

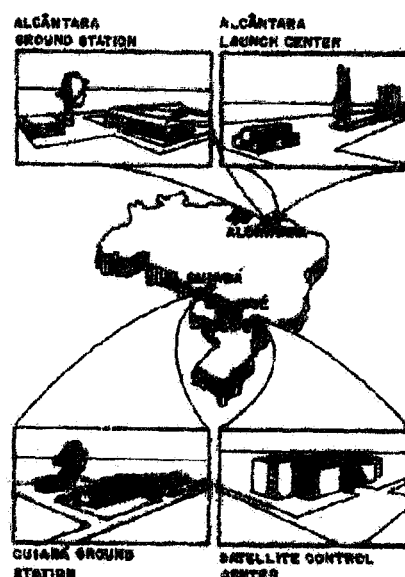
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OPERATIONAL TRAINING FOR THE MISSION OPERATIONS AT THE BRAZILIAN NATIONAL INSTITUTE FOR SPACE RESEARCH (INPE)

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ABSTRACT

The paper describes the selection and training process of satellite controllers and data network operators performed at INPE's Satellite Tracking and Control Center in order to prepare them for the mission operations of the INPE's first (SCD1) satellite. An overview of the Ground Control System and SCD1 architecture and mission is given. Different training phases are described, taking into account that the applicants had no previous knowledge of space operations requiring, therefore, a training which started from the basics.



1.0 INTRODUCTION

In order to control its satellites in orbit, the Brazilian National Institute for Space Research (INPE) had established a ground control system called Satellite Tracking and Control Center (CRC). It is composed of a Satellite Control Center (CCS) located in São José dos Campos (23 17 S; 45 51'W), a Ground Station located in Cuiabá (15 33'S; 56 04'W) and another Ground Station in Alcântara (02 20'S; 44 24'W) (Fig.1).

Fig.1 - Geographic Distribution of CRC.

Connecting all these sites there is a private data communication network, called RECDAS, and a voice communication system. CRC had no previous experience in controlling satellites in orbit and the launch of the first (SCD1) data collecting satellite constitutes the maiden operation for CRC. This paper describes the selection and training process of spacecraft controller (CONSQT) and RECDAS and computer operators undertaken by CRC for this mission. It should be kept in mind that there are no experienced people for these positions readily available in Brazil and the training started from the very basics.

Also, the late delivery by the software developers of the satellite simulator and even satellite control software modules made the task of training the operational people quite a difficult one.

A brief idea on the ground control system and the SCD1 main subsystems and the Satellite mission is given in order to define better the boundary conditions for the training.

2.0 GROUND CONTROL SYSTEM OVERVIEW

In this section we define the scheduling problem beginning with a simplified version and evolving to a more realistic definition.

The Ground Control System was conceived to keep high its availability and at the same time, to keep to a minimum the man-power required to operate it. This premise reflects itself in the overall architecture of the system: there are two redundant Ground Stations and redundant equipment at the Satellite Control Center (CCS) as well as two physical lines in the RECDAS.

The Satellite Control Center hardware is composed of a DEC VAX11/780 and two VAX8350 computers. The first one is dedicated to software development while the other two are dedicated to software development while the other two are dedicated to mission operations. In order to increase system availability, two VAX8350 are in cluster arrangements. There is also volume shadowing software implemented increasing in this way disk availability. The operational system used is VMS 4.7 version.

The CCS application software is a brand new one developed in house. It is written in FORTRAN. The communication between CCS software and Ground Station equipment is done according to ESA SDID protocol.

Going now to the Ground Station hardware, its front end and receivers are manufactured by Scientific Atlanta (USA). The High Power Amplifier is manufactured by MCL (USA). The telemetry baseband equipment is a mixture of LORAL 9USA), Inter technique (France) and in-house built equipment.

In order to minimize the operational man-power requirements, the Ground Stations hardware is configured and monitored by DEC VAX II computer which can also assume some of CCS functions in emergency situations.

The Telecommand, Telemetry and Ranging functions are performed according to ESA PCM standards.

Insofar as the data communication is concerned, it is a private packet switching network implementing X.25 access protocol with bit rate of 9600 bps between the nodes. The nodes are built by a Brazilian manufacturer compatible with French SESA nodes. The network management computer is COBRA, a Brazilian-built computer.

3.0 THE FIRST (SCD1) SATELLITE AND ITS MISSION

The mission of SCD1 satellite is environmental data collecting. A network of automatic Data Collecting Platform (DCP) is scattered throughout Brazilian territory. They collect and transmit to the satellite in UHF band environmental data (temperature, pressure, wind speed, river level and so on).

SCD1 carries as its payload a frequency transponder which transposes the collected data to the S-band. When the DCPs, SCD1 and the Ground Station are in mutual visibility the data are received by the Ground Station which transmits them, via RECDAS, to the Data Processing and Distribution Facility. The last one processes and distributes the data to the users.

SCD1 is a low earth orbiter. Its altitude is 750 km and its inclination is 25°. In this way whole Brazilian territory is covered, assuring at least one contact per day with the DCPs.

The satellite has an octagonal prism shape with base diameter of 1m, height of 1,055 m and its weight is 115 kg. Satellite's all but one faces are covered by solar cells. The remaining face is used as a heat sink. It should not be directed to the sun. In order to avoid this problem an attitude manoeuvre is foreseen after 6 months in orbit. No other manoeuvres are planned for the satellite. The thermal control is passive. The attitude subsystem is constituted by a magnetometer and two sun sensors.

The TT&C antennas are located on the opposite bases. Because of their radiation patterns silent zones appear during the passes over the Ground stations. This fact has to be considered by the Ground Control System in planning the daily activities.

The two experimental subsystem on board of the satellite are the on-board computer and the solar cells developed in-house and they are to be flight qualified. The on-board computer is used only to turn on and off

the solar sensors and magnetometer and to perform tries on computer memory loading.

The satellite will be injected in its orbit in such a way that the Alcântara Ground Station will be the first Ground Station to track the satellite. Cuiabá Ground Station will track the satellite starting from the third orbit. There will be no tracking support from foreign Ground Stations. NORAD will provide initial orbit information.

4.0 OPERATION WORKING MANNER AND CANDIDATE SELECTION PROCESS

SCD1 passes over the Ground Stations, as it happens with all low earth satellites, are short ones, in this case, of order of 10 minutes and they drift in time.

There is a visibility gap of approximately 9 hours every day when the satellite is not visible by the Brazilian Ground Stations. This visibility gap could not be used to reduce the number of working shifts because it is drifting every day (Fig. 2). This would require the working shifts to be drifting too. As a consequence it would make difficult for the controllers to organize their personnel life. Therefore, it was decided to run the satellite control on 24h/24h basis in six hours fixed shifts.

For security reasons there should be two operators per shift at the same site.

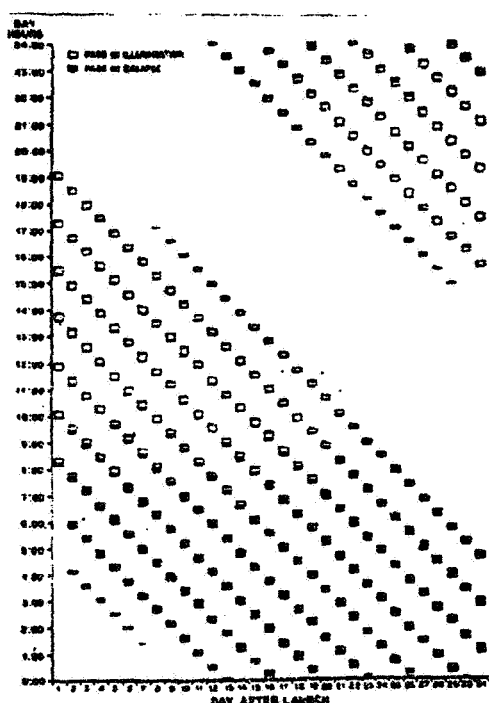


Fig. 2 - SCD1 passes over Cuiabá Ground Station.

Some man-power reduction have been planned taking advantage of CCS building layout. The RECDAS Network Management Center and São José dos Campos communication node are located near the VAX computer room. Due to this fact and the very simple to operate, it was decided that RECDAS operators should do also the job of VAX operators.

The Satellite Control Room is located above the VAX computer room and, therefore, there should be 2 CONSATs per shift.

The operational needs determined the initial educational level of the prospective operators and controllers. The minimum requirement was to have completed high school education with good scholastic standing. In the process, some college students were selected.

As far as the CONSAT position was concerned, it was decided that more software-oriented people should be selected. For the RECDAS operator position, people with a background in hardware (electronic technicians) were to be selected because it required dealing with protocol analysers, modems, data sets, and so on.

The selection was based on the C.V.s, interviews and psychological tests allowing candidates to decide on one of the available working shifts. The psychological tests included auditory and visual memory tests, concentrated attention tests (Toulouse-Pieron), personality tests (R.B. Cattell & H.W. Eher). An essay done by candidates complemented the personality test allowing, also, to perform some graphology analysis. Although there was no preference for male or female candidates, most of the satellite controller positions were filled by female candidates and the network/computer operators by male candidates, reflecting, perhaps, the educational preferences of Brazilian youth at the present time.

5.0 Basic Training

Since none of the selected people had any idea whatsoever about how the satellite looks or works or why it stays in orbit, it was decided to give them initially a general training module on satellites and their missions, satellite architecture, flight dynamics, CRC organization, satellite control team organization, etc. This module took about 45 hours of classroom presentation. After finishing this general module, the training was split into two branches: one for CONSAT and the other for the RECDAS/VAX operators.

The CONSATs had a module dedicated to the operation of the satellite control software. It took 30

hours of classroom explanations, followed by the same number of hours of hands-on training. In this way the CONSATs were acquainted with the satellite control software, booting, screen layouts, CCS computer connection with the Ground Station equipment, telemetry reception and processing, history files archiving and retrieval, telecommand generation and transmission, ranging requesting, alarms, and their meanings, file transfer, etc. During and at the end of this module, an evaluation of the student's knowledge was performed.

Another module was dedicated to the Flight Dynamics software. It comprised 25 hours of theory and 15 hours of practice on such matters as predics generations, orbital and attitude data pre-processing and attitude determination. This was more of a get-acquainted module because this software is actually operated by more specialized people.

The following training module was on SCD1 architecture, its specific telemetries and telecommands and operating modes (launch, stand-by, orbit determination, attitude determination, normal, experimental, experimental standby, manoeuvre and manoeuvre standby). This module took 35 hours of lectures. Subsequently the students used a Portable Simulation System based on a PC to practice on SCD1 telemetries and telecommands.

During this training period, CONSATs attended other activities which had been performed at the CCS at that time. These were the Cuiabá Ground Station calibration using real satellites in orbit (ESA's Hipparcos and ERS1) and SCD1 system test.

The RECDAS/VAX operators started their specialized training with a module on data communication, networks and protocols including X.25. Node hardware and software, NMC computer and software, modems, monitor and test tools and operational procedures were also part of this module. It took 25 hours of theory and 30 hours of practice. Several evaluations of student performance were done. A need for supplementary training on data communication was detected; therefore, a supplementary 8 hour module was offered.

Another module on general computer architecture and specific VAX operation was given. It took 10 hours of classroom lectures and about the same number of hours for hands-on practice. Then, the time came for the RECDAS/VAX operators to start to work on the shifts. For about one month, they worked under supervision of more experienced operators and then they assumed the duties on their own.

All contracted people were trained in the operation of voice system, air conditioning and no-break system of the CCS building.

6.0 Mission Operation Training

The mission operation training was based on the SCD1 software simulator. This simulator was developed in-house. It gives CONSATs a realistic operational environment generating realistic telemetries and reacting in a realistic manner to the telecommands. It simulates possible satellite failures and reproduces, within certain limits, realistic on-board thermal and power generation conditions. They are determined by the SCD1 orbit and attitude which are also simulated. The passes over Ground Stations are simulated. This means that some Ground Station equipment had to be included in the simulation process.

The operational training of the CONSATs started with a review of the satellite control software operation and SCD1 telemetries and telecommands because of the late delivery of the simulator. The CONSATs trained in the nominal satellite operating modes and transition between them. This process allows CONSATs to memorize the subsystem telemetries which define each one of the operating modes and the telecommands which cause transitions between them. After performing a mode transition, a detailed discussion of the effect of each one of the telecommands on the SCD1 subsystems was done, using satellite electrical architecture drawings for system visualization. During this part of the training the satellite simulator was set to a mode in which there was a continuous satellite pass over a Ground Station. This part took about 20 hours of the training.

A second phase in the training started imposing a time constraint (satellite passes) on the CONSAT activities, using different time lengths for the satellite passes. The CONSAT had to perform ranging requests, several modes of telecommanding and telemetry limits checking. The simulator was set to satellite nominal operation. This phase required 15 hours of training.

From that point on, failures in the subsystems were introduced. These were the failures covered by the satellite EMECA. The CONSATs reaction to the failures were observed. Although it was not expected that in real operation the CONSATs by themselves would assume the necessary recovery procedures, it was considered that CONSATs must be exposed to these failures in order to assure their self-confidence during unexpected events in real operations. This phase took 20 hours of training.

Finally, before starting the rehearsals, a training which involved whole Ground control system (Satellite Control Center, RECDAS and Ground Station) was performed. this training made use of the satellite suitcase model located at Cuiabá Ground Station and connected to its front end. The CONSATs performed suitcase model telecommanding, received respective telemetries and requested a group of ranging measurements. As mentioned before, during their basic training the CONSATs attended the Ground Station calibration by means of ESA's Hipparcos and ERS1 satellites as well as SCD1 system tests. This time it was the first time the CONSATs as well as RECDAS operators and Ground Station operators were involved in an end-to-end training. This training was repeated twice.

At this point, the CONSATs were considered apt to be a part of the spacecraft control team and they participated in the mission rehearsals.

7.0 Conclusions

The launch next December of the first satellite developed and manufactured by INPE will constitute a major endeavor for its new Satellite Tracking and Control Center (CRC).

The selection and training of the satellite controllers (CONSATs) and RECDAS/VAX operators, all of them having no previous experience in this kind of work, constituted a major challenge to CRC. It should be mentioned that delayed delivery of the Satellite Control Software and SCD1 simulator added an extra constraint to the training process.

As it appears now the selection process was acceptable because out of 17 people selected initially only one was not able to meet the requirements.

It was observed that CONSATs needed constant review of the satellite control software operation. It is expected that this need will decrease over the long term when people become more mature in the CONSAT function. In addition, it was noted that a good knowledge of the Ground Station hardware by the CONSATs helps to speed up the process of learning the satellite control software.