project. Each option for interfacing is presented with a technical analysis.

Three options for data communication interfacing were identified. The first option does not properly characterize a gateway between INPE and CNES networks, considering that it would implement a *Direct Connection* between a CNES earth station and the REDACE System. This option would be solely intended for support, by CNES, to INPE's space missions.

The second and third options characterize data connections between the networks of both agencies and could be utilized for cross-support in space missions of the two agencies.

The second option is the *Connection with ETTD*, which is characterized by the local connection of a CNES data terminal equipment (ETTD - Equipement Terminal de Transmission de Données) with the External Connections System (SCE) of the REDACE System to be located in Brazil.

The third option is the *Connection with MCR*, which is characterized by connecting a Multiprocessor for Network Communications (MCR), of the REDACE System, to a CNES ETTD equipment, to be located in France.

2. INTERFACING OPTIONS

2.1 - DIRECT CONNECTION

2.1.1 - GENERAL DESCRIPTION

This option would be implemented by means of a direct connection between the so-called External Connections System (SCE) of the REDACE System and the CNES (ground) Station, bypassing the CNES Digital Data Transmission System - STDD (Systême de Transmission de Donnêes Digitales). This option would only support the use of CNES Station by INPE.

2.1.2 - DETAILED DESCRIPTION

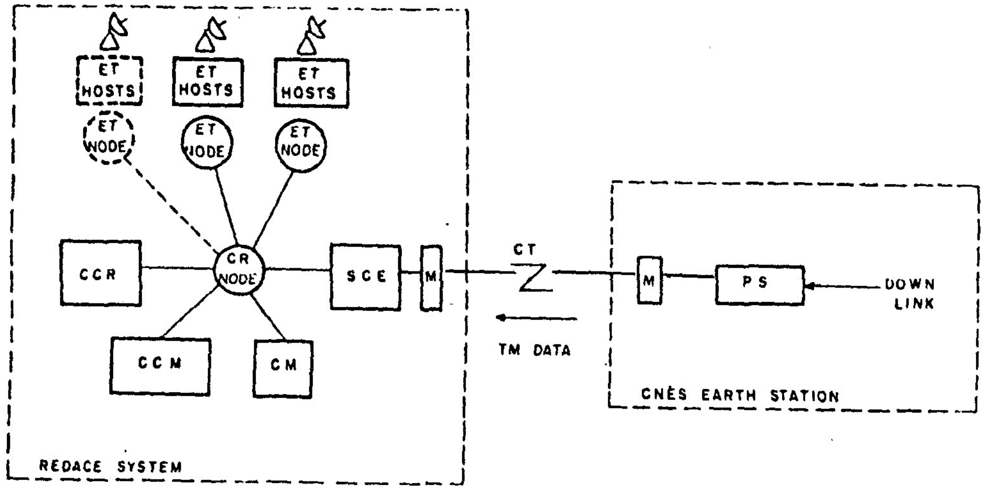
This option considers the direct connection between the SCE System, in the REDACE System, and the Primary (bit) Synchronizer of the CNES Station telemetry channel. This option allows the direct transmission of the telemetry bit string, received by the CNES Station, to the Mission Control Center (CCM) at INPE,as represented in Figure 1. A MODEM is to be connected to the Primary Synchronizer in order to transmit the telemetry bit string. However, due to the possible data jitter at the Primary Synchronizer output and the absence of synchronism between the MODEM and this synchronizer, the MODEM clock for the incoming data must be, at least, twice the data rate received from the Primary Synchronizer. In practice, this data rate should be increased fourfold. The MODEM connected to the SCE System will have to recover the clock of the transmitting MODEM connected to the Primary Synchronizer. After the recovery of the bit stream, the SCE System will search for the frame synchronization in order to recover the data frames relayed by the satellite. These data frames are to be transmitted to the Mission Controle Center through the REDACE System.

This option does not support other space data system services like telecommand, ranging, etc.

2.1.3 - REQUIREMENTS FOR IMPLEMENTATION

a) Detailed study of the Primary Synchronizer characteristics. In particular, special attention should be given to the interface between the Primary Synchronizer and the MODEM.

b) Contracting of an international private data communication link.



M - MODEM
CM - MISSION CONTROL
ET - EARTH STATION
CR - NETWORK CENTRE
CCR - NETWORK CONTROL CENTRE
CCM - MISSION CONTROL CENTRE
SCE - EXTERNAL CONNECTIONS SYSTEM
PS - PRIMARY SYNCHRONIZER
TM - TELEMETRY
CT - TELEPHONE CHANNEL

Fig. 1 - INPE-CNES interface: direct connection.

c) Specification and development of the pertinent software to be resident in the SCE System.

d) Evaluation of the up-link and down-link telecommunication compatibility (frequency, modulation, etc.) for cross-support.

e) Memorandum-of-Understanding between both agencies, establishing the services to be supported by CNES to INPE.

2.1.4 - TECHNICAL ANALYSIS

This option would solely support the TM service. It does not provide CNES support for Ranging and Telecommand Services which could, otherwise, be essential services for INPE.

Another critical aspect is the fact that INPE's satellite is expected to have a down-link data rate of 2.000 bits/s, which would require a data transmission rate of 9600 bits/s for the MODEM connected to the CNES Primary Synchronizer. Considering that no protocol is to be used in the long distance data link between the MODEMS, for such a fairly high data rate (9600 bits/s), this communication channel would present a high error data rate, without possibilities of error recovering.

It is worth mentioning that this is an option of notable technical simplicity and low cost.

2.2 - CONNECTION WITH ETTD

2.2.1 - GENERAL DESCRIPTION

In this option, an ETTD equipment would be utilized to connect the REDACE System to the STDD System (CNES,1984b), providing a fully compatible connection between both systems.

The ETTD equipment, used in this option, is a block multiplexing/demultiplexing device interfacing the Data Communications Equipment and the user's Systems. It checks the cyclic redundant code (CRC) of each incoming and outgoing block, and flags accordingly the PF1 e PF2 status bits. The ETTD does not format any block. They must be formatted by the sender system or subsystem. In its MUX/DEMUX function, the ETTD has a buffering capability in order to accomodate the flow of blocks according to the line speed; in this way it is programmed to allocate priorities among the various types of data.

When an ETTD is transmitting a block,there is no check of the source code which is delivered by the sender system or subsystem. For example, a TLM block is delivered to the ETTD by the UTTM (Telemetry Processing Unit) which stamps the source field. This source field is not checked by the transmitting ETTD.

However, when the ETTD is receiving a block, it checks the destination code before delivering the block to the user's equipment. For example, the station ETTD will check the correctness of a received command block destination code before delivering the block to the UTTC (Command Processing Unit). If that destination code is not correct, the block is rejected.

The block diagram showing the use of an ETTD equipment in a typical interconnection Station/Network Control Center/Satellite Dedicated Control Center is represented in Figure 2.

2.2.2 - DETAILED DESCRIPTION

This option proposes a connection between the REDACE and STDD systems via an ETTD equipment. The solution requires an access compatibility between both systems. This is to be achieved by the SCE System (REDACE System) through a protocol mapping.

In general, the user agency generating a message destined for the servicing agency should comply with its specific format, and vice-versa. Depending on the type of service under consideration, not only the message format of the servicing agency must be observed, but possibly its useful data contents, as well, depending on the destination it is supposed to have.

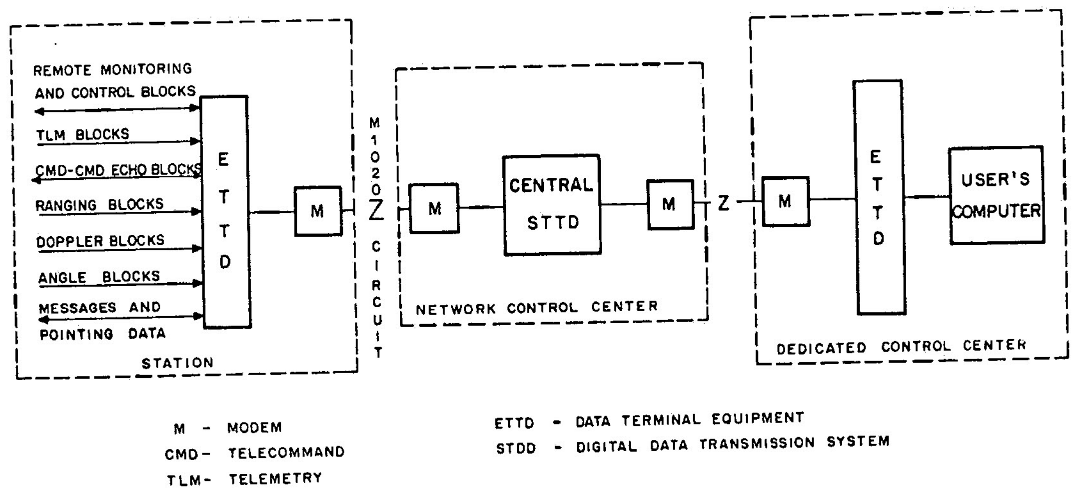


Fig. 2 - Typical interconnection STATION/NETWORK CONTROL CENTER/SATELLITE DEDICATED CONTROL CENTER.

The ETTD considered in this option could be located either close to the SCE System (in Brazil) or close to the STDD Central Equipment (in France). Due to the fact that the ETTD already provides built-in testing capabilities with the STDD, and considering that the CNES data communication protocol does not incorporate any resource for data link error recovery, these same testing resources would be of great convenience if utilized for validation of the long-distance data link characterized by the ETTD placed close to the SCE System.

According to these clarifications,we have to consider the use of the ETTD located in front of the SCE System in two configurations: INPE receiving a support from CNES network or, INPE providing a support to a CNES project.

a) INPE receiving a support from CNES network.

In this configuration,INPE Mission Control Center (CCM) is considered by the CNES STDD exactly like a CNES control center; i.e., the ETTD located in Brazil may be programmed with a source/destination code reflecting the supported project. If the project changes, this code can easily be modified (PROM). Of course, in this configuration the block structure and its contents will have to comply with CNES formats.

INPE user project will have a specific source/destination code chosen in agreement with CNES, with the supporting CNES stations (diagrammed in Figure 3) using their own source/destination codes.

b) INPE providing a station tracking support to a CNES project.

In this configuration the problem is slightly more complex depending upon whether the support being provided includes, simultaneously, one or several stations.

If using a single station, the ETTD in Brazil is to be considered like that ETTD supporting a CNES station. This ETTD in Brazil will have to interface with the SCE System (INPE responsibility). The format and contents of the network and message headers of the incoming and outgoing blocks have to comply with CNES specifications in order to be correctly handled by the communications system. The block information field (BIF) can be specific of the INPE systems if agreed upon between requesting and supporting agencies.

If using more than one station during a support to the same project, i.e., several stations connected to the same ETTD during a particular phase, it is necessary to define and implement a mechanism which allows the identification of the connected station at a specific time. This is relatively simple for the outbound data (like TLM), once the source code is generated by the sender system, or subsystem , and not checked by the ETTD. However, it is more complex for the inbound data to the station (like CMD), once the destination code, which is unique, is checked by the ETTD, but the incoming command block must be routed to one appropriate station among several ones. The identification mechanism can be carried out by the REDACE System according to directives provided by the user project via voice and/or TTY, but it will be INPE's responsibility to provide the correct configuration.

There are probably other solutions. The purpose of these remarks is not to define the solution, but only to outline the problem.

In the configuration where INPE tracking stations provide support to a CNES project (configuration (b)), there is also an important point to consider, which is the correct flagging of the PF1 and PF2 status bits indicating if an error occurred in the leg INPE station - ETTD (in Brazil). It will be INPE's responsibility to deliver to the ETTD: either error-free data encapsulated in CNES blocks or CNES blocks with encapsulated data and corresponding status bits set correctly for indicating whether the data is in error or not. Naturally, this provision will be limited by the error correction/ detection capability of INPE's network.

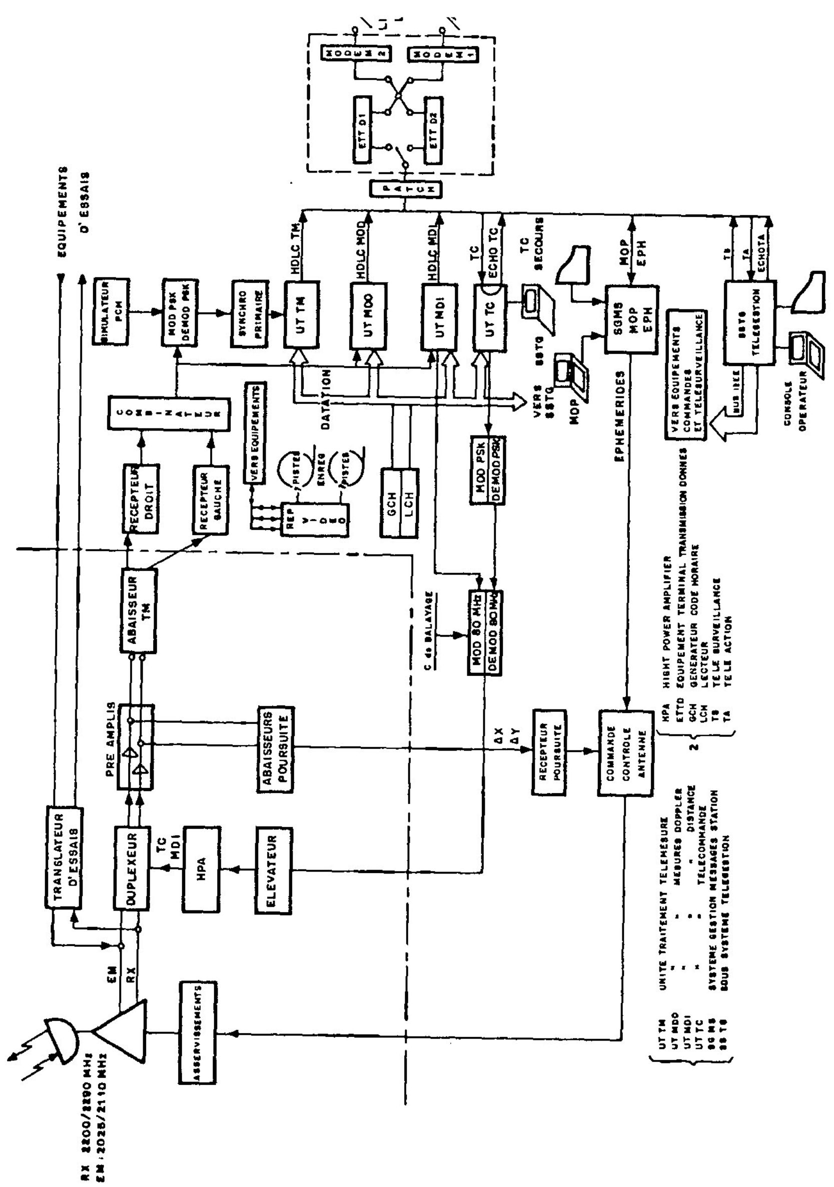


Fig. 3 - CNES Station block diagram.

It is remembered that the ETTD does not generate any data block. All the blocks have to be generated by the subsystem which provides the service; sometimes it could be difficult to "simulate" these blocks, if the concerned subsystem was not designed for this purpose. As an example, it is the command block, which is tightly dependent on the station command encoder (and vice versa), that checks the correctness of CMD parameters and generates the CMD echo block. Within the REDACE System the CMD encoder and the SCE System would have to implement the CMD echo function.

So, a very careful decision has to be taken concerning where and how the blocks will be generated, i.e., either at the earth station or at the SCE System for obtaining proper and convenient service.

The scheme of Figure 4 represents the proposed connection for this option. This proposal permits the simultaneous utilization of diversified services such as telemetry, telecommand, ranging, etc.

2.2.3 - REQUIREMENTS FOR IMPLEMENTATION

a) acquisition by INPE of two ETTDs (one for spare) compatible with the STDD;

b) if simultaneous services from INPE to CNES and vice-versa, are desired, a third ETTD unit should be acquired with associated PROM spares;

c) development of the software to be resident in the SCE System for proper implementation of this option;

d) development of the software to be resident in the Mission Control Center computer for proper implementation of the data formats to be utilized in some of the predicted services, such as ranging, doppler, ephemeris, etc;

e) contracting of an international private data communication link;

f) evaluation of up-link and down-link telecommunications compatibility (frequency, modulation, etc.) for cross-support;

g) memorandum-of-Understanding between both agencies, establishing the services to be supported by CNES and INPE.

2.2.4 - TECHNICAL ANALYSIS

This option would enable the concurrent and reciprocal execution of all the predicted services (telemetry, telecommand, etc.) that could be requested either by INPE or CNES. It has also the advantage of minimizing the software development, considering that the compatibility of the ETTD equipment with the STDD System would already be guaranteed, and that a relatively simple software would have to be implemented in the SCE System.

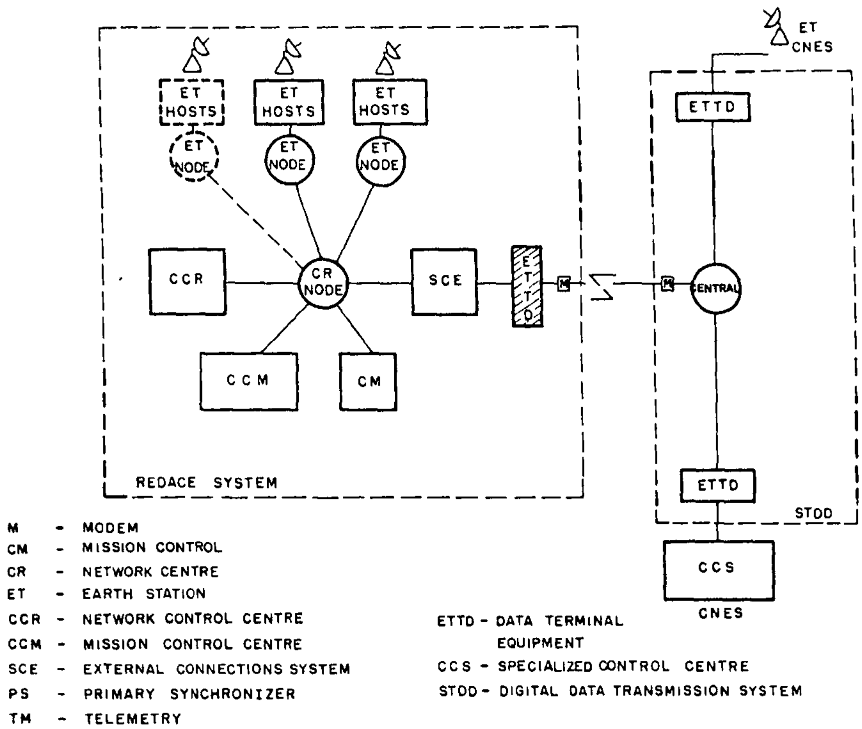


Fig. 4 - INPE-CNES interface: connection with ETTD

2.3 - CONNECTION WITH MCR

2.3.1 - GENERAL DESCRIPTION

This option characterizes a connection of the REDACE System's SCE to the STDD System, by means of a Multiprocessor for Network Communication (MCR) connected to an ETTD. An MCR located at CNES and connected to the ETTD would be remotely connected to the SCE, in Brazil. In this case, a long-distance data link with error recovery capability would be provided between the SCE and the MCR.

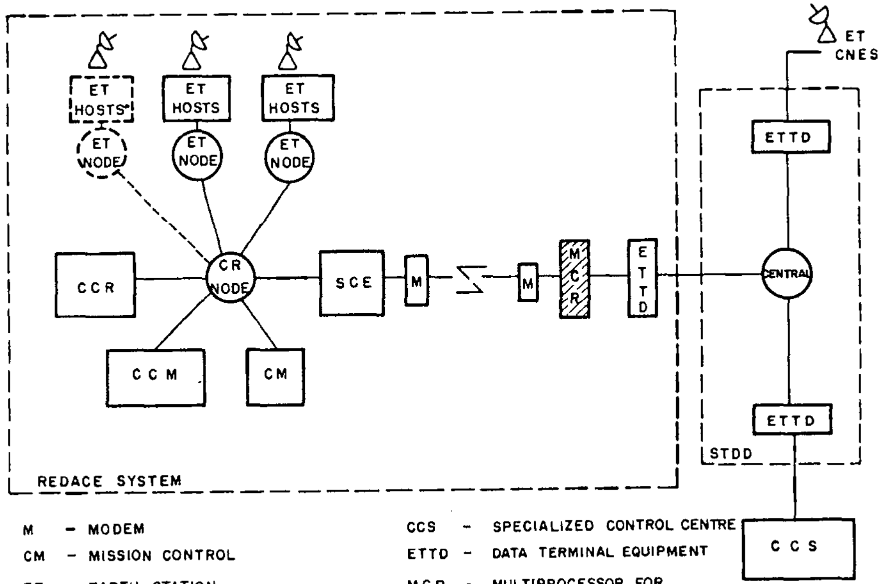
2.3.2 - DETAILED DESCRIPTION

It can be observed in Figure 5 that the MCR, as well as the ETTD, would remain in the CNES facilities, such that the MCR - ETTD and the ETTD - STDD (Central)connections would be in short distan

The SCE-MCR-ETTD data communication path would operate in a full-duplex mode, with data rates up to 9600 bits/s. The MCR - ETTD connection would have to observe the maximum data block flow permitted by the ETTD, as established by CNES documentation (CNES 1984).

In the SCE-MCR long-distance international data link, a link level protocol (in the ISO/OSI reference model sense) would be implemented. In this case, the data contained in the link level protocol would carry a CNES block, excluding the original HDLC envelope. This link level protocol would be based on the INPE Protocol for Space Mission (PRIME).

In the MCR-ETTD and ETTD-STDD (Central) link segments, the data would naturally flow according to the CNES HDLC protocol, carrying the CNES data blocks.



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CCM - MISSION CONTROL CENTRE
SCE - EXTERNAL CONNECTIONS SYSTEM
PS - PRIMARY SYNCHRONIZER
TM - TELEMETRY

CCS - SPECIALIZED CONTROL CENTRE
ETTD - DATA TERMINAL EQUIPMENT
MCR - MULTIPROCESSOR FOR NETWORK COMMUNICATIONS
STDD - DIGITAL DATA TRANSMISSION SYSTEM

Fig. 5 - INPE-CNES interface: connection with MCR.

This option would permit the simultaneous utilization of the data link by various services (telemetry, telecommand, ranging, etc.) predicted for cross-support. The REDACE System, which includes the MCR, would be represented by a unique address, in the ETTD, with respect to the STDD. The format field of the CNES block would differentiate a set of subaddresses, to be associated with the different services, at the output of the ETTD connected to the MCR. On the other hand, the STDD would represent a host to the REDACE System, so that the SCE would guarantee the proper routing of data for both networks by means of a mapping table, previously loaded in it by the REDACE System Network Control Center (CCR).

The Mission Control Center of the user space agency will have to observe the data formats of the cross-supporting station for its local services, like ranging, and other (CNES 1984c). The SCE would not support any data processing for these services.

2.3.3 - REQUIREMENTS FOR IMPLEMENTATION

a) acquisition of two ETTD's (one for spare) compatible with the STDD;

b) if simultaneous services from INPE to CNES, and vice versa, are desired, a third ETTD unit should be acquired with associated PROM spares;

c) development of the specific software to be resident in the SCE System for proper implementation of this option;

d) development of the specific software to be resident in the MCR, solely for implementation of INPE link level protocol (PRIME protocol - Level 2);

e) development of the specific software to be resident in the Mission Control Center computer for proper implementation of the data formats to be utilized in some of the predicted services, such as ranging, doppler, ephemeris, etc.

f) evaluation of up-link and down-link telecommunications compatibility (frequency, modulation, etc.) for cross-support;

g) contracting of an international private data communication link;

h) memorandum-of-Understanding between both agencies establishing the services to be supported.

2.3.4 - TECHNICAL ANALYSIS

This option permits the simultaneous utilization of all the services /telemetry, telecommand, etc.) that could be cross-supported by both agencies.

This option would aim at an increase in the data transport reliability by using a data communication protocol with error recovery capability in its long-distance international data link segment. The only advantage of this solution is the theoretical recovering of error-free data in both ways. However, it will be necessary to examine, in details, this solution when the expected communications protocol is defined. Also, when the station systems specifications are known, in order to verify the compatibility between CNES "throughput" concept and INPE communications protocol, besides INPE earth station systems specifications. The error-free communication would not be globally assured yet. The data link segments of the STTD, which does not support an error recovery protocol, would be more susceptible to errors, considering such data links as those of urban, short distance type. However, it has to be outlined that the CNES networks system is designed to operate via circuits under the recommendation M.1020. The standard quality of these circuits is such that a system with error recovery capability seems not to be mandatory. Moreover, if the requested line rate is 9.6 kbps and if the data link quality is marginal, the transmission speed can be decreased (if compatible with the rate of the useful data to be transmitted). Standard MODEMS transmission rates are 2400, 4800, 7200 and 9600 bps. The speeds which can be selected in the ETTD are 600,1200,2400,4800,7200 and 9600 bps.

The inconvenience of this configuration is the necessity to operate and mantain INPE's MCR System at CNES, Toulouse.

3. CONCLUSIONS

This final version of the Preliminary Phase accounts for two main modification. The first concerns feedback received from CNES personnel with respect to a better explanation of the ETTD equipment and CNES STDD System. The second one concerns the REDACE System, which has been subject to a complete redefinition of its architecture, as adopted in May 1986, as well as in consideration to its protocol (the so-called PRIME protocol), whose specifications have just been defined (December 1986).

The three options which were analysed furnish the very basic information necessary for the next phase of this project, the Evaluation Phase. In this next phase one of these three options will be recommended, with some additional analysis on the implications that its development would amount to (chronogram, cost, etc.) for effective implementation. After the Evaluation Phase, it will be possible to begin the following Decision Phase. Following, the Development Phase will be executed, resulting in the conclusive Operation Phase.

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