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THE ANTENNA MANAGER SOFTWARE FOR THE BRAZILIAN SATELLITE: IMPLEMENTATION AND STUDY

Maria de Fátima Matiello-Francisco
Ana Maria Ambrosio
Mario José C. Ciurria

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horizon, i.e., when the first acquisition scenario occurs;

- TAA: applied when the satelite orbits are well known; it is executed to capture satellite signal on the horizon when the second acquisition scenario occurs;

- PROGRAMMED MODE: chosen to cover some special cases, for instance, when malfunction of the antenna autotrack system occurs, or when there is a silent zone in the horizon. It can be applied to cover whatever part of the satellite orbit is chosen. It must be executed when the second acquisition scenario occurs;

- ASSISTED TRACKING: activated automatically when the satellite signal is lost, used to cover the silent zones. In this case the on-board transmitter is supposed to be turned on; no frequency sweeping is necessary.

2. THE ANTENNA MANAGER SOFTWARE REQUIREMENTS

The Antenna Manager Software - GAN is designed to acquire and keep automatically the execution of the appropriate tracking strategy. Its main requirements are itemized below:

- to execute the SCAN strategy which consists of computing, using Pass Prediction Data, a set of target points and commanding the Antenna Controller Unit (ACU) to execute a scan around each indicated point;

- to execute the TAA strategy, which consists of: computing, using Pass Prediction Data, a set of angular discrete positions that cover the orbit on horizon, sending to the ACU each calculated point at the specific time; making a frequency sweeping and telecommand transmission just after each new pointing is completed. This management procedure also implies in establishing connection with the Telecommand Set before sending each telecommand package and, finally, commanding the Telecommand Set disconnection when this tracking strategy is completed;

- to execute the PROGRAMMED MODE, which consists of: computing, using Pass Prediction Data, a set of angular discrete positions that cover the orbit during the complete pass, sending a target point to the ACU each 0.1 second; repeating a frequency sweeping and keep sending telecommands until an operator interruption occurs; establishing connection with the Telecommand Set before sending the telecommands and establishing disconnection whenever it may be considered appropriate;

- to execute the ASSISTED TRACKING strategy when the satellite enters in a silent zone. This action consists of computing, according the Pass Prediction Data and the Angular Measures, the estimates of target points of the satellite orbit and of transmission of each target point to the antenna controller every 0.1 second;

- to repeat a frequency sweeping when asked by operator;

- to abort a frequency sweeping or an acquisition and the related tracking process whenever in execution, when required by operator;

- to acquire angular measure from the ACU every second, when the autotrack operation mode is *being executed*;

- to read the status of the ACU in support to each of the strategies under execution and to provide monitoring data to the Ground Station Equipment Supervisor Software;

- to send information to the ground station operator about the status of the strategy under execution;

- to execute the remote configuration of the antenna system parameters, whenever required by Ground Station Equipment Supervisor Software.

3. PROBLEM ANALYSIS

This section presents the results of the analysis of the GAN software requirements, considered as a component of the Satellite Control System Software. Section 3.1 presents the achieved results when applied the method based on the Structured Analysis and Design method which was adopted in the mentioned system software, as a whole. Section 3.2 presents the results achieved following the steps of the JSD (Jackson System Development) method, which was applied en the GAN analysis phase as a study.

3.1 <u>A method based on structured analysis and design</u>

The method (Ref. 1), characterized as conventional (Ref. 2), was applied in the GAN software development process, for determining, in its requirements analysis phase, the functions and their mapping, as "black boxes", in the dataflow diagram.

Figure 3.1 presents the Dataflow Diagram (DFD) where the related processes are arranged in three modules, according to a scheme of concurrence adopted in later phases of the project.

The independence of the Sweeping Module is necessary because the frequency sweeping is a control function that, once activated, must be concurrently executed with the acquisition and tracking management function. In a strategy execution, the function which Execute the Frequency Sweeping synchronizes the commands sent to the Frequency Synthetizer Equipment and those commands sent to Telecommand Encoder Equipment, when the telecommand have to be transmitted to turn on the on-board transmitter.

The functional autonomy of the Assisted Tracking Module is clearly recognized in two different ways in Figure 3.1, when observing its paralellism of execution with the Acquisition Manager Module. In one, it can be observed that the "Refine the Orbit" function has to be executed in parallel with the "Read Angular Measures" function, during the autotrack periods. In another way, it is observed that the "Propagate the Orbit" function has to be executed in parallel with the "Read Status of the Antenna Controller Unit" function during occurrence of silent zone periods.

Finally, it is observed that the functions: "Communication with the Operator", "Execute Configuration and Monitoring of the ACU", "Read Angular Measures", "Read Status of the ACU", "Execute TAA", "SCAN" and "Programmed Mode Strategies", presented in Figure 3.1 are aggregated in the Acquisition Manager Module due to their strongly coupled nature. That is, they depend on common management to organize the execution of the independent functions after an event occurs.

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Maria de Fatima M. Francisco, [1]
Ana Maria Ambrosio, [1,2]
Mario José C. Ciurria [1]

[1] Instituto de Pesquisas Espaciais - INPE, P.O. Box 515, 12201 São José dos Campos - SP - Brasil
[2] Sociedade Civil de Educação Bras Cubas, 08700 Mogi das Cruzes-SP-Brasil

ABSTRACT

This paper presents the design and implementation of the Antenna Manager Software, defined to acquire the first brazilian satellite from the horizon, track and reacquire it after silent zones. Three strategies are defined to cover the satellite passes. They consist of pointing the antenna, commanding the execution of the TT&C station up-link frequency sweep, sending a telecommand to turn on the on-board transmitter, and, accepting commands from operator. This problem was analysed by the use of a finite state automata and implemented in VAX-FORTRAN language through a decision table. The advantage of this design is the use of a table for handling events, which allows the re-utilization of the software for other missions, only by implementing changes in the decision table. Results on the study of the JSD Method, applied to this software, are also presented. These results show another way to analyse and solve the same problem.

Keywords: automata, real time, parallelism, handling of events.

1. ACQUISITION AND TRACKING

A description of the characteristics and needs to perform acquisition and tracking for the Brazilian Data Collection Satellite - SCD1 is presented in this section.

To establish the connection between the satellite SCD1 and the Cuiabá or Alcântara ground station, a frequency sweeping procedure must carried out. This procedure is defined as a function of the features of the satellite orbits when it is flying over the ground station and by the features of the satellite on-board receiver. This procedure is programmed and executed at the station by the so called Frequency Sweeping Synthetizer equipment.

Two satellite acquisition scenarios are defined in an attempt to simplify the operations in both ground stations:

- Scenario 1 - considered in the first satellite passes on ground station. In this case the on-board transmitter is considered to be turned on. Therefore, it is assumed to be not necessary to send telecommands to activate reception of telemetry. However, it is necessary to increase the range of acquisition with the antenna scanning between each horizon position, to minimize the difficulty posed by the Doppler effect caused by the launcher.
- Scenario 2 - considered in the later satellite passes. In this case the on-board transmitter is assumed to be turned off. Therefore as soon as the connection between the satellite and the ground station is established (with support of frequency sweeping), it is necessary to send telecommand to turn on the on-board transmitter for the station to receive telemetry.

During tracking of the satellite by the Ground Station (G.S.), it is used an antenna system which provides:

1) correct pointing of the antenna at a specific time of the orbit, permitting the antenna to follow the subsequent orbit described by the satellite;

2) acquisition of successive points of the orbit being effectively tracked by the antenna when it is in "autotrack mode";

3) continuous monitoring of the status of antennna system that notifies the controller on the capture and loss of the satellite signal;

4) modification of the antenna system configuration parameters.

Due to the SCD1 satellite features, in some of its passes over the G.S., there are periods in which the antenna looses capture of the signal from satellite. These periods are named "Silent Zones". When the silent zones occur the antenna must be positioned following an orbit prediction algorithm, to maintain tracking and to recover to the signal capture state, after the silent zone is covered.

Considering the information mentioned above, four acquisition and tracking strategies for the SCD1 satellite are defined. Three of them must be chosen by the operator before a satellite pass. The fourth strategy (Assisted Tracking) must be executed automatically during occurence of silent zones. The four strategies are:

SCAN: applied during the first passes; executed to capture signal from the satellite in the

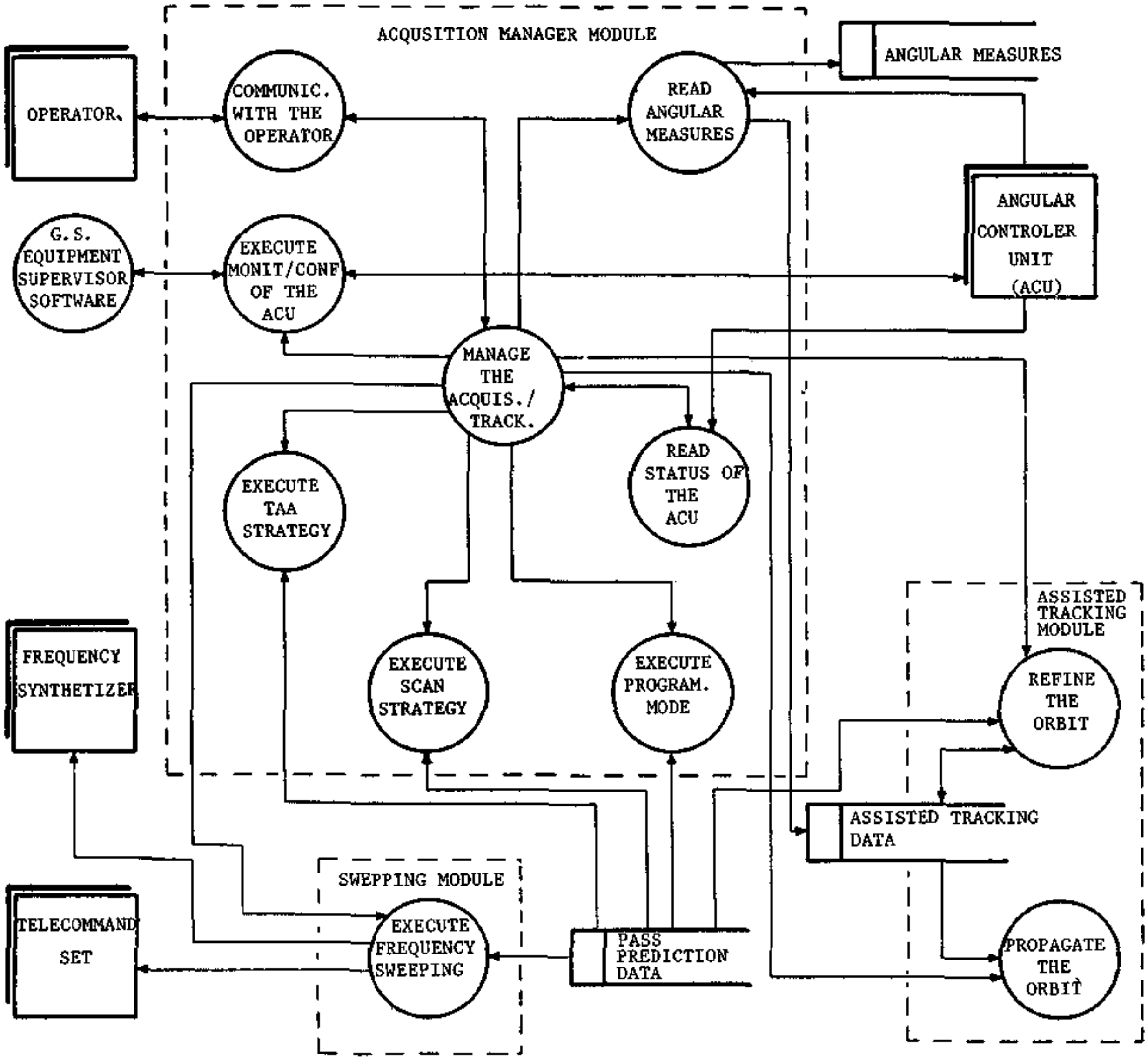

Figure 3.1: Dataflow Diagram.

Considering that events take place asynchronously and that their treatment depend on the system context, the partition in functional processes, with the description of their data flows, besides the aggregation of these same processes in parallel modules, do not show enough evidence on the dynamic nature of the actual problem. A solution for this type of analysis limitation can be overcome with the use of a finite state automata. With the automata, the "Manage the Acquisition and Tracking" function can be analysed in details, considering now that the cascading effect of events that can take place can be characterized. The automaton is illustrated in the Figure 3.2.

3.2 The JSD development method

In the Jackson System Development (JSD) (Ref. 3), an operational method (Ref. 2), the analysis of the problem begins, tentatively, with the building of the real world model, with a structured, gradual detailing of the involved functions in advanced steps of development method.

The analysis of the antenna management problem through the JSD method, the real world model is firstly defined by entities identified in scope of the system. The list of entities which were selected and their related actions are enumerated as follows.

. Antenna - point, acquisition/loss of the satellite signal;

. Operator - choose one of the options:
  . execute/abort the SCAN strategy,
  . execute/abort the TAA strategy,
  . execute/abort the PROGRAMMED MODE strategy,
  . activate/interrupt the execution of the frequency sweeping without telecommand;
  . display the tracking in console information;

. Frequency synthetizer - receive the programation of a sweeping function according to the convenient scenario, and execute it;

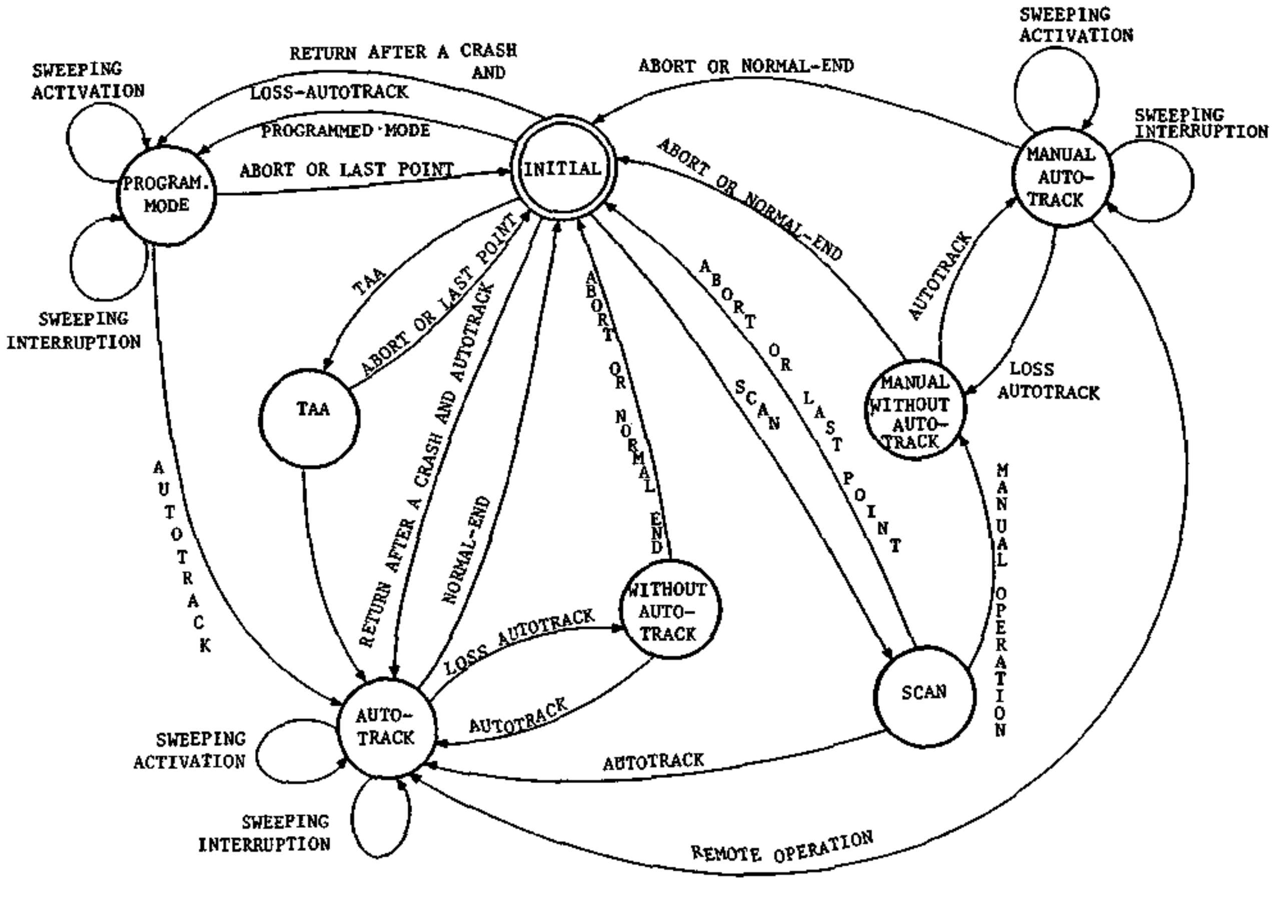

Figure 3.2: Finite State Automata.

. <u>Telecommand set</u> - establish ground station computer connection and disconnection, receive TC from station computer, irradiate the TC.

In the second step of this method the order of the actions is established. To each entity, a related structured diagram is built, but they are not presented here, to avoid extending this work.

The initial model is defined in third step, and drawn (in bold) in the specification diagram, as shown in Figure 4.1. In the inicial model, so called sequential "model processes" are created from each entity and the connections among them are defined by data streams.

Each model process is defined by a structure text. In the following, forth step of the method, the fucntions are introduced in the initial model definition. The required functions, which are introduced in this work, are those described in Section 2.

Some functions as: "Execute SCAN strategy", "Execute TAA Strategy", "Read Angular Measures", "Read ACU Status", etc., are introduced in the model as "function processes", while the other functions are transformed as part of the "model processes" as defined before, in the initial model. For each function process there is also a structured diagram and text.

When analysing the execution of each strategy, it can be seen that they perform the transmission of target points to the antenna at precise intervals of time, which impplies in the definition of TGMs ("Time Grain Markers") for signaling the time in which each target point is to be considered in the process. Subsequently, the data stream "P", containing the points generated by the corresponding strategy process, is rough merged with the TGM, denoted as "T" as seen in the diagram of the Figure 4.1. Meanwhile, the T6 and the T5 TGMs are not defined to signal the pointing time, but on the other hand, they are used to signal the rate of angular measures acquisition while obtaining, by the software, the status of the ACU system.

The Angular Measures and the Status of ACU processes have similar characteristics. They have a "state vector" connection which is rough merged with a TGM, resulting in the AM&T6 and S&T5 rough merges respectivelly.

In the TAA Strategy, each antenna pointing need to be synchronized with the telecommand transmission and with the frequency sweeping execution, such that a single TGM (T3) is rough merged with the data stream "P", which contains the target points, and with the data stream "TC", which contains the telecommands, including also the data stream "FS", which contains the frequency sweeping ativation messages, involving the "Antenna", "Syntethizer" and "Telecommand" processes resulting in a P&TC&FS&T3 rough merge.

As it is shown in the Figure 4.1, the "Assisted Tracking" and the "Programmed Mode" strategies have the same rate of data transmission of each target point to the Antenna, so their "P" data stream are rough merged with T1, which sets the data rate. However, these strategies are not related to each

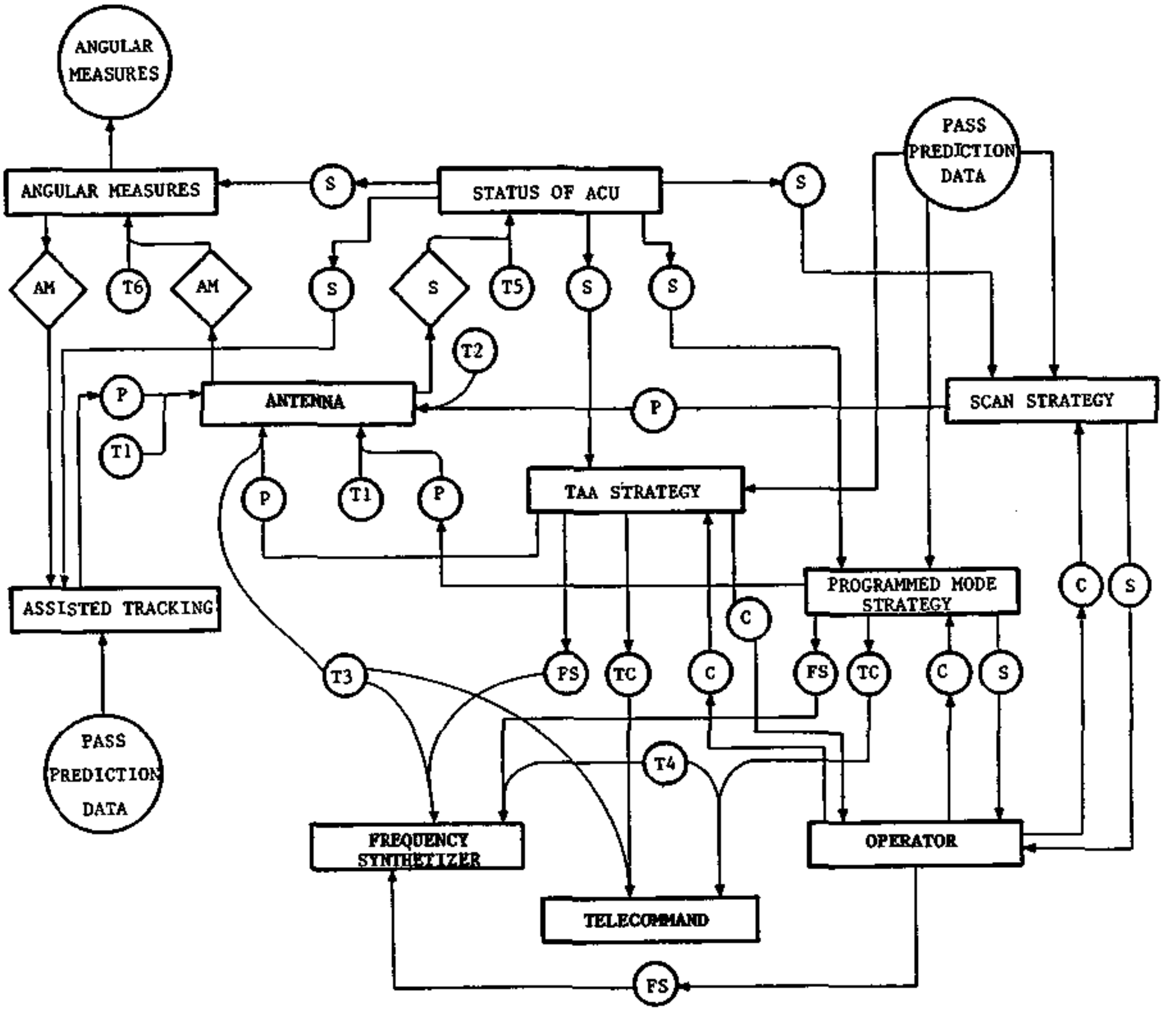

Figure 4.1: System Specification Diagram.

other, which, still, implies in the definition of two different simple rough merges as follows.

When the "Programmed Mode Strategy" is activated in scenario 2, the "Frequency Sweeping" and "Telecommand" processes must be executed, concurrently, in the begining of the strategy. However, these two processes may not be synchronized with the antenna pointing. To overcome this, the TC&FS&T4 rough merge is obtained to determine the rate of transmission of telecommands and for activation of the frequency sweeping process, as required by this strategy.

The temporization analysis of the system, is possible with the introduction of TGMs, concluding the JSD specification phase, which results in the system specification diagram, as illustrated in Figure 4.1.

4. IMPLEMENTATION

The evolution of the implementation phase of the Antenna Manager Software is presented in this section. In its following items 4.1 and 4.2, the same paralellism covered in the 3.1 and 3.2 items are maintained, in terms of the presented methods.

4.1 Decision table

The finite state automaton applied to study the problem in the analysis phase, was mapped in a decision table. This table was implemented through a matrix where the lines characterize the automata states and the columns characterize the associated events. The element of the matrix describes the action which has to be taken in a determined state of the system when an associated event occurs. The codification of the decision table, in VAX-Fortran language, permitted to centralize the management of all the events in a single process, as specified in the DFD's function, named "Manager the Acquisition and Tracking". The other DFD's processes of the Acquisition Manager Module were conceived as servers. They recognize the events and execute specific tasks when required by management process.

This conception permitted the implementation of the server processes, in VAX/VMS environment, some of them as independent asynchronous routines (ASTs- "Asynchronous System Traps") and others as concurrent VAX/VMS detached processes. These servers are sometimes actived by requisition of the management process or, autonomously, through system timers as the "Read Angular Measures" process, whose periodic execution is a requirement of the system.

The signaling of the events detected by server processes to management process is done through a common area named "Occurred Events Vector".

4.2 Specification diagram

When the problem was analysed with support of the JSD Method, it could be drawn that the implementation phase was immediate, because the VAX/VMS operational system provides all the resources to implement the Specification Diagram. In this environment, the processes presented in the System Specification Diagram, as given by the Figure 4.1, could be implemented by the so called concurrent images or asynchronous routines (ASTs). On the other hand, the data stream connections could be implemented by using "VAX/VMS global sections".

It is verified that, the implementation diagram corresponds to the system specification diagram, and, therefore, to the real world model.

5. REUTILIZATION BY OTHER MISSIONS

This work is not intended to compare the mentioned methods, instead, it presents solutions when a conventional and an operational method is adopted, in the analysis and implementation phases of a real time system.

The utilization of a finite state automata technique aggregated to a conventional method like the Structured Analysis, actually adopted in the Antenna Manager Software, was verified to be very adequate to the solution of the problem. This technique, used during the analysis phase, permitted an almost straight mapping to the coding decreasing, therefore, the amount of work to evolve from the analysis to the implementation phase. The control of events, centralized in a single machine process, which implements a decision table, permitted to standardize the treatment of the occurred events and to implement the processes named "servers", as independent asynchronous functional procedures, as well. After observing the implementation of these functional procedures it can be concluded that similarity exists in the solution of implementation obtained with application of the JSD operacional method, in terms of the modularity. This result was important because JSD method is oriented to real time systems.

Although, in the conventional method, the control of events has been centralized and in the JSD method it has been distributed, both implementations provide support to the re-utilization of the related software by other missions. In terms of the decision table, the insertion/exclusion of elements is very simple, permiting changes in the actions (function modularity) and the introduction of new events and states in the system, in fairly simple way. In the second case, the JSD Method, after being already aware of functional modifications during the design, the process of analysis with the generation of the "initial model" begins with the identification of the real world entities which the system has interfaces with.

Assuming that the real world does not change, the same "initial model" can be used when the re-utilization of the system is necessary, in support to other missions. The system admits functional changes and can include them as a funcional modification which becames necessary during the design phase.

It is important to observe that the second case (JSD method) was not implemented. For this reason, it must be observed that actual parameters for real analysis on the implications of the JSD method, that would be generated by the system, when a function is inserted or deleted, are not known. Howevver, the results which were obtained with the study of JSD Method gave to the development team of the Antenna Manager Software great satisfaction and security about its performance, as a verification method of the system design phase.

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Autor

Maria de Fátima MATTIELLO-FRANCISCO, Ana Maria AMBROSIO, Mario José C. Ciurria

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Edenilse F.E. Orlandi
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