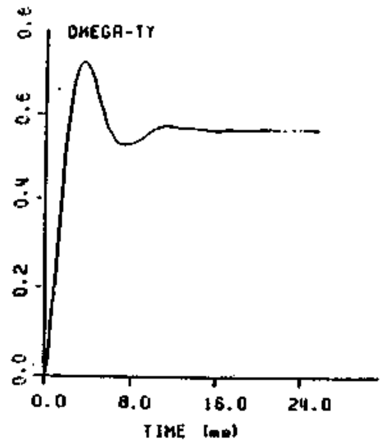

Fig. 4.1: Output ω_{T_y} to ramp input at ω_x and null input at ω_y

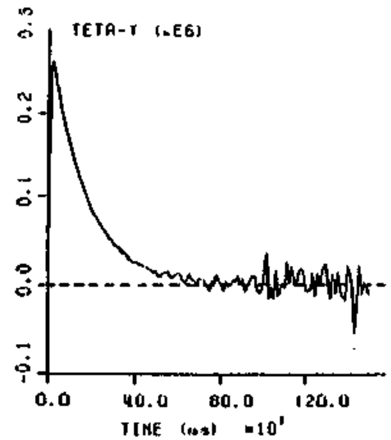

Fig. 4.2: $\theta_y(t)$ approaching 0 as excitation is in channel ω_x

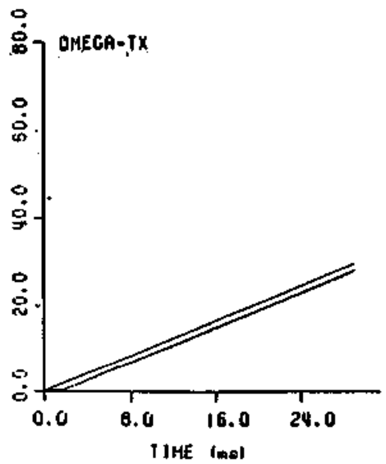

Fig. 4.3: Output ω_{T_x} to ramp input at ω_x and null input at ω_y, showing slight steady state error

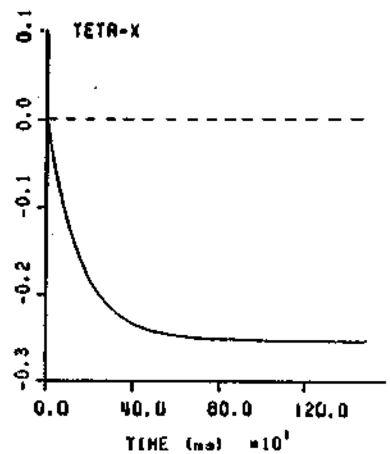

Fig. 4.4: θ_x for K = 495 and k = 1.4 showing feasibility with respect to $\sup_t |\theta_x(t)| < 0{,}3^o$

THE ON-BOARD COMPUTER SOFTWARE FOR THE 1st BRAZILIAN SATELLITE

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1. INTRODUCTION

The On-Board Computers (OBC) for the Brazilian Complete Space Mission (MECB) are based on INPE's On-Board Supervision Standard (PISB) which defines a fault tolerant distributed processing system organized in two hierarchical layers. The high level processing units (Masters) are utilized for the whole satellite supervision as well for the communication with the Ground Segment; the low level processing units (Slaves) are dedicated to specific subsystems. The processing units are interconnected by a set of redundant serial buses.

The OBC mission requirements are performed by the Application Programs. They are implemented by a set of processes resident in the processing units; the communication among them are based on message exchange. An Operating System was developed in order to provide process communication, synchronization and scheduling.

The Operating System is composed by a set of Nuclei, one for each processing unit, that provides a highly modular structure to support any possible hardware configuration, error handling and also to create a process environment in which the hardware layer is transparent to the application layer.

2. THE OBC NUCLEUS

The OBC Nucleus provides the following functions:

a) Process Management: allows activation and deactivation of processes;
b) Process Scheduling: enables the processes to be executed correctly;
c) Process Communication and Synchronization: allows message exchange between two specific processes;
d) Memory Management: allows dynamic buffer allocation and deallocation;
e) Time Management: delays the calling process for a specified period of time;

f) System Initialization: loads the other Nucleus routines and Application Programs from the Ground Segment.

g) Interrupt Service Routines: attend the interrupt requests and signal the handling process;

h) Input/Output Monitors: provide the interface between the hardware and the process;

i) Error Handling: executes error analysis and recovery procedures when an error is detected;

j) Interprocessor Communication: handles the buffer sending and receiving from the other processing unit.

In order to perform these functions the Nucleus supports two primary abstractions: process (which does work) and message (which allows interprocess communication).

The Nucleus Data Structure is a set of information, accessed in mutual exclusion, necessary to the execution of all Nucleus routines. It includes information about the processes (State Queue and Process Control Block), Message Queues and Nucleus control.

Process Control Block (BCP) is a set of information items that describes the features and the state of a process.

There are five process states, as follows:

a) Waiting: needs a time condition to be executed;

b) Blocked: needs a resource (message buffer) to be executed;

c) Ready: has all conditions to be executed, except the processor;

d) Executing: possesses the processor;

e) Inactive: must not be executed.

The process scheduling is based on a periodic interrupt, named Time Base Interrupt, which provides the time condition to process execution.

The processes in the Ready and Waiting states are structured in queues; the Executing State (only one process per Nucleus) is represented by one variable.

The Ready Queue order is based on process priority and the Waiting Queue order is based on the moment of process activation.

A Message Queue is a set of data storage elements, denominated message buffers, which can be utilized by the processes.

Each message buffer consists of two parts: Message Descriptor (4 octets) and Data Field (28 octets). The Message Descriptor is composed by:

a) Linking word (2 octets): pointer to the next message buffer in the message queue;

b) Routing control (2 octets): this word is utilized to transfer the message buffer from the source to the destination.

3 OBC APPLICATION PROGRAMS

The Application Program layer consists of a set of processes that communicates with the other processes through message exchange.

The Application Programs is divided in two classes: On-Board Supervision programs and subsystem monitoring programs.

The On-Board Supervision programs consists of a set of procedures that provides the following facilities:

a) On-Board/Ground communication;

b) Internal Bus Level protocol (NBI Protocol);

c) Housekeeping service.

The subsystem monitoring programs meet the user requirements using the facilities provided by the Nucleus and the On-Board Supervision programs. These programs perform data acquisition and control according to the mission specification.

3.1 ON-BOARD/GROUND COMMUNICATION

The On-Board/Ground communication is divided in two programs: the Telemetry (TM) Format Generator and the Telecommand (TC) Analyzer.

During normal operation, only the unit specified as Master has a TM Format Generator process active. This process continuously generates a complete TM Format at a rate of one format every three seconds; which consists of six frames: the first frame contains a Real Time Telemetry (RT TM) and the other frames contains a Telemetry Message with data acquired remotely by all the OBC units.

The TC Analyzer has the following functions:

a) to receive the messages from the Ground Segment, to decompose them and to analyze the commands contained in these messages. If the command is of the time tagged type it is placed in the time tagged command queue, otherwise it is sent to the appropriate process using message buffers;

b) to verify the time tagged command queue periodically and to send the command, that will be executed at that time, to appropriate process.

c) to execute Memory Load commands to the Master unit. The data contained in these commands are loaded in the appropriate memory location.

3.2. INTERNAL BUS LEVEL PROTOCOL (NBI PROTOCOL)

The NBI Protocol is an Application Program which has the function to establish communication between the Master and the Slave units. It is executed periodically at each Time Base.

The Master Unit coordinates the communication between the processing units. Only the Master Unit can start a communication with the other units.

There are two types of data used in the communication:

a) Message buffer : which has a fix length (32 octets).

b) Command : used to control the transmission and reception of a message buffer.

3.3 OBC HOUSEKEEPING PROGRAMS

The Housekeeping Programs are the procedures that verify the behavior of the On-Board Supervision Subsystem and send reports to the Ground Segment.

The Housekeeping Programs are composed by the following routines:

a) Historic Reporter: this routine receives reports from the other processes, checks if the number of reports of a determined type did not exceed the maximum allowed and stores them into housekeeping buffers;

b) Clock Synchronization: it receives the Clock Synchronization command from TC Analyzer and sets right the hardware and software clocks. Periodically the Master Unit sends a message to the Slave Unit to synchronize their clocks (every 18.2 hours).

c) Process Activation/Deactivation: it receives an Activation/Deactivation Command from TC Analyzer and activates/deactivates the appropriate process.

d) Garbage Collector: it periodically clears housekeeping buffers stored for more than 18.2 hours.

e) Diagnosis processes: these routines verify whether the subunits are operating properly. If an error is detected in the subunits, a report is sent to the Historic Reporter.

. OBC INITIALIZATION

The OBC initialization is started either by the power on or when a serious error is detected. It is divided in two parts:

a) A loader (bootstrap) program that clears the RAM memory (except an area reserved for the error report); then it transfers the initialization program from PROM to RAM memory.

b) An Initialization Program which loads the On-Board Software from Ground Segment and sends the OBC memory dump to the Ground Segment. This allows in-flight software reprogramming.

This program is also able to send Memory Load commands or memory dump to the other unit as well as to receive Memory Load commands and memory dump from the other unit under Ground Segment request.

The Slaves initialization program has also the capability to send subsystem data to the Ground Segment via Real Time Telemetry.

5. CONCLUSION

The software described in this paper was developed and implemented in the OBC for the first Brazilian satellite. Currently the OBC qualification model is being tested and the OBC flight model is being manufactured.

The basic software was developed in such way that it can be easily adapted for future missions.

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THE ON BOARD COMPUTER (OBC) FUNCTIONAL TESTING

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ABSTRACT

The testing procedures ensure that the OBC hardware and software work according to the functional specifications. They simulate real operating conditions, implemented through communication with ground receiving telecommands (TC) and sending telemetry (TM). The results are obtained from the TM analysis which is distributed in three different types of verification sets:

1- TM structure validation.
2- OBC memory content verification.
3- OBC operating information and satellite sensors data analysis.

GENERAL SATELLITE DESCRIPTION

The first brazilian satellite is an experimental spacecraft for real time reception and retransmission of data gathered on surface by automatic environmental data collecting platforms. For the purpose of this paper, the satellite can be seen as consisting essentially of three subsystems:

1- the TCTM Subsystem which is responsible for the housekeeping TM, TC, and ranging;
2- the On Board Supervision Subsystem which comprises a computer and a TM encoder. Its purpose is to acquire, process, and store data, from the various subsystems, for later transmission to the tracking station. The computer can substitute for the real time telemetry encoder if needed, and can also distribute telecommands that are not to be executed in real time. The OBC consists of two microprocessor based units: a Communication and Processing Unit (UPC), and a Communication and Distributed Processing Unit (UPD/C);

3- the payload which consists of a transponder that retransmits data, received from various Meteorological Ground Stations spread through out the country to a control station located at Cuiaba.

All real time testing procedures are executed by the Check-Out Software System. The OBC testing System will be described later.

RESOURCES USED

The hardware and software configuration for the OBC testing can be seen in Figure I, Figure II, and Figure III.

There are three types of verification sets:

1- TM structure validation: this task is performed with the aid of program P1.

2- OBC memory content verification: performed with the aid of program P2.

3- OBC operating information and satellite sensor data analysis: it is performed with the aid of program P2 by comparing the received data with the predicted operating situations, and the Real Time data.

TEST PLAN

Basically the following steps where adopted for testing the OBC:

1- Turn the OBC on and verify TM.

2- Load the On Board Operational Program (POB).

3- Perform a memory dump to check wether the POB was loaded correctly.

4- Turn sensors on and off. Check results by comparing Real Time TM and Stored TM.

5- Modify the OBC clock contents and verify the effects by analyzing the OBC TM.

6- Turn sensors on and off, in a time delayed way, using the OBC. Check results as described in step 4.

7- Change sensor input physical conditions. Check new acquired values as described in step 4.

8- Verify the OBC operating conditions examining the correspondent OBC TM fields. Compare the related situation with the foreseen operating conditions.

9- Change unit status - master to slave. Verify the results by repeating step 8.

10- Turn OBC off.

CONCLUSION

The functional testing procedures, described here, proved to satisfy the design purpose, that is, to efficiently test the OBC. Moreover, part of the programs developed will be used later, in the Satellite Control Center, for monitoring and analyzing the satellite operation.

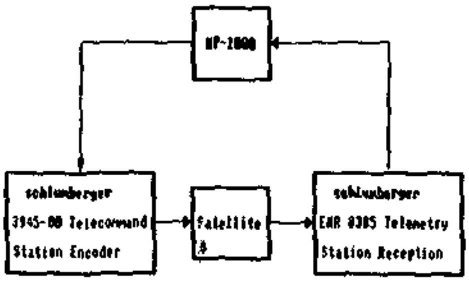

Figure I - Hardware configuration.

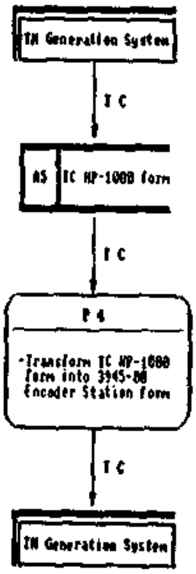

Figure II - Software TC sending process.

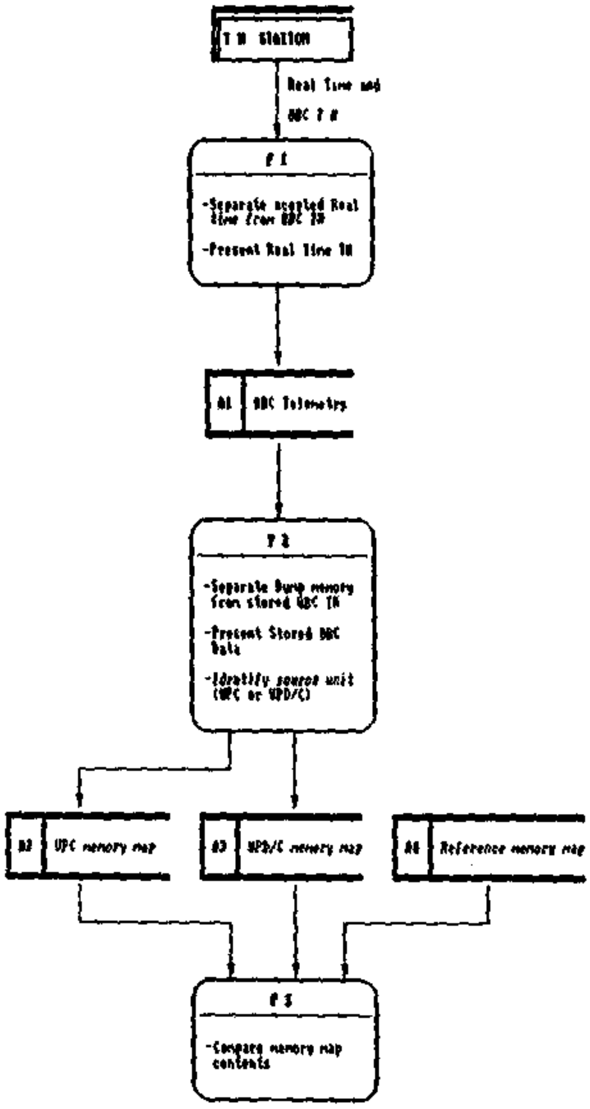

Figure III - Software TM analysis process.