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STATUS OF STATION AUTOMATION

M. E. SHAWE

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GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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ABSTRACT

The SRT work directed toward automating many of the subsystems in data acquisition links is described. Status of the subsystem efforts is covered with likely direction for the future. Problems contained in work of this kind are mentioned briefly and the future work on this project in relation to major GSFC projects is described.

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STATUS OF STATION AUTOMATION

I. HISTORY

In October of 1965 the first description of the station automation* project was written by the author. The lead paragraph stated "It is felt that by judicious use of automatic equipment to supplement man in some repetitious task, station operations may occur more swiftly and passes be handled more efficiently resulting in greater station capacity with little added manpower."

Functions which are candidates for "judicious" automating include:

A. Tracking Station Equipment Pre and Post Pass Set-Up and Test and Operation.

1. Equipment Set-up and Control of Antenna, Transmitters, Switching Systems, Receivers, PCM/DHE, Command Generators, Tape Units (Digital), Computer.

2. Pass Simulation and Telemetry Test.

3. Communications Test.

4. Spacecraft Position Determination.

5. Telemetry Decommutation and Data Compression.

6. Spacecraft Quick Look Evaluation.

7. Command Initiation.

8. Data Display.

B. Tracking Station Management and Control.

1. Pass Scheduling.

2. Spacecraft Telemetry and Tracking Pass Support Requirements Listing Telemetry and Tracking.

3. Preventive Maintenance Scheduling.

*Station Automation, M. E. Shawe, X-521-66-168, April 1966

C. Auxiliary Functions Include:

1. Station Inventory Control.

2. Fly-By-Test Support.

3. Equipment Operating Logs.

All of the above candidates were selected for the purpose of being able to:

- Select, interconnect and test telemetry equipments for support of multiple satellite passes.
- Acquire data and record for later transmission.
- Transmit commands and monitor satellite performance.
- Operate communications facilities in order to exchange status, command, and experiment data with GSFC.
- Maintain a continuous body of knowledge on the ability of the station to support multiple passes.

The purpose of this document is to provide a situation report on the Automated Ground Station project.

II. JUSTIFICATION

The increased complication of spacecraft and the increasing demands for real time control placed a requirement for greater reaction speed and flexibility on the Satellite Tracking and Data Acquisition Network, STADAN. A study of the Santiago station (Figure 1) showed that if the station were to try to take all passes of spacecraft that come into view as many as 9 telemetry links could be required. This was predicated on manual interconnection and test of a link taking between 10 and 25 minutes and post pass test of 5 to 10 minutes. The graphical analysis showed that if these pre and post pass times were reduced to one minute, peak loads were reduced to 5 telemetry links. It appeared at that point in time that the automation and consequent reduction of switchover times could pay large dividends in increased operational capability both from the number of spacecraft handled and the knowledge of system operational status.

Prior to this the stations had been evolving toward a composite system which was considered a group of telemetry subsystems-duplicated where necessary to

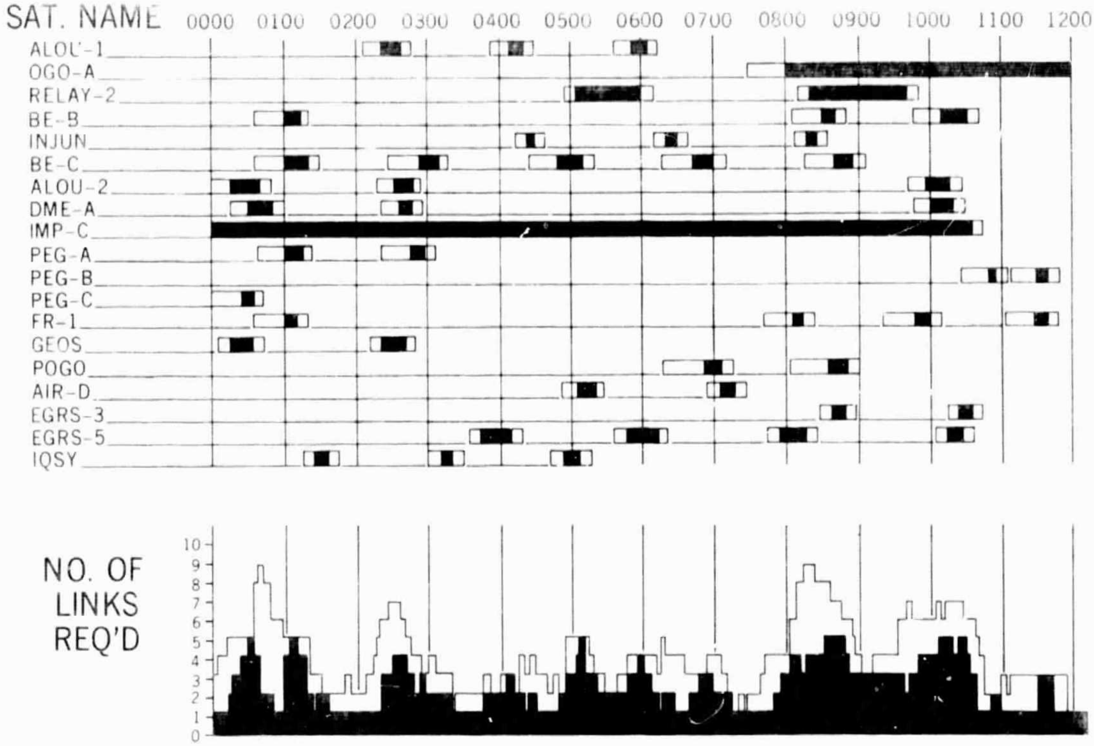


Figure 1. SANTIAGO, March 1966

provide multiple links. A switching system providing remote patchboard programming and remote push button selection was being designed to speed up the switchover process. However the system (shown in Figure 2) retained essentially a manual approach to the switchover problem. Computers were being used in STADAN but were considered as peripheral to the station data acquisition function.

It became apparent that the only effective way to reduce the switchover time, in view of the many repetitious control and test functions, was to use a computer as a keystone element in the design of future stations. The Station Automation program based on this premise was to design such a system to include computer control of equipment for switching, test and operation as in Figure 3. It was recognized that once this capability existed at a station other benefits would accrue such as the auxiliary functions above.

III. GOALS

As a practical matter it has been recognized that the switching and tests could not be performed in much less than 1-minute due to AGC speeds, statistical

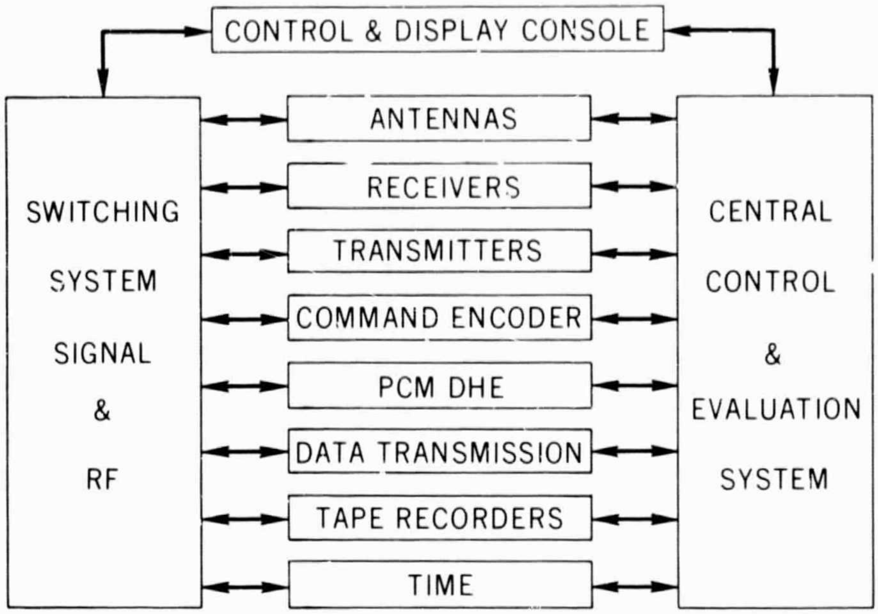


Figure 2. Block Diagram Without Computer

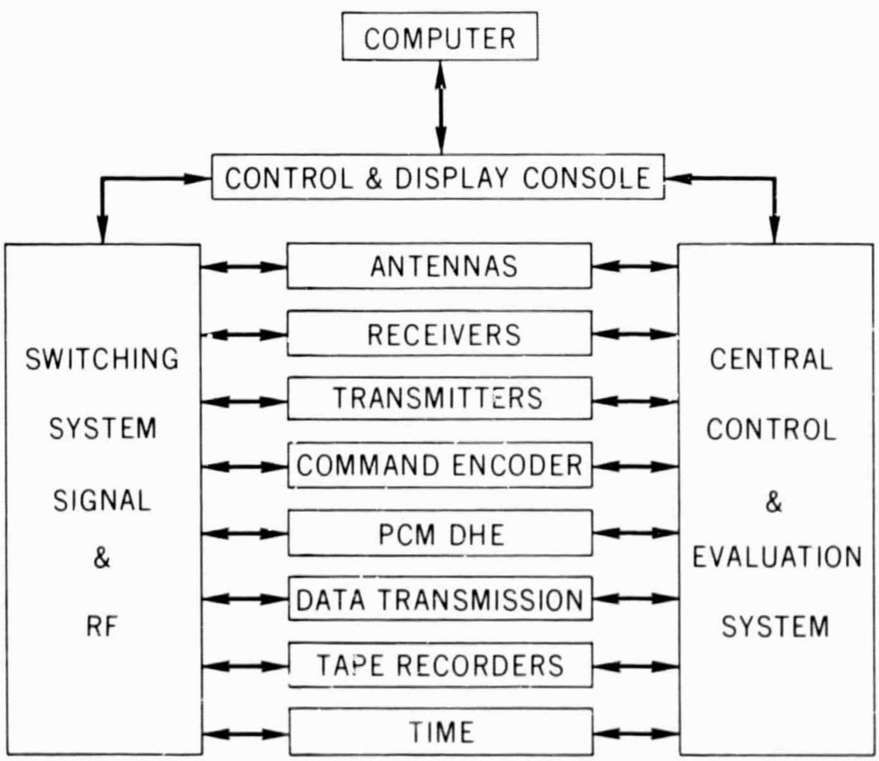


Figure 3. Block Diagram With Computer

analysis of errors, and antenna slewing rates. For these reasons 1-minute was established as a design goal for pre and post-pass switchover and test.

The Automated Station was to be designed on a system concept recognizing the interrelationships between subsystems within a station and between stations on a Network basis. The SRT program has been coordinated with the station scheduling, control center, communications and data processing SRT improvements taking place in other divisions.

The direction has been to build upon the present station and prove the computer control concepts by actually accomplishing them in hardware and software in the Network Test and Training Facility (NTTF). The subsystems capable of computer control and interfacing would be developed with SRT funds and time phased with the overall project effort.

In performing the tasks the tradeoffs between special purpose hardware and computer solution of problems would be experienced and solved. The system would give a real awareness of the reliability problem and a good idea of its solution. The concept of central computer control would be tested.

Successful operation of an automated facility would demonstrate a capability which would be put in STADAN to provide a near real time data acquisition and control capability approaching that desired for the Data Relay Satellite System*

IV. PROGRESS

The Station Automation project has pulled together the various subsystems as shown in Figure 4, determined the development schedules, and planned for the computer interfacing with and programming for each subsystem. At the same time studies have been directed toward determining the effectiveness of technological improvements in the overall station and network operation. It only remained to include the element of cost in order to make cost/effectiveness tradeoff studies.

Figure 4 shows as subsystems the functions to be performed in a typical automated station telemetry link. The dotted lines are control functions which are performed using the computer system. Originally it was expected that the SRT effort would be directed toward including the tracking function as another signal generation, transmission, reception, decoding and data processing function of the automated system. However, lack of personnel and funds have restricted work in this area to only cursory review of concepts.

Figure 5 is a block diagram from the original write-up of Station Automation. It has been modified to reflect the latest subsystem changes. Under the computer

*GSFC MKI Tracking and Data Relay Satellite Concept, Interim Report, X701 69 98.

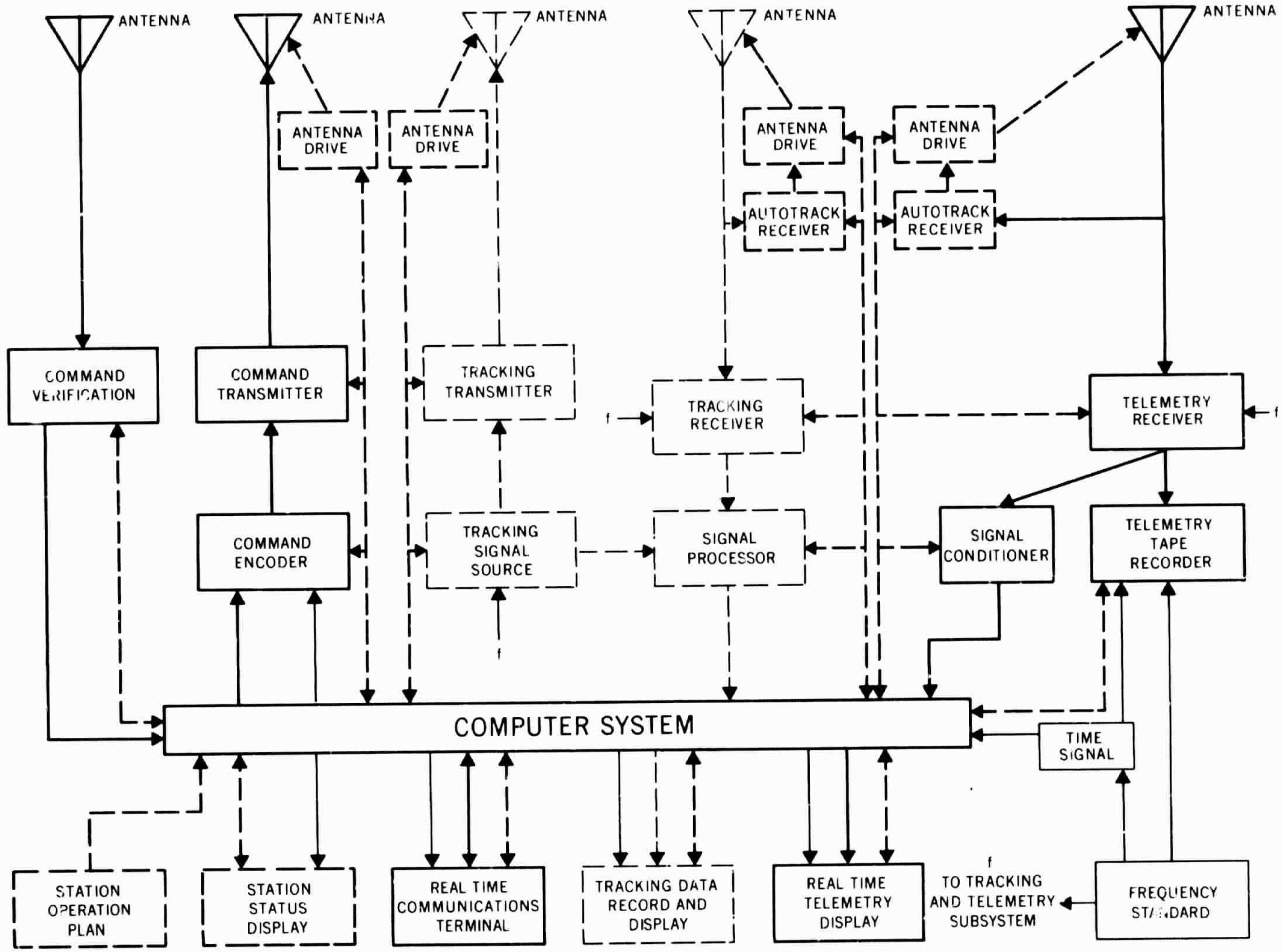


Figure 4. Functional Block Diagram Station Automation

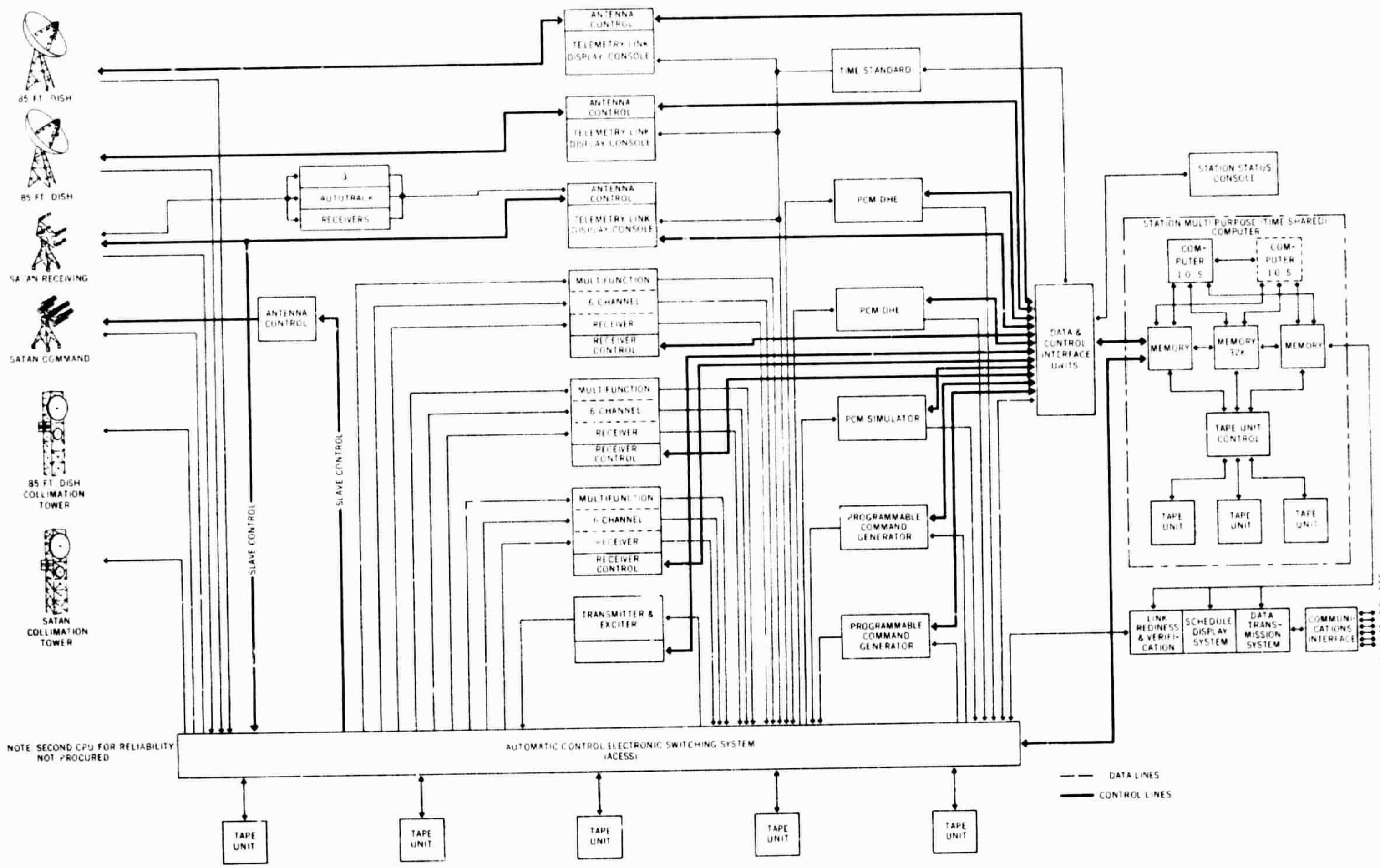


Figure 5. Tentative Block Diagram of Automatic Tracking Station

control a predetermined portion of the station equipment is connected together by ACESS to form a telemetry link consisting of receiving antenna, receivers, PCM/DHE, decision element (Computer), Data Display, Command Generator and Verifier, Command Transmitter, and Command Antenna. The command equipment may be switched in and out of a link during a pass and be time shared for other spacecraft support requirements. The main features which allow Station Automation are ACESS, the computer controlled switching system, and the muliprocessing computer, which provides equipment control. The display system provides a man/machine interface to keep station personnel informed and allows human intervention as necessary.

A. Cost/Effectiveness

A program has been written, guided by P. Pease, which in effect is a large statistics generator. Using the mathematical techniques of Operations Research, the program accepts many variable parameters, some of which are listed below:

- Number of Spacecraft in orbit of various types
- Number of Equipment in the station of various types
- Number of personnel of various types
- Time spent switching the station
- Time spent during prepass testing
- Amount of Status Monitoring capability
- Factors contributing to operational capability (Maintenance procedures, spare equipments, mean time to repair (MTTR), mean time to failure (MTTF), etc.)
- Number of spare parts of various types
- Time to replenish spares

The problem is similar to the classic one in which a loading area is used for placing a product on the customer's trucks. Given some number of customers arriving at some variable schedule, what production capability and number of loading slots are needed to keep both customer waiting time and our investment in facilities to a minimum? In our case the customers are the spacecraft, and the loading docks are our telemetry links with production capability consisting of the maintenance personnel, spares, procedures, etc. The problem is to maximize link "available" time. The program has been used to arrive at performance measures of manual, semiautomated and automated stations.

The program may be used to vary all parameters, e.g., number of spares, MTTF, and MTTR, to see the effect on station operation by optimization procedures which can produce "best mixes of parameters.

Within the past year J. Moye, S. Paseur, and P. Pease have performed a complete analysis of equipment costs for the manual, semiautomated (5-minute switchover) and automated (1-minute switchover) stations combined with an analysis of present station performance and future station performance (above) to produce* cost/effectiveness trade-off curves which can help management select the most desirable direction to move for the future to meet the predicted station loading derived by the T&DS Development Committee headed by Mr. Halib.

Figure 6 is an example of the results. Analysis has shown that the 5-minute and 1 stations give a 20% to 40% improvement in efficiency at 80% station

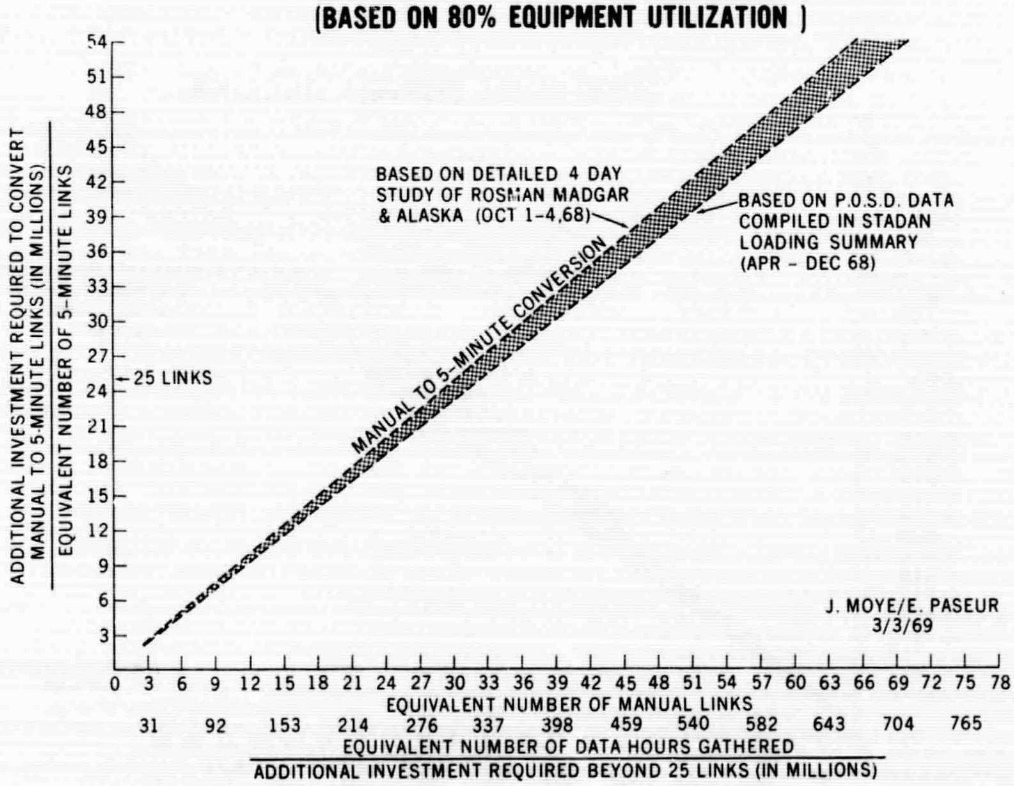


Figure 6. Graph of Station Costs Versus Link Requirements for 5-Minute Station

*Cost Effectiveness Analysis of Station Automation, J. Moye et al., X Document in preparation.

equipment time utilization. The utilization figures were based on studies of actual station scheduling and switchover times and validated using Project Operations Support Division (POSD) data derived independently. Agreement was within 10% with POSD figures predicting greater improvement. The improvement first assumed more equipment utilization (80%) than at present. Then the improvements due to automation were calculated by shortening the switchover times. The shaded areas are the regions between the two sets of efficiency figures.

Given an expected number of data hours, Figure 6 may be converted to the number of manual links needed, e.g., 490 hours requires 48 links (assumes 80% equipment utilization). The equivalent number of 5-minute links obtained is between 37 and 39. Equivalent number of links may be converted to additional investment required by multiplying the per link cost times the number of links. Cost figures per link have been calculated and are available to qualified individuals for the Additional Investment Required Scale (ordinate) for manual and 5-minute links. The figures may then be used to make comparison studies. Similarly on Figure 7 the load handled by 48 manual links may be supported by

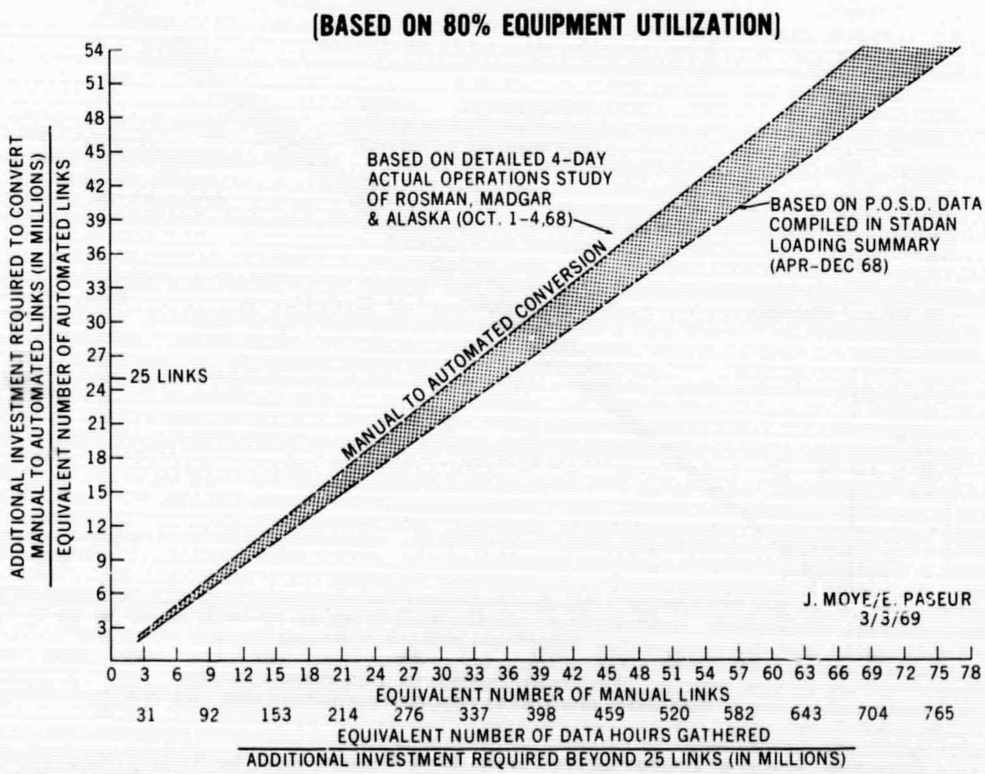


Figure 7. Graph of Station Costs Versus Link Requirement on 1-Minute Station

between 33 and 38 one-minute links. The change in personnel required for manning an automated station is expected to result in a net savings in manpower. These figures are presently being estimated to determine net amortization of investments for 5-minute and automated stations. It should be pointed out that the 5-minute station is the initial step in a design effort toward a 1-minute station.

B. Computer

1. Hardware—Directed by J. Rogers a Sigma 5 real-time multiprocessing computer has been procured and installed in the Network Test and Training Facility (NTTF) where it is planned that the developmental Automated Station will be assembled. The computer is a medium size machine able to perform real-time control and general purpose computing, accomplishing both kinds of work on a time shared basis by means of interrupt hardware and software. The operating system gives first priority to processing real time control programs in the foreground while remaining computer capacity may be used for the general data processing in the background. The system has standard peripheral equipment shown in Figure 8.

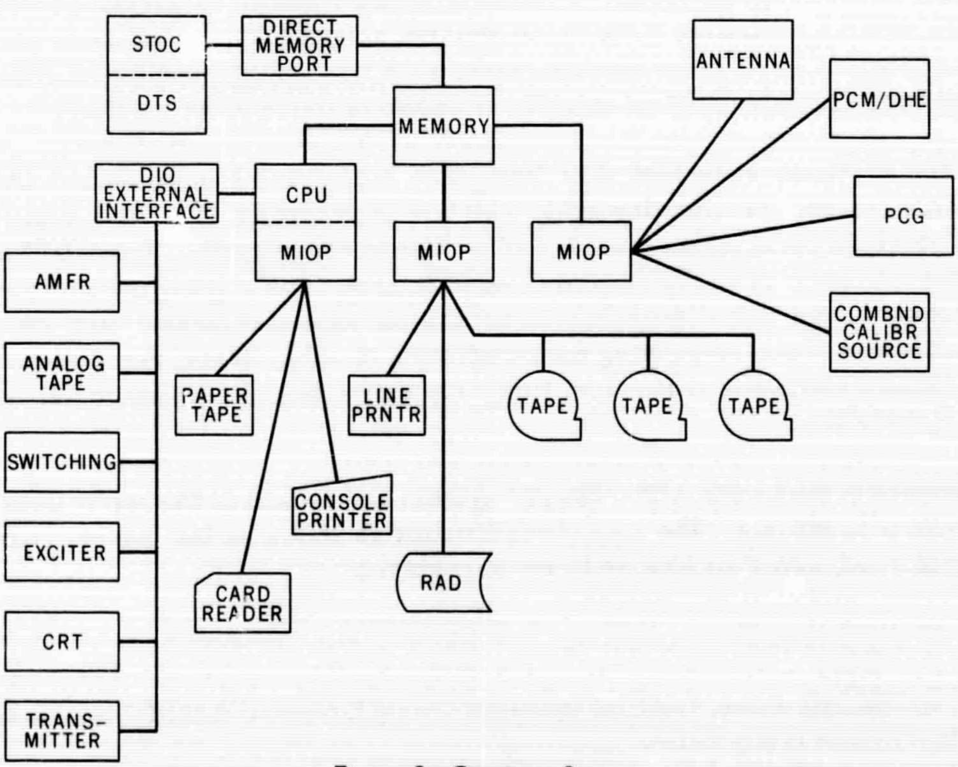


Figure 8. Computer System

Additional interrupts and general purpose register blocks have been added to accommodate the Station Operations and Control (STOC) requirements.*

To reduce SRT funds expenditure present plans call for simulation by programming of a second Central Processor to fully test the reliability aspects of such a system. The hardware system has operated satisfactorily in the NTTF environment. The previous problem had been in getting the manufacturer to efficiently install field modifications and system additions and return the system to operating condition.

2. Software—The computing system was delivered with a standard set of software including Basic and Batch Processing Monitor (Executive), FORTRAN IV compiler, Meta-Symbol Compiler, re-entrant mathematical subroutines, general debug routines, system diagnostics, and system generation program. Actual real time control programs for all station subsystems are being written and debugged as the particular subsystem is installed and interfaced with the computer.

The Batch Processing Monitor delivered with the computer, while capable of scheduling and accomplishing real time operations, is not designed to operate in an environment which is almost 100% real time. It spends precious microseconds in bookkeeping functions that are of more benefit to the background programs such as compiling rather than automated operations. A work order has been given to a local programming company to assess the problem of creating a real time monitor using as much as possible of the present monitor.

The above effort is part of an Integrated Automated Ground Station (AGS) Software System specification study which is in progress. The first report† has been received covering an overall look at the software system required for successful operation of an Automated Ground Station. The report includes philosphy of system design with discussions of programming and documentation standards, identification of and scheduling for integration of subsystems, recommendation for efficient computer utilization, time cost estimates, timing estimates, data flow constraints.

Figure 9 shows the AGS software system and indicates the application of the subsystem programs. The Executive/Monitor is shown as the central controlling element which gives an idea as to its importance.

*GSFC Specification Station Technical Operations Control Equipments S-534-P-7 May 17, 1967, New Specification in preparation.

†Automated Ground Station Software Study, Vol. 1 & 2 Wolf R&D Corp.

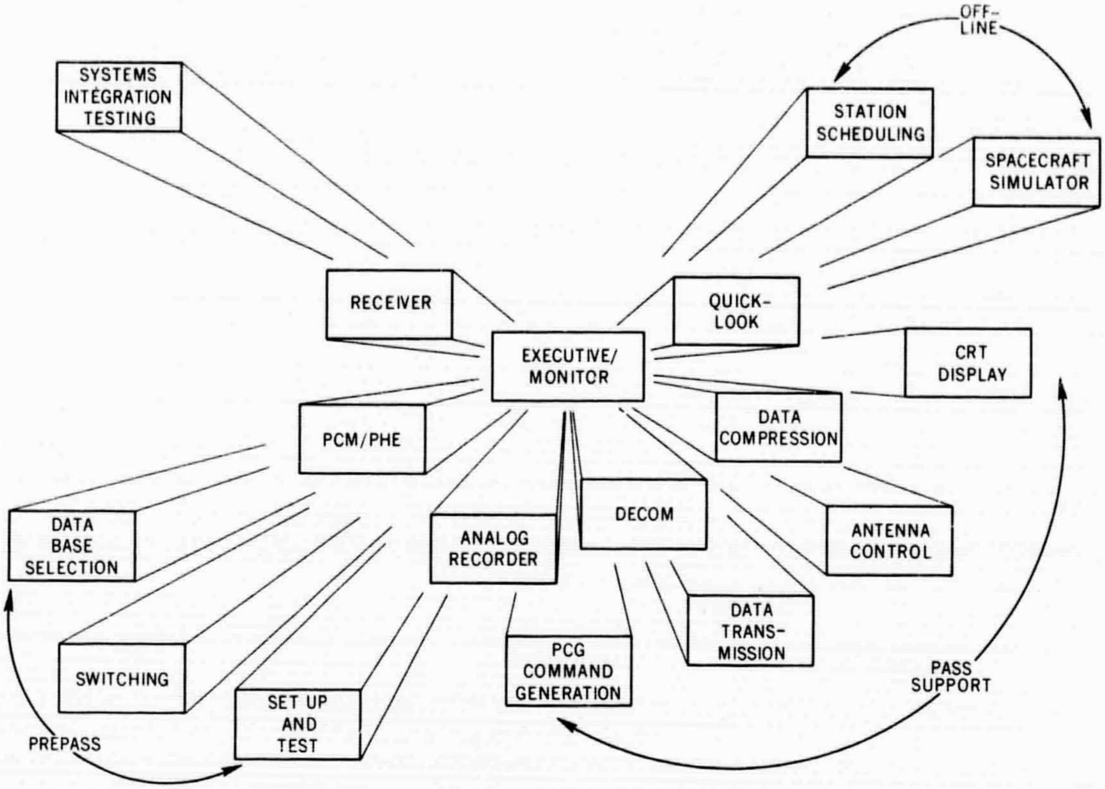


Figure 9. AGS Software System

The specification study is an important part of the software configuration control applied to the AGS project. Program writing debugging and documentation is thereby expected to be more efficient and manageable.*

C. Switching System (ACESS)

The computer controlled switching system combined with the computer tuning and adjustment of telemetry link subsystems are expected to provide the major reductions in set up and test time during pre and post pass operations. It would be very difficult to reach a one minute switchover time by any other means. There are simply too many pieces of equipment to switch and test. The ability to switch out defective equipment and switch in a substitute selected by the computer from its inventory is provided by the combination of ACESS, equipment control, and link readiness testing.

*Automated Ground Station Software Development, J. C. Rodgers, X-521-67-492, October 1967.

A study has been performed to verify the number of switching points required in a station. It has shown that working within network wide guidelines economies of patch points and line drivers can be effected if an entire new switching system design were attempted. These resulted when it was determined that the equipment used by 28 of 31 satellites was essentially the same and could be connected in very similar manner, thereby reducing the number of switching options necessary. Before reducing the number of switching points one must consider the need of future satellites for the additional options.

The major problem at NTTF is to marry the existing switching system to the Sigma 5 computer. In order to do this the patchboards and push-buttons must be replaced by switches. The most straightforward method is to substitute a computer controlled crossbar switch or relay for the present patchboards. The RF switching system is already designed for computer control. The methods used above will provide rapid return to normal station configuration to meet the normal test and training functions in NTTF.

D. <u>40' Antenna</u>

The substance of the antenna program, guided by G. Winston and N. Raumann, as it relates to the AGS project is to replace the antenna programmer by a computer and additionally make use of the general computing and control capability as shown in Figure 10. As has been discussed* the computer may be used to replace the servo amplifier and to perform optimal pointing control by combining autotrack and programmer control. Automatic start up, diagnostic tests, operation and shut down are also planned.

The basic antenna/computer interface was delivered with the Sigma 5 computer. The final detailed interface and wiring for the 40 foot dish at NTTF is being fabricated. A program is being written to enable the computer to control the antenna based on orbit predict data. The program will be checked out using an analog computer to simulate the 40 foot dish. Since the computer and interface are capable of controlling more than one antenna, the analog computer may be used in the future to simulate multiple links. A program is also being written to combine the programming and autotrack modes of antenna pointing.

In addition to the experiments to test digital computer control of an antenna, a program is in progress enabling diagnostic tests of antenna power supplies, servo amplifiers, hydraulics etc., and monitoring of discrete items such as mode, temperature, pressure, limits, circuit breakers, etc. The goal is automatic pre and post pass antenna checkout.

*Antenna Control in Station Automation–George Winston, X-523-67-496.

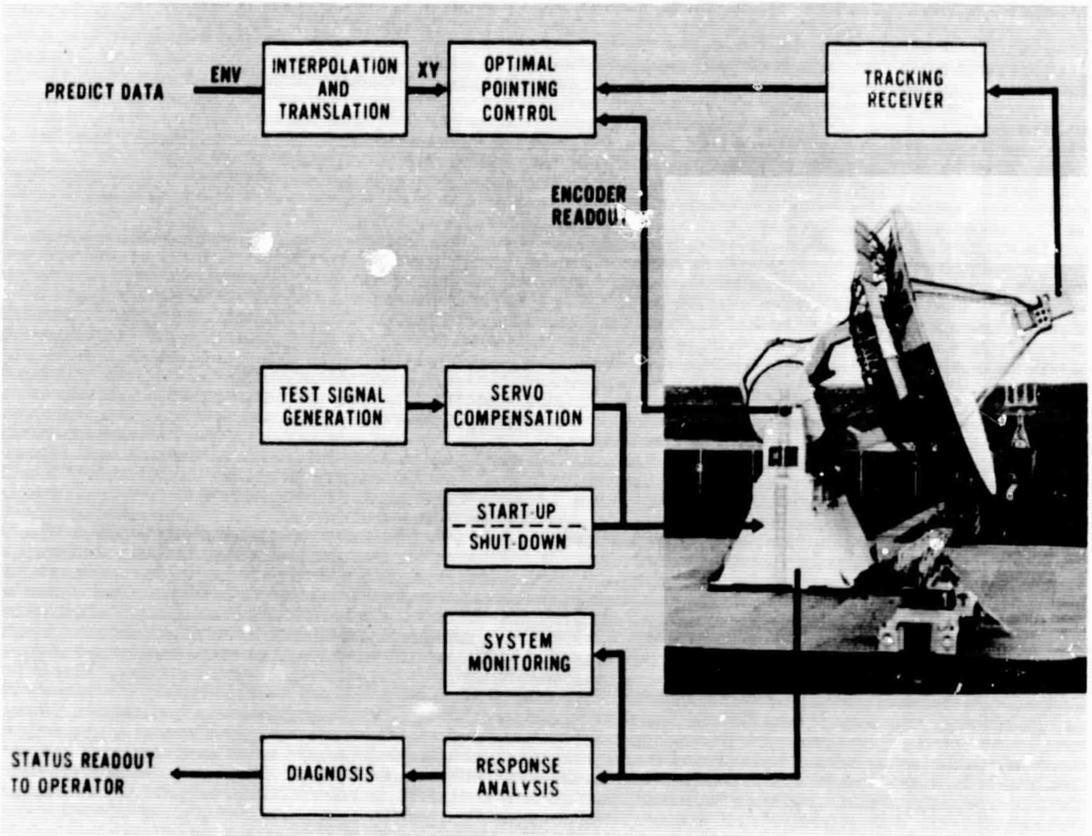
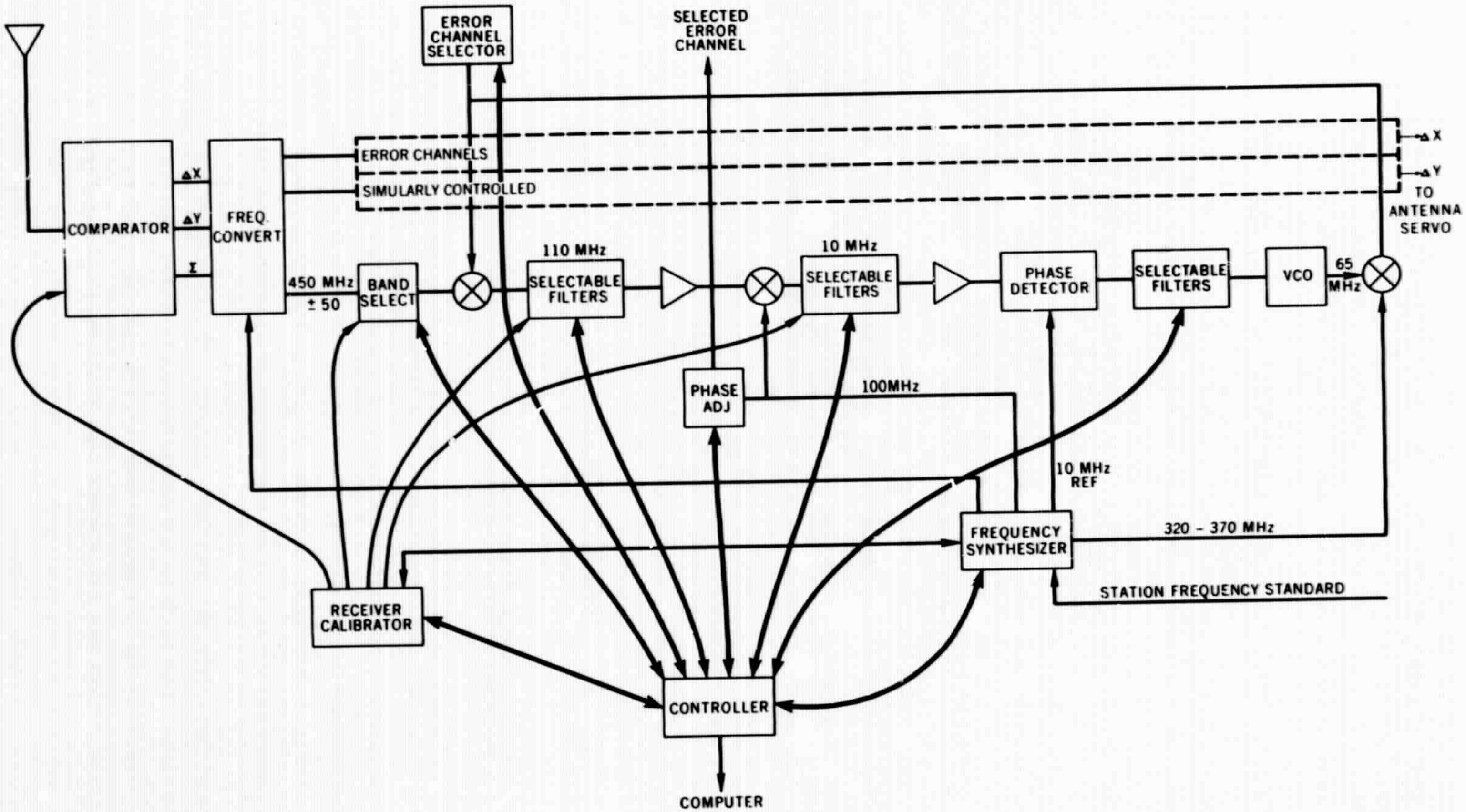


Figure 10. Antenna Control in Station Automation

E. Automated Multifunction Receiver

The AMFR* will be unique to the automation program. It is a six channel receiver designed to eliminate man as an operator. The unit will be set up, calibrated, and diagnosed by the use of internal circuitry and test points under the control of a program in the central computer. All parameters such as bandwidths, frequency tuning (synthesis: 1 cycle steps), unique frequency search, demodulators, AGC speeds, etc., will be accomplished digitally to allow computer control. Essentially, the knobs have been removed in order to allow digital control. Calibration will be accomplished by a specifically designed computer control receiver calibrator. The unit is not built-in and is being bought as a separate item. It feeds discrete spectrums to the AMFR and internal test points are monitored digitally and items are compared and verified in the computer. Rapid

*Generic Concepts of the Automated Multifunction Receiver, John Bryan, X-523-67-233.



ᴦ,gure 11. Block Diagram AMFR

test and calibration routines are used in the computer to control these functions and test the results. When the calibration fails, the information already gathered by the calibration and test routines are made available to diagnostic routines which determine malfunctions to the module level. The results of the determination are made available to station personnel by means of printout and/or data on the cathode ray tube display.

AMFR delivery occurred in the middle of calendar year CY 69. Six to eight months checkout and interfacing will take place during which demodulators will be added, calibration curves will be run, and definitive measurements will be made on all bandwidth, noise levels, and other parameters. The phasing of this checkout operation will coordinate nicely with the delivery of the calibrator unit near the end of CY 69.

F. Pulse Code Modulation--Data Handling Equipment (PCM-DHE)

The PCM-DHE (technical officer–P. Pease) is a stored program unit designed to (1) condition incoming PCM signals and generate reconstructed bit

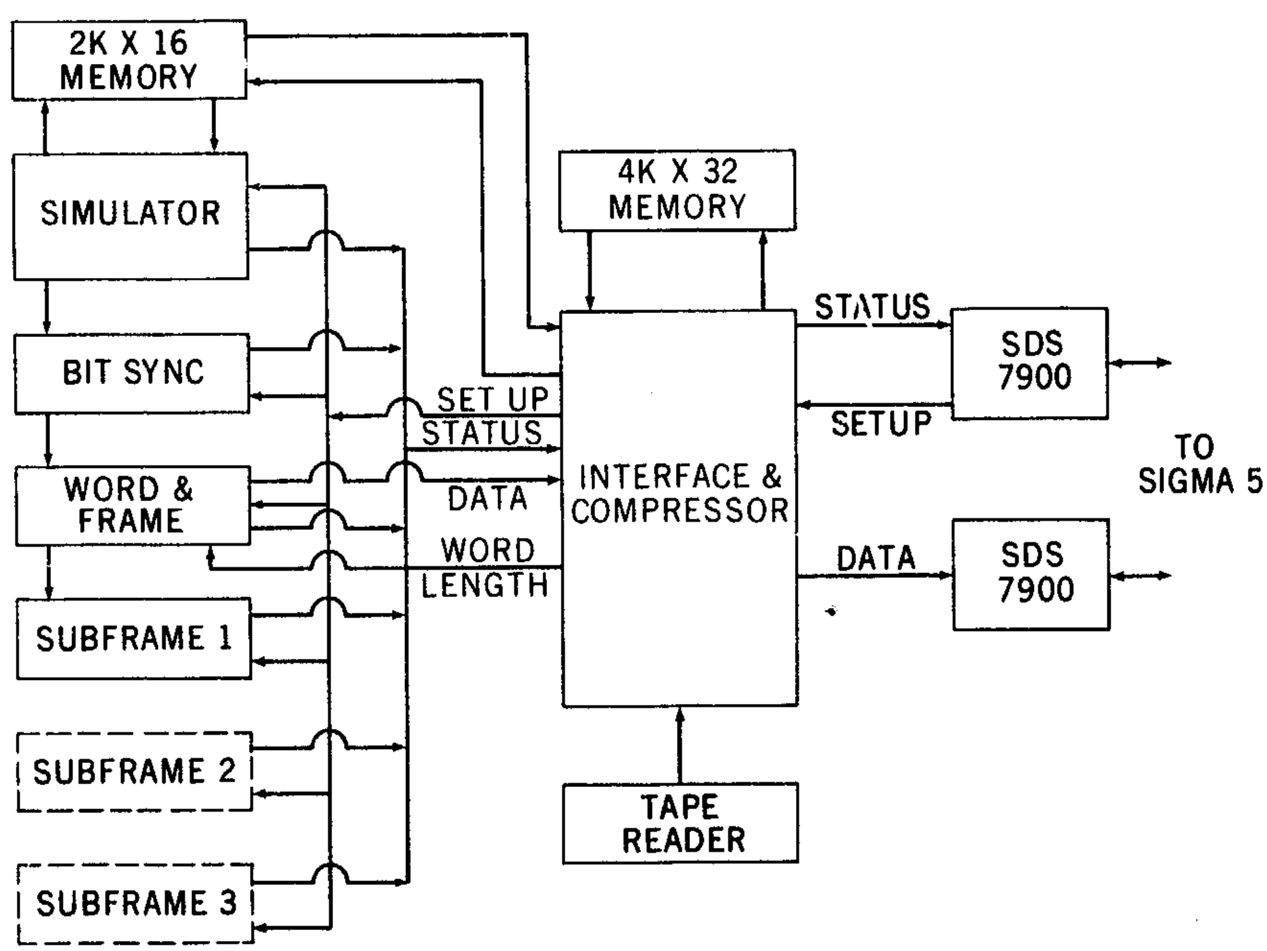


Figure 12. Block Diagram PCM

streams with optimum signal characteristics under adverse signal to noise conditions; (2) achieve optimum group synchronization performance consistent to the error rate; (3) prepare data for insertion into the computer and select system format by program change of core memory. Set-up operation and control may be performed manually or by computer. The unit is modeled after the previous generations of PCM data handling equipments developed in the STADAN Engineering Division (SED). Related specifications written by SED included complete computer control. On our NTTF unit the outputs and displays were removed since PCM-DHE would always operate directly with the computer. On-line data compression is included. The system includes a computer controlled simulator providing various combinations of signal to noise ratios, bit-jitter amplitudes and formats with which to test the entire system. Originally the unit was to time-share a common memory with the computer, however, the best technical solution was a small memory internal to the PCM/DHE.

The PCM compiler is being written which will enable programmers to write the decommutation programs in an easily understandable English language. The program will enable generation of set-up simulator and DHE computation compression programs. The second program called the Sigma 5 control program provides for computer control set-up verification and includes the input/output handlers for data transmission between PCM/DHE and the computer. It also enables an operator to modify the bit and group synchronization parameters to optimize data recovery. This feature must be carefully controlled and limited to special situations. Calibration and diagnostics will be worked out in conjunction with the Link Readiness and Verification System programs provided by SED projects.

As of this date the contractor has taken steps to divest himself of this type of digital equipment product. Since a different contractor would mean additional delays in an already late delivery it appears desirable to terminate the contract and obtain a PCM unit identical to that in the field.

G. Programmable Command Generator (PCG)

The Programmable Command Generator* (PCG) shown in Figures 13 and 14 is a computer controlled unit delivering tone, tone-digital and PCM commands compatible with the GSFC command standards. Commands are verified by feedback from the antenna, by echoing from the satellite, or by later playback from magnetic tape. Commands may be inserted into the unit manually or automatically by means of a control panel or keyboard, a paper tape, a telephone line input compatible with a 205B data set, or computer memory to computer memory transfer. Outputs consist of paper tape to provide permanent command tapes when inputs are from other computers or telephone lines, a printer providing written record of verified commands with time, a typewriter for system operation and a panel light display associated with the manual control panel.

*Programmable Command Generator, J. Shawhan & E. Melendey X52169188.

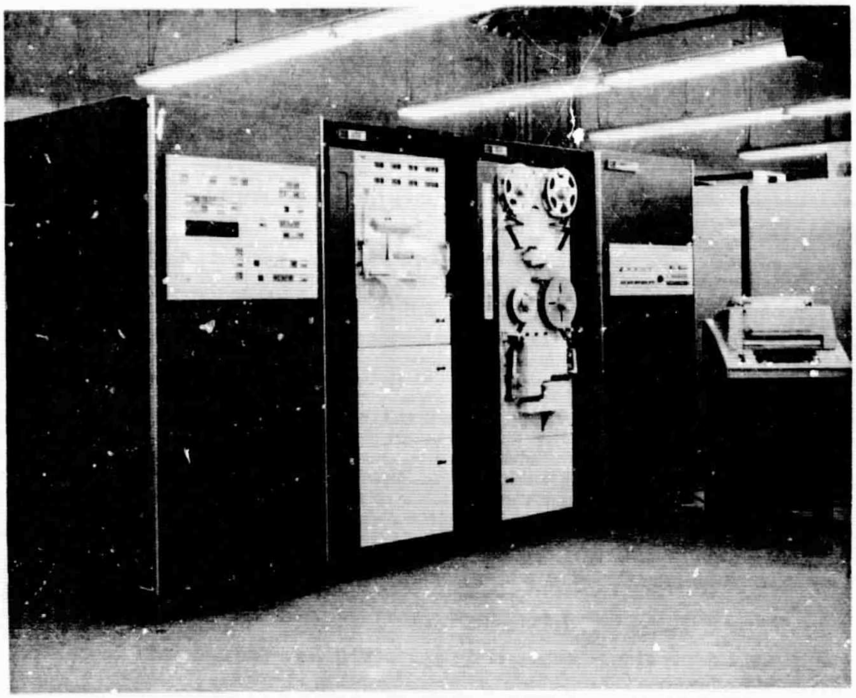


Figure 13. Picture of PCG

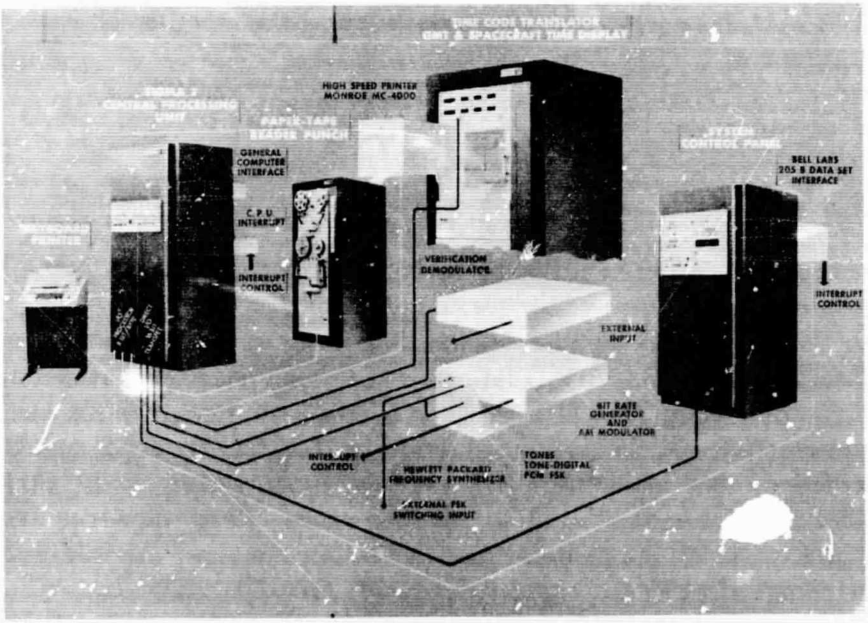


Figure 14. PCG Exploded View

The system is capable of complete hands-off operation, and its internal computer provides flexibility so that with program modification it may be used to perform additional special purpose command operations as may be required for individual satellite control. A complete set of system diagnostics for the special purpose command generation circuit, frequency generation circuits, control panel, as well as standard computer diagnostic routines are used for automatic fault detection.

The PCG was delivered January 1968 and accepted April 1968. Since then it has been operating 8 hours per day, five days per week, performing standard command generation as well as diagnostic routines. During this period normal maintenance has been performed. Additionally there have been five failures which were two loose cards, two display lights burned out, and a short due to a strand of steel-wool such as that from the floor buffers.

The PCG is presently being modified to incorporate the memory load program which has recently been added to the GSFC Command Standards. Also the programming system will be modified to enable near simultaneous commanding of different satellites on a time shared basis. This requires that more than one PCM program be resident in memory to enable switching from one to another in milliseconds, as opposed to the present system of having one program each for generating tone commands, tone digital commands, and PCM commands. This latter feature will make the unit directly applicable to the command operations envisioned for the Data Relay Satellite Systems. If additional systems were bought for STADAN, it is felt that possibly the manual control panel could be eliminated in favor of the keyboard and that advantage could be taken of microelectronics to reduce the present size of the system from four racks to two racks.

H. Transmitter

The command transmitter (Figures 15 and 16) for use with the Automated Ground Station consists of an exciter and a solid state power amplifier. The exciter (technical officer—D. Santarpia) was delivered in March 1968 and accepted one month later. It provides VHF, UHF, L, and S-band phase modulated signals. Coherent extractor frequencies are provided to the AMF Receiver for ranging. Remote band selection and frequency selection in 10 Kilohertz (kHz) and 100 kHz steps are provided. The modulation index of phase modulation can be varied over ±3 radians in 0.3 radians steps at up to 500 kHz rates. Relay closures are provided as outputs to verify the proper selection of parameters. An internal counter provides readout of the exact frequency. An acquisition mode which sweeps the frequency is available for use when ranging. The unit is characterized by excellent stability and low phase noise and phase jitter due to the frequency synthesis technique. Special precautions have been taken to maintain low spurious

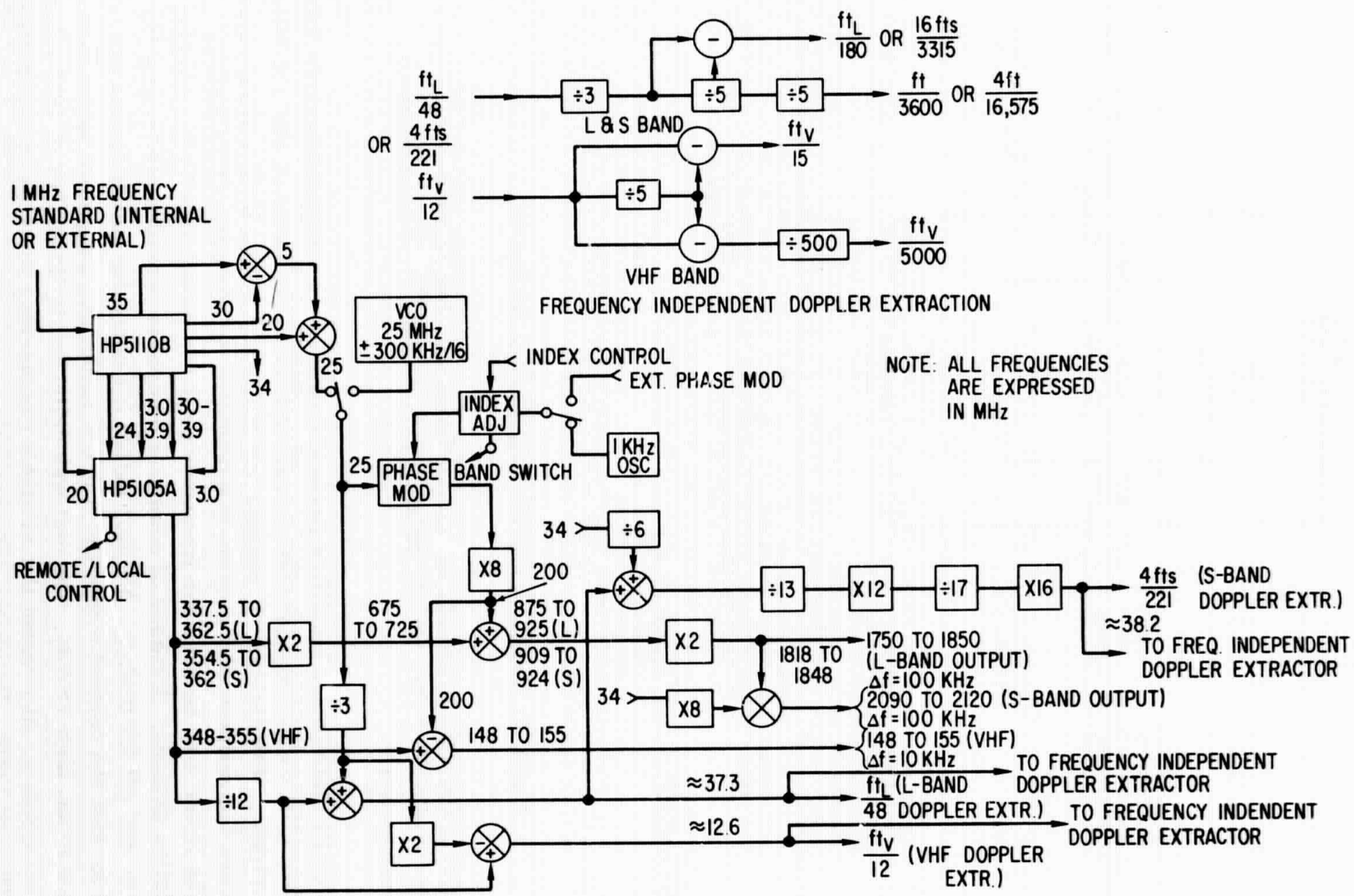


Figure 15. Multiband Transmitter Exciter Functional Block Diagram

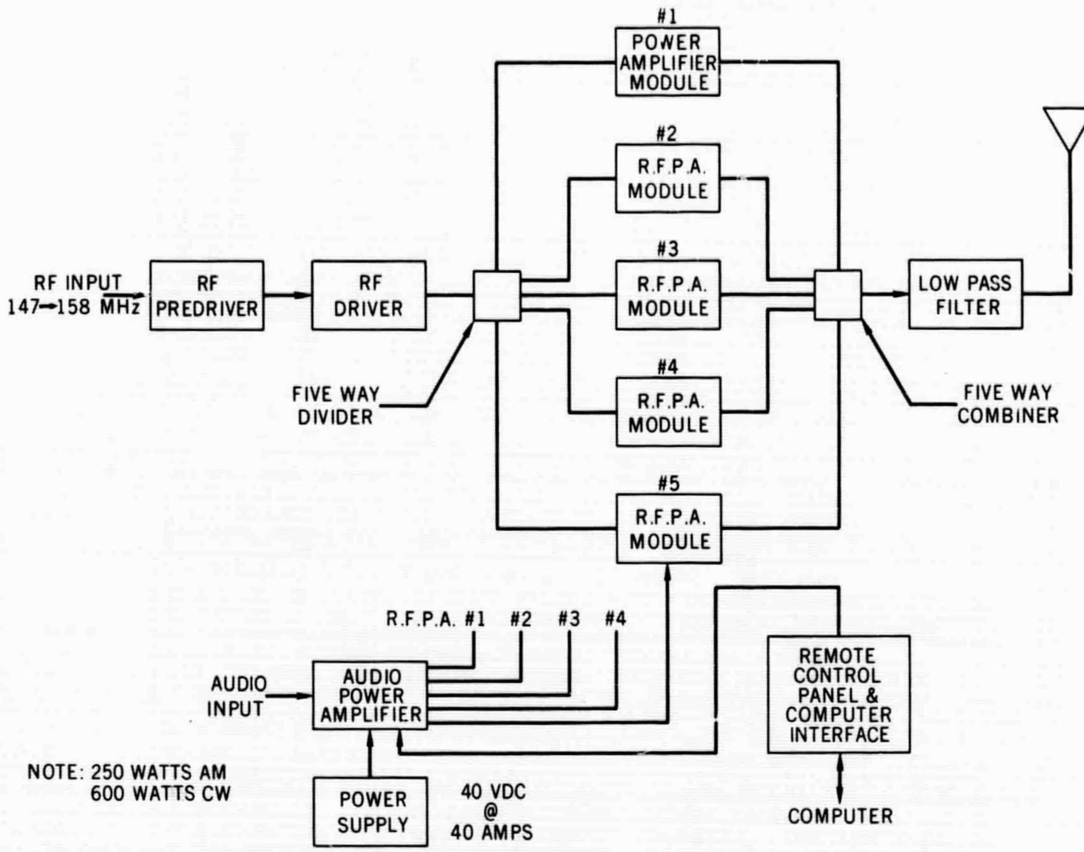


Figure 16. Block Diagram–RF Power Amplifier/AM Modulator

frequencies. The unit, presently being interfaced with the Sigma 5 computer, the power amplifiers below and the antenna system, will be de-bugged as an operational system.

The solid-state power amplifier (technical officer–H. Kingman) accepts VHF signals from the exciter and provides broadband RF in the range of 148-158 MHz as determined by the exciter. It accepts any frequency in this band without retuning and delivers 250 watts at 95% amplitude modulation or 600 watts at continuous wave. The latter may be used for frequency or phase modulation by the addition of modulation devices. A means of computer control is provided for turning the carrier on and off for testing. Monitor points for computer interrogation are provided to test the control mode, the AM/CW mode, and the power alarm (low output, low input, high VSWR). The unit was delivered in November of 1967 after in-plant acceptance. At present the STADAN Engineering Division is negotiating for 20 follow-on units. Programs are presently being written for the combined operation of the exciter and power amplifier in the automated ground station.

I. Display System

An automated system under internal programming can proceed about its work until it breaks down or meets a situation for which it has no internal instructions. Whereupon it must turn to its operator for more information. The frequency with which it calls for help is one measure of the degree of automation. The interface whereby the automated system keeps the operator informed and receives instructions is called the man/machine interface (logical!). Eventually, man might be electronically connected to a computer by means of his central nervous system. At present however, the state-of-the-art suggests a central cathode ray tube (CRT) display whenever the number of display parameters is large enough so that nixie and incandescent display elements become unwieldy as well as more cost than a CRT unit. Human engineering is also a consideration since an exposure to many varying displays spread over a large area can be distracting and contribute to human error.

A CRT system, specified by E. Melendey and J. McKiernan, is presently under procurement. The unit, Figure 17, contains its own local memory which is used as a source of data for updating the display. The Sigma 5 central computer containing the data bank, can dump new data for display directly into the local memory as new data becomes available. A keyboard is provided to enable the

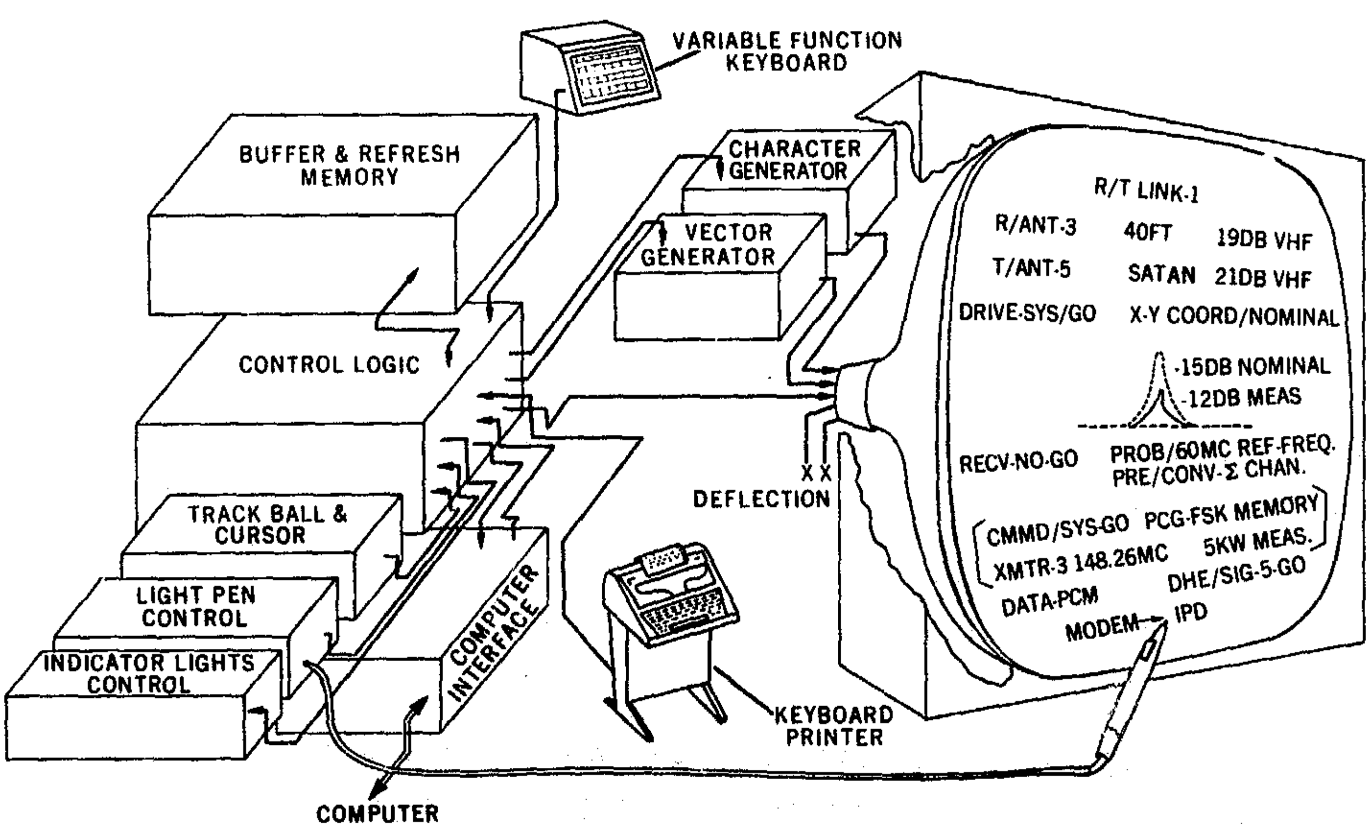


Figure 17. CRT Display–Functional Block Diagram

operator to make manual intervention, perform control functions, and request new data. The prototype developmental unit will have a capability of drawing vectors and modifying information by means of a spot of light which can be located anywhere on the face of the CRT by means of a track-ball. These latter items must prove useful before they will be put into units going to the field.

As an example of the way the display system might be used, information available concerning the status of the station and the spacecraft in view at a particular moment might be treated as a book. The operator may call up for display the pages he needs and read the data therein. In the event of malfunction or out of limit conditions detected in the system, the critical information is displayed automatically. The critical item(s) may be made to change intensity or flash to obtain the operator's attention.

Fabrication is expected to be straightforward since it is not pushing the state-of-the-art. The developmental aspect of the program is determining how a CRT display system can best, from a hardware and software standpoint, provide a man/machine interface and make optimum use of the many station and spacecraft sources of data providing information to the system data bank. The unit is expected between six and nine months following award of the contract and will be brought to NTTF for interfacing and testing of the display and system programs. This first unit will be the prototype for the maintenance supervisor's display. Remote, independent units, using the same memory, probably will be used assigned to each of the antennas to retain link operation. The remote units will have independent access to and control of their own data. Thus, central equipment pools will provide operation on a link concept.

V. PROBLEMS

The major problem at present is the reconciliation of the conflicting requirements to provide real time computation to multiple users and at the same time provide flexible executive control and scheduling of these users. The executive or monitor program must make schedule tables to keep track of and control operations. Thus it must do bookwork, requiring instructions to access and modify these tables. The present effort must keep the bookwork to a minimum and still allow rapid interrupts and servicing of users. In order to make it easier on programmers to write programs, procedure oriented languages (POL) such as FORTRAN are made available. However, POL are not as efficient in the use of memory space as programs written in machine language. Furthermore, real time POL are not available. A possible solution is the use of multiple pass compilers first to convert the POL into a machine language, and second to optimize the resulting program deck from the standpoint of memory utilization/ execution time.

To allow immediate response to interrupts, real time programs must have memory relocatability. This implies that all routines must be capable of relative addressing, i.e., change of execution address by the addition of a constant. This relocatability requires address modification by extra instructions in a monitor program, as well as a loader conversion routine to move the program from disc to magnetic core. The possible solutions to this involve storage of routines in machine language and application of reasonable limits to relocatability.

When an interrupt occurs, the executive routine must maintain a knowledge of the status of the machine at point of interruption and in fact, remember this consecutively in the event of multiple serial interrupts. It does this by means of a sign post made up of particular instructions which direct the program back along the way it has come. The time spent in examining the signposts can be reduced by the use of general purpose register blocks to minimize the length of the save/fetch routines involved in an interrupt and restoration to the original environment. The major challenge of the automated ground station project is in the solution of problems such as the above.

A. Project Planning

The effort thus far has disclosed that the magnitude of system developments have reached a point where it is difficult to plan and execute the major developmental systems and time schedule usage in the field. Projects of this nature must be planned on an overall system basis with close phasing of developmental and engineering efforts. Otherwise, timing is off and developments are brought to fruition after the needs of the field and the engineering model becomes a second developmental model or the development is so far ahead of the needs of the field that it is not implemented until a new generation of technology forces a second development. In either case, the developmental model is not the model for engineering of field units.

It is also true that the Government procurement process makes it difficult to apply directly to follow on units the knowledge gained by a contractor in the design of a developmental model. The reason for this is the length of time necessary to test the concepts and operation of a developmental model. Quite properly, the time taken to run a definitive series of tests and to develop operational methods is longer than reasonable to keep a contract open for optional follow-on units. Also, since the follow-on buy is usually a large one, it is doubtful procurement would let the first contractor receive a second contract on a sole source basis. It is necessary then that the results from the development be factored into the follow-on specifications.

Perhaps the answer is the recombination of the development and engineering roles according to disciplines such as antenna, RF, Computers, Command, etc.

However, a system design group <u>must</u> be established to plan the orderly evolution of the network as an overall system.

VI. OUTLOOK

A. Relationship of the Automated Ground Station (AGS), STOC, and Data Relay Satellite System (DRSS)

Increased automation is finding its way into the STOC project. The requirements for a computer have grown to major proportions as a result of the major workload increase predicted by the Tracking and Data Systems Development Committee. The present subsystems such as the Link Readiness and Verification System, the Remote Control and Monitoring System, the Schedule Display System and the Data Transmission System automate the link testing, scheduling and communications functions and will enable the maintenance supervisor to have a much better knowledge about the station equipment. These features combined with the degree of equipment control and computer controlled switching contemplated by the STOC 2 project staff should enable shortening of station or link switchover time to an average of five minutes or less. The larger computers now planned to accommodate increased STOC scope can be used to provide automatic control of the Antenna, AMFR, Switching System, Command Generator, and Command Transmitter and the display of system operations. It is expected this will enable elimination of operators and reduction of station switchover time.

In his cost effectiveness study Mr. Moye has a comparison of a manual station at the present 60% equipment utilization with 5 minute and one minute stations providing greater (up to 80%) equipment utilization. The increased effectiveness due to shorter switchover times allows fewer stations to support the 1972 and 1980 predicted loads of 315 and 385 telemetry link hours per day. Resultant savings provide amortization in an average of 7.3 years for the added investment for the 5 minute station and 7.7 years for the one minute station.

In view of the above and if DRSS enters the picture in 1974/75 time frame, a basic question arises. <u>Should the expenditures for STOC/AGS be made if DRSS can pick up the projected increasing workload</u>? This decision can only be made by a high level study which considers the support capability of DRSS, its probability of approval and success, and the future role of STADAN with respect to DRSS.

B. NTFF Effort

For all practical purposes the STOC requirements have now caught up with and absorbed the Station Automation effort. Therefore it is very important, since we are dealing with large complex systems, that the present AGS/STOC 1 (prototype) effort in NTTF and the follow-on STOC 2 effort for the network be directed toward creation in NTFF of a 'STADAN Standard'. This standard station would benefit network operation by providing uniformity of training, maintenance procedures, field modifications, and station operation procedures. It would benefit network engineering by enabling system engineering changes, both hardware and software, to be done locally. Continued advanced development efforts would be based on this standard.

In order to work toward a "STADAN Standard" the decision should be made as soon as possible as to which computer will be used for the STOC 2 project. This would enable the conversion of the present system in NTTF to the new STOC computer so that the NTTF development effort may be aligned closely to the support of STOC 2 and its evolution.

One proposal has been suggested that the development effort in NTTF continue but be directed to:

1. Test STOC 1/Signa 5 system.
2. Using Sigma 5 system develop critical hardware/software techniques in support of STOC 2.
3. Update the NTTF Sigma 5 to the STOC 2 computer as soon as possible.
4. Develop the full STOC 2 system in NTTF.
5. Extend and improve STOC 2 by continued development and engineering in the NTTF System.

The automation effort to increase network effectiveness is equally applicable to DRSS. In fact the real time multi-satellite data acquisition problem raised by DRSS compounds the switchover time and equipment control problems expected in STADAN. The above STOC support effort and continued in-house development work on specific subsystems will also provide benefit when applied to the difficult problems of DRSS. (1) Modification of the PCG to provide millisecond switching between command formats to enable time shared use of command generators for commanding 40 spacecraft through DRSS. (2) Extension of the PCG to provide codes with ranging capabilities and minimum susceptibility to

RFI and Multipath interference. (3) Modification of the PCM/DHE to decommutate codes with minimum susceptibility to RFI and multipath. (4) Test of control and switching techniques for up to 40 receivers and PCM systems with data switching to control centers, orbit calculation computers, and information processing computers. (5) Simulation and test of a multiple antenna data acquisition terminal.

VII. CONCLUSIONS

The purpose of this document has been to describe the status and at the same time the extent of the automated ground station effort, to show its relationship to the STOC project and possible applications in a DRSS program. This should enable management to reassess the project to determine its suitability in the NTTF environment and its value particularly in the light of the major decisions being made concerning the future of STADAN and DRSS.