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AUTOMATED GROUND STATION SOFTWARE DEVELOPMENT

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AUTOMATED GROUND STATION SOFTWARE DEVELOPMENT

I. INTRODUCTION

The GSFC Tracking and Data Systems Directorate is developing a prototype Automated Ground Station at the Network Test and Training Facility (NTTF). The development is intended as a joint effort between the Advanced Development Division (ADD), STADAN Engineering Division (SED), Computation Division, STADAN Operations Division (SOD), and NTTF personnel. Figure 1 is a block diagram of the equipment to be installed in the NTTF. This figure represents one link of a ground station, where a link is defined as the equipment necessary to support a satellite pass. Typically a STADAN Tracking Station consists of from one to four links. The design objective of the computer software will therefore be control of four links by a single computer in the manner shown in Figure 2. Although the block diagrams form a part of the system design phase, to be discussed later, they are included here to promote understanding of the Automated Ground Station.

A block diagram of the computer on order is shown in Figure 3. Significant features of the computer are .850 μsec cycle time, multiple memory banks (6max) permitting independent operation of the central processor and input-output processors (6max), a twenty-four million bit fixed-head disc memory, 3 tape systems and expandable priority interupts (240max).

Fifteen tracking station functions have been identified as operational requirements of the computer system. They are performed in the prepass, pass, postpass and off-line modes. Appendix A contains a brief description of the tracking station functions listed below.

1. Tracking Station Management and Operation Control.
    a. Pass scheduling
    b. Equipment operating logs
    c. Inventory Control
    d. Spacecraft pass support program generator
    e. Tracking station pass support program generator
2. Tracking Station Equipment Set-up and Test
3. Tracking Station Status Check

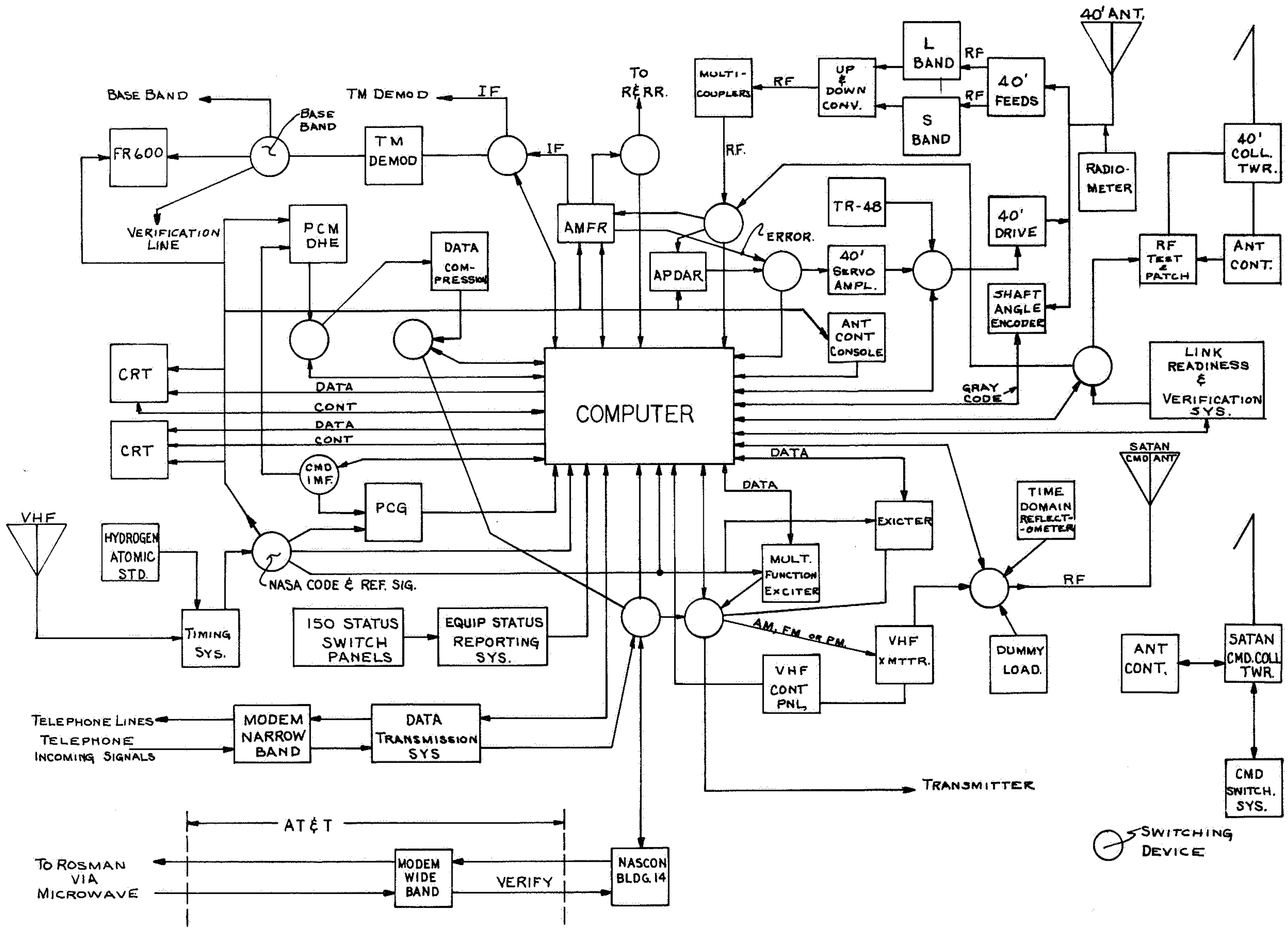


Figure 1. Automated Ground Station Equipment To Be Installed in NTTF

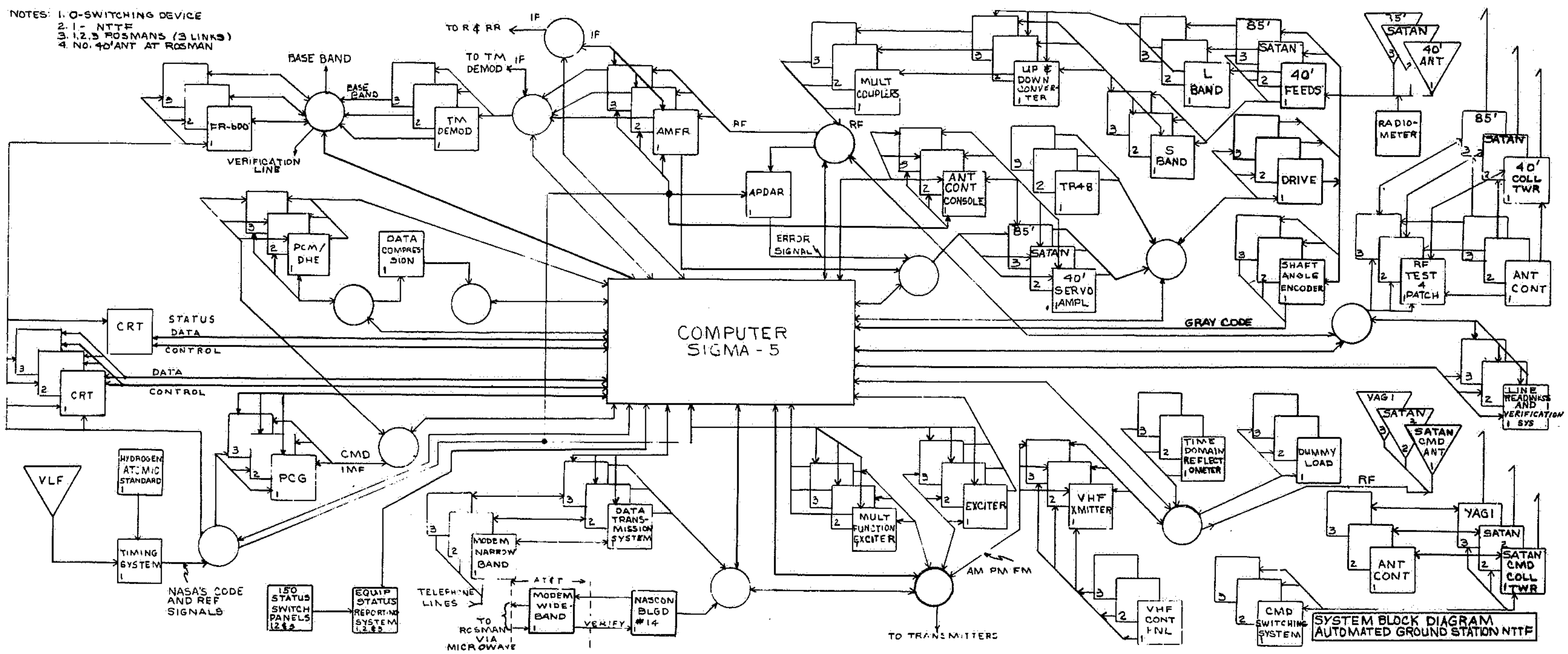
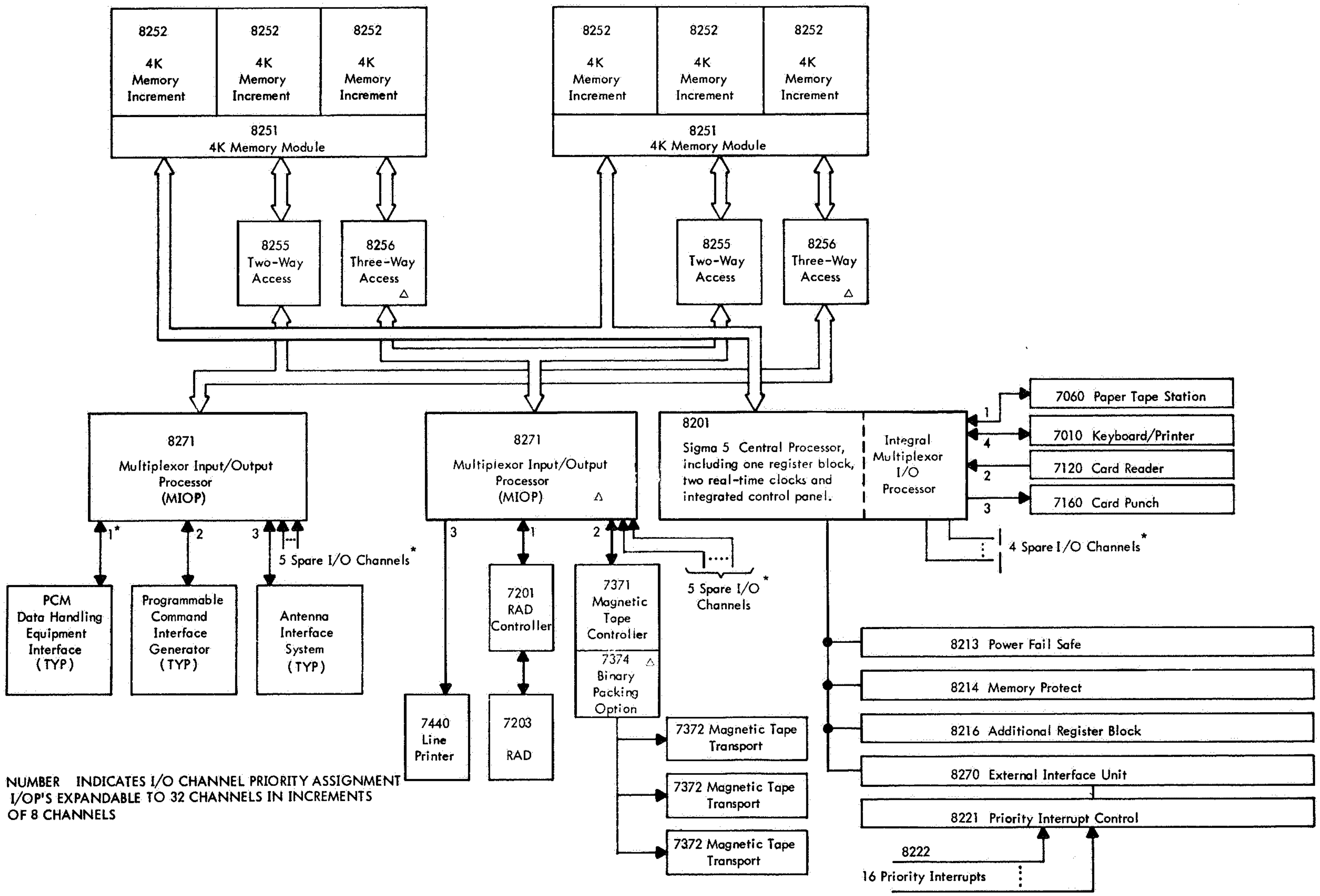


Figure 2. Multiple Link Automated Ground Station



* NUMBER INDICATES I/O CHANNEL PRIORITY ASSIGNMENT
* I/OP'S EXPANDABLE TO 32 CHANNELS IN INCREMENTS OF 8 CHANNELS

Figure 3. Automated Ground Station Computer

4. Control of Tracking Station Equipment

5. Pass Simulation and Tracking Station Checkout

6. Pre and Post-pass Communications Check

7. Spacecraft Position Determination from Orbital Elements

8. Telemetry decommutation

9. Data Compression

10. Quick-look Spacecraft Evaluation

11. Spacecraft Command Generation and Verification

12. Generation of Spacecraft Tracking Data

13. Fly-by Test Support

14. Experimental Data Processing

15. Station Display

Development of the Automated Ground Station Software has been divided into five major phases, each phase is divided into tasks, and each task is further divided into subtasks.

The major phases are:

System Analysis
System Design
Program Development
Program Coding
Program Test

The intent of this document is to discuss the above phases and the tasks and subtasks included as part of the phases. The sequence of work to develop computer programs can be divided and labeled in different ways. But when the various descriptions are examined in detail they are quite similar. Chart 1 is a block diagram of the computer program development process to be used for the Automated Ground Station.

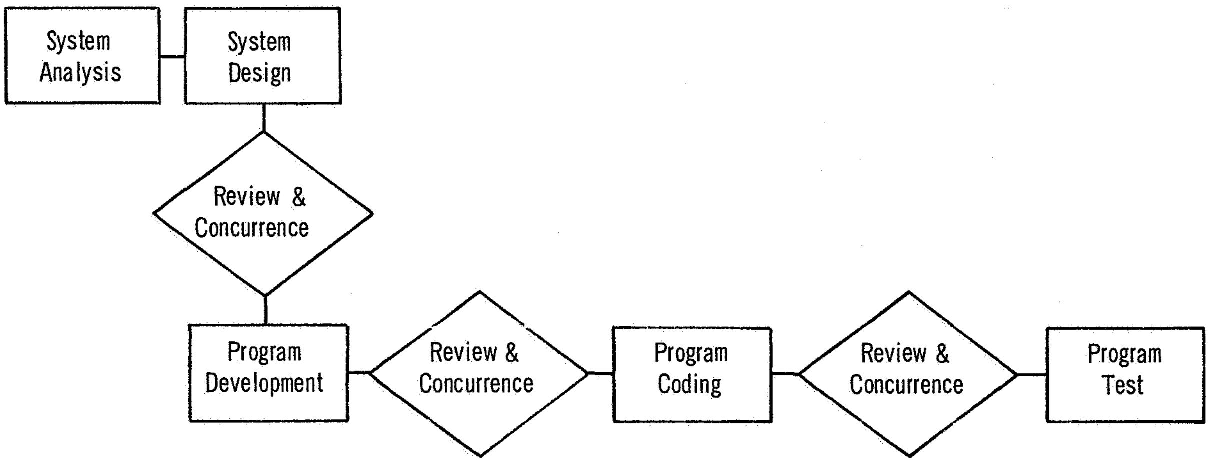


Chart 1. Automated Ground Station Program System Development Process

Although this document is written about the Automated Ground Station the procedures could be applied to any computer controlled system.

II. SYSTEMS ANALYSIS

Systems Analysis is the process of determining the Automated Ground Station requirements for the program system. This phase consists of investigating and defining in detail the particular functions to be performed by the computer.

The System Analysis Phase is sub-divided into the following tasks:

a. Analyzing Systems Requirements

b. Determining the Required Resources

c. Analyzing the NTTF and Station Environment

d. Analyzing Computer Production Requirements

e. Analyzing Similar and Interfacing Systems

f. Analyzing Requests for System Changes

A. Analyzing the System Requirements

In this task the requirements of the automated station are determined and documented. The requirements are then reviewed for completness, feasibility and compatability among functions of the Automated Ground Station. This task is divided into the following subtasks:

- Determine the Functional Requirement of the AGS
- Determine Support System Requirements
- Study Costs Effectiveness and feasibility for critical equipment including computer vs hardware application
- Discuss Ambiguities and problem areas with subsystem designers (RCVR, Antenna etc. designers)

The functional requirements are a set of charts presenting the total system requirements in an easily comprehensable form flexible enough to present the details of the system. For computer control of the station equipment the charts identify each control, decision, status, presentation and interface function for each subsystem shown in Figure 1. The station operational modes in which the functions are performed or utilized are identified and the interrelated functions are cross references. This information is obtained from subsystem documentation and contact with the subsystem designers. Appendix B is an example of the functional requirements of the Automated Multifunctional Receiver (AMFR). This information is expanded to include interface word size and frequency of data transfer. The charts are also an aid in spelling out areas requiring additional documentation and missing interfacing equipment.

Support system requirements include such items as how and where to get program cards punched, how and where tape systems are maintained. For the automated Ground Station computer support will be provided by the Network Test and Training Facility personnel. The card punch which was originally to be a part of the AGS computer procurement was cancelled since GSFC owned IBM/360 computers are capable of punching cards from AGS computer tapes. In this instance the 360 computer will be an AGS support system. Other support equipment such as keypunch systems must be scheduled.

B. Determining the Required Resources

From the AGS functional requirements and contact with subsystem designers and operational personnel, estimate the need for manpower, computer time, elapsed time and other resources. Prepare the Data System Development Plan and Project Implementation Plan. This task is subdivided into the following subtasks:

- From an analysis of the information gathered in the previous task, produce a total block diagram of the hardware system showing control paths, data paths, and data rates. Figure 1 is such a drawing without the required amount of detail.

- Layout a preliminary program system design in terms of overall functional blocks.

- To assess in detail the work to be done, examine each program to be produced to establish program flows, functions, inputs and outputs, and testing requirements and estimate the man-months, computer hours and elapsed time necessary to produce and test the programs.

- Determine software cost and prepare a PERT* schedule including hardware and software development.

- Produce the Data System Development Plan and Project Implementation Plan.

C. Analyzing STADAN Environment

Study the STADAN environment and operations, to determine how the AGS will be employed, the amount of links required at various sites, and what the responsibilities of the tracking sites are to other NASA operations; and to determine the effectiveness and deficiencies of existing station operations that might be improved by the AGS. This task is divided into the following subtasks:

- Gain familiarity with the STADAN tracking sites organization and operating procedures by reading pertinent documentation, conferring with Network Engineering, Network Operations etc., personnel and visiting a typical station.

- Review automation plan with selected site personnel to obtain their ideas on automation.

- Identify and analyze areas needing improvement in the existing stations.

*PERT-Program Evaluation and Review Technique

D. Analyzing Computer Program Production Requirements

Determine the requirements for programs production and test, the language to be used, the adequacy of the monitor, the adequacy of available equipments to produce the AGS software by studying the total environment for program production, the availability of the computer, EAM* equipment, operators, back-up equipment and other programming support. The subtasks are:

- Determine programming language or languages to be used.

- Determine priorities during the production period.

- Investigate the monitor or executive system controlling work on the computer, determine amount of modification needed.

- Investigate activity and support program systems including print, compile, assemble etc., to determine availability, state of checkout and functional capabilities.

- Examine procedures and backlog of EAM shop.

- Determine Procedures for submitting programs for computer run.

- Determine existing and potential hardware constraints such as amount of storage, input/output devices, number of interrupts etc., that influence the design of the program system. Advise programmers on characteristics and limitations of the computer production tools.

- Investigate potential back-up computer and conditions of use.

E. Analyzing Similar and Interfacing System

Identify other systems, procedures and techniques existing or planned that may influence the AGS or provide useful information for planning purposes.

- Obtain familiarity with similar systems such as the A/F Spacetrack effort and the Satellite Test Facility. Identify similar portions, extract and evaluate useful facts.

*EAM (electronic accounting machine) term on general use for keypunch and line formatting and processing equipment

- Identify applicable programs, procedures, techniques by searching technical books and journals and sources such as SDS USER group, IBM SHARE.

- Isolate elements of AGS software such as routines and data files that may be available from manufacturer and other systems.

F. Analyzing Request for System Change

Establish procedure for processing requests for changes.

- Establish control working group for processing change requests. Table 1 lists the responsibilities of the AGS Software Control Working Group.

- Establish procedures for processing change requests including the identification of who may initiate and who must authorize their evaluation.

Table 1

Responsibilities of

Automated Ground Station

Software Control Working Group

---

1. Approve each program specification before start of programming.

2. Monitor program writing and implementation progress.

   a. Approve programs for compliance with AGS programming standards.

   b. Update detailed PERT programming schedule monthly (time control).

   c. Perform budget control (technical control) of:

      (1) Utilization oi core storage*

      (2) Utilization of processing time*

      (3) File storage space

Table 1 (Continued)

(4) Channel utilization

(5) Multiplexor utilization

3. Control specification changes

a. Programmer specification changes will be referred to control working group which evaluates design change request as they occur on the basis of their design merit, importance to user, effects on schedule costs, etc., modifies specifications and communicates changes to all affected organizations.

4. Oversee program and system testing

a. Approve system test data

b. Inspect results of testing

*Critical (quote in program spec)

III. SYSTEM DESIGN

System Design is the process of designing a set of programs capable of fulfilling the AGS requirements determined in the systems analysis phase. The system design phase of the AGS has been subdivided into the following tasks:

a. Total System Design

b. Computer Program System Design

c. Program Systems Test Plan Development

d. AGS Functional Description Production

e. Indoctrination of Programming Personnel

A. Total System Design

Develop the total Automated Ground Station System; the hardware configuration that is expected to meet the requirements of AGS, produce a set of operational system flow charts. The total system design subtasks are:

- Interpret functional requirements in terms of equipment, requirements for switching, missing interface equipment, input types and volume, required responses time and operating environment.

- Consider alternative ways to satisfy requirements for the total system. Where to provide storage of PCM data and where to provide control of the commands are examples.

- Consider interactions among functions alternatively designed.

- Establish criteria for expected performance based on the objectives.

- Design and exercise simulations to help determine optimum equipment needs (number of analog tapes, computer tapes, etc.).

- Design or procure necessary equipment.

- Produce a set of system flow diagrams. A set of system flow diagrams consists of a drawing of Figure 2 with data lines and control lines, data rates included, and an operational flow diagram of the type shown in Figure 4, for every subsystem making up the system.

- Continually coordinate system design with subsystem designers.

- Produce an Equipment Interface Specification.

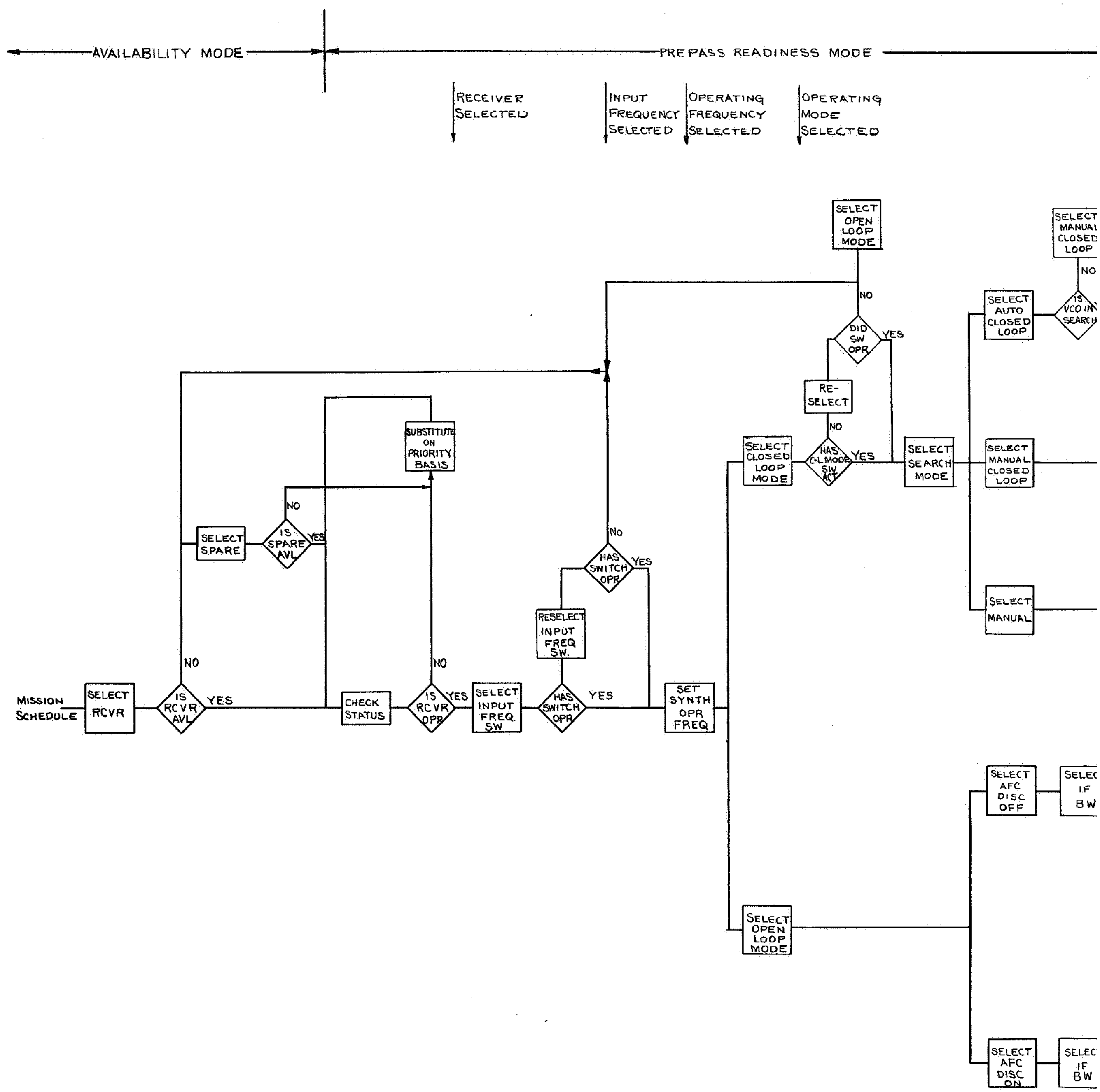
B. Computer Program System Design

Develop the design for the program system part of the total AGS design. The subtasks are:

- Identify input data characteristics and output requirements of the total AGS and of each subsystem in the total system.

- Design the monitor or executive controlling program in terms of a program flow diagram.

FOLDOUT FRAME



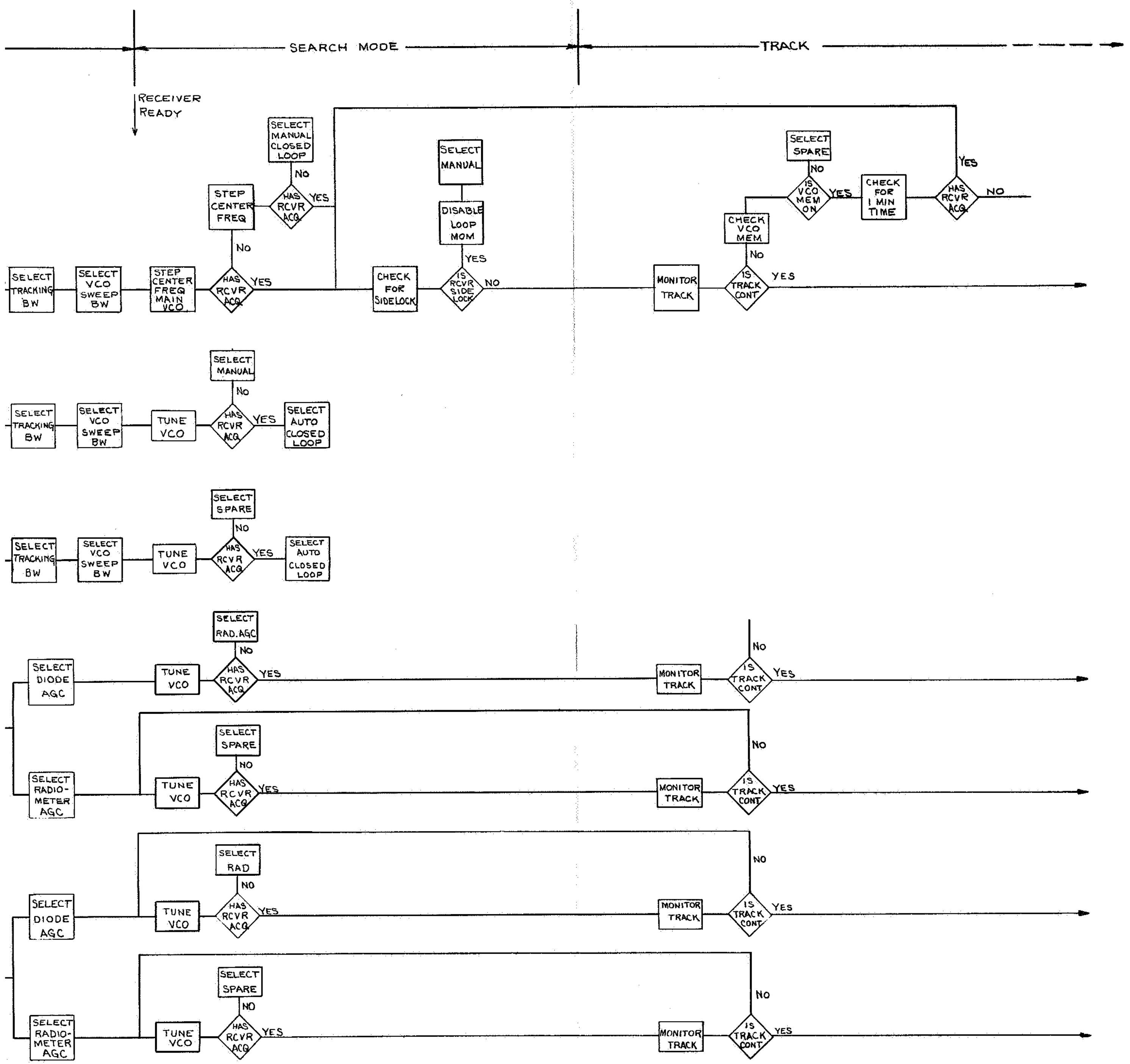


Figure 4. AMFR System Flow Diagram

- Determine the number of programs to be used in performing the required functions.

- Estimate the size and complexity of each program.

- Design and specify the computations, logical manipulations and transformations to be done within each program.

- Identify the information to be contained in the data base system.

- Determine procedure for system data editing, formatting, storing, retrieving, and updating.

- Produce programming standards document.

- Diagram the flow of data and functions through the sequence of programs making up the AGS software system.

C. Program Systems Test Plan Development

The division of the program system into smaller parts for design and coding creates a need for integrating program parts produced by several programmers. Both simulated and real data will be needed for test purposes. A separate test group to design program, subsystem and system tests, produce tests material, run tests and evaluate results can be both beneficial and objective. The objective of this task is to develop and document program system test requirements, test plans, and test designs to provide the specific plans and criteria for program and system evaluation. The subtasks are:

- Develop program subsystem and system test requirements based on the system requirements defined in Task 2 of the System Analysis phase.

- Develop and document design of program subsystem, and system tests, specifying data paths, inputs (including out of tolerance inputs), expected outputs and results.

- Review Test requirements with AGS Software Development Control Group.

D. AGS Functional Description Production

Produce and coordinate a document that describes in detail the AGS under development and the environment in which it is to operate. The subtasks are:

- Identify the level of technical detail that will promote understanding of the AGS.

- Determine the contents of the Functional description such as:

  Total System Design
  Program System Design
  Implementation Plan
  Operating Procedures
  Data Base Design
  Specification of Interface Requirements

- Assign responsibility for component parts and schedule the production of the document.

- Distribute functional description to subsystem designers, STADAN Operations, NTTF personnel; obtain feedback, resolve ambiguities; make necessary changes to the document or System Design; obtain concurrence and publish.

E. Indoctrination of Programming Personnel

Train programmers in the use of the computer and production tools and indoctrinate them in the design and details of the program to be produced.

- Arrange for programmer training in the use of the AGS computer, the NTTF support facilities (card punching, use of computer operators, etc.), the programming language, the compiler and executive monitor, as needed.

- Indoctrinate the programming (and other) personnel in the design of the AGS, Programming Standards, the particular functions for which they are responsible, and in the design control and review procedures.

IV. PROGRAM DEVELOPMENT

Program Development is the detailed analysis and evaluation of the functions of a program is to perform, the design of program logic and a data structure that will perform the AGS functions and the specification of program logic in detailed flow charts ready for coding. The program Development phase repeats on a smaller scale and finer level of detail much of the work performed in the System Design phase. A thorough job of Systems Analysis and system design will reduce the amount of additional information needed for this phase. Since this work will be divided into many pieces, it requires more people than the system analysis and systems design phases.

The program development phase is divided into the following tasks:

a. Program Design

b. Program Files Design

c. Data Base Design

A. Program Design

From the specifications developed in the system design phase, design and document the individual programs and routines. The subtasks are:

- Design logic and flow chart each program in detail.

- Specify all input and output message formats.

- Search program libraries for available subroutines.

- Coordinate design and communication requirement with executive control program requirements.

- Determine data rates and characteristics of input and output equipment.

- Analyze timing requirements and resolve potential timing problems.

- Review program designs with the AGS Software Development Control Group.

- Write and coordinate program specifications.

B. Program Files Design

Develop and define the form of the data elements to be manipulated by each program, layout storage allocations and document program data structures.

- Identify the files used or generated by the program that are unique, and those that are common to this and other programs, and analyze the flow of data among the programs.

- Design formats of internal tables for each program.

- Coordinate designs with Central Data Base.

- Specify for each program, all inputs and outputs, identifying source and destination, formats and sizes.

- Allocate blocks of core, tape or disc memory for storage of programs and data.

- Review design with AGS Software Development Control Group.

C. Data Base Design

Develop and maintain a central Data Base for information used by more than one program in the program system; document the data base structure and the procedures for maintaining it.

- Specify the data base structure and convention of information description.

- Specify size, coding, and structure of files, tables and items of common information.

- Produce and/or modify flow diagrams of the file maintenance programs used to create and maintain the central data base.

- Devise and coordinate the procedures for interacting with the data base.

- Establish schedules and methods for the periodic maintenance of the files.

V. PROGRAM CODING

Program Coding is the translation of the program flow charts into program instructions. Program coding will be done by dividing the program into many small routines, each of which is coded, compiled and checked out separately before being assembled into larger blocks and finally into a complete program.

Because coding is subject to many errors, thorough checking is required prior to program test to detect and remove illegal operators, mispelled and misplaced data references and errors in logic. The Program Coding phase is performed in two tasks:

a. Program Coding

b. Program Desk Check

A. Program Coding

Program Coding translates the flow diagrams and other statements of program design into coded instructions. Subtasks include:

- Studying the program standards.
- Studying the program and data base designs.
- Writing coded program statement from detailed flow charts.
- Looking for common or standard data processing functions and searching routine libraries for applicability sub-routines to insert in the program code.
- Reviewing the program code by looking for misspelled, illegal, or missing operation codes and expressions; underdefined, doubly defined and unreferenced data; logical errors.

B. Program Desk Check

Desk checking the programs consist of looking for illegal expressions, erroneous data references, program logic errors, programming inefficiencies and deviations from program specifications.

- Obtain a keypunched and verified symbolic program listing.
- Desk check program listing for errors, checking for illegal expressions, coding mistakes and data errors.
- Compare the program code to program flow charts to insure that all functions are coded and to be sure that no logical errors have occurred.

- Review the programs with the AGS Software Development Control Group.

VI. PROGRAM TESTING

The purpose of program testing is to determine if the computer programs satisfy the functional requirements of the AGS. In developing a system of this size, subsystem tests must be made to check the performance of individual parts of system. Both simulated and real data will be used. Simulated data will be used where close control of the test conditions is required. Real data reflect the actual operations and are preferable for testing system reliability and validity. The program test phase is subdivided into the following tasks:

a. Test Procedure and Environment Familiarization

b. Program Code Compilation and Check

c. Individual Program Tests

d. Program Subsystems Tests

e. Program Systems Test

A. Test Procedures and Environment Familiarization

Using the test requirements as a framework, the procedures for using the computer, the utility system and the support systems must be learned. The subtasks are:

- Study the test requirements if not already known.

- Study the utility system, support programs, monitor system, test generation programs, test recording programs, and test reduction programs.

- Learn the computer room procedure and paperwork required.

B. Program Code Compilation and Check

As the individual blocks of code are written in either symbolic assembly language or procedure oriented language, each block is assembled or compiled into machine readable (binary) form, the listings will be checked for errors, the code will be corrected and recompiled. This process will continue until a satisfactorily compiled program or routine is obtained. The subtasks are:

- Submit blocks of symbolic code for compilation calling for printouts.

- Receive printouts of compilations and desk check for grammatical and logical errors.

- Correct errors, repunch cards as required; produce new deck or tape; and modify, reassemble or recompile program as appropriate.

- Assemble sub-blocks of code into larger blocks until program or routine is compiled as a completed unit.

- Store correct program in binary form in program card file and/or on system tape for testing.

C. Individual Program Tests

In accordance with the program systems test plan for program testing specified in Section IV, individual program performance tests will be designed and run to isolate and correct errors. The tests will be rerun until all program requirements and design specifications are met. The subtasks are:

- Produce test data required by test design of Section IIIC.

- Run program using simulated inputs and environment and test for expected outputs.

- Develop recording specifications as needed.

- Document results of program tests.

- Write complete description of the program tested.

D. Program Subsystem Tests

This task is similar to the preceding one except that subsystem tests are run to isolate and correct failures in functional interactions. The subtasks are:

- Integrate individual programs that constitute subsystems.

- Produce test data required by the test design.

- Run program subsystem tests using simulated inputs and environment and test for expected outputs.

- Document results of subsystem tests.

E. Program System Test

The program system test will be a series of tests of increasing size and complexity of the total program systems to isolate and correct system malfunctions. The subtasks are:

- Integrate program subsystems for program system test.

- Run system tests with simulated and real inputs and environment and tests for expected outputs.

- Document the results of the system tests and error corrections.

- Rerun corrected program system tests for expected outputs.

VII. CONCLUSION

This document is to serve as a guideline in the development of the Automated Ground Station software. Because of the amount of topics covered, details cannot be included, and therefore, the relative sizing of the various phases is not apparent. Some statistics on the relative size of software development phases have been gathered by Systems Development Corporation for the Naval Command System Support Activity.* In gathering the statistics, the software activities of several large military projects (SAGE, SETE, NTDS and NAVCOSSACT) were broken into analysis, coding and checkout. The appropriate relative percentages of total effort were analysis 35%, coding 20%, and checkout and test 45%. Analysis in the statistics corresponds to the Systems Analysis, System Design and Program Development phases of this document. Coding corresponds to the Program Coding, phase and the Program Code Compilation and Check task (portion of the Program Testing phase) of this document. Checkout and test corresponds to the program test phase of this document. The percentages of 35, 20 and 45% highlight the necessity for thorough systems analysis and design and forewarn those involved in the earlier phases to document and prepare for the test phase.

*Page 57, Reference 3

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APPENDIX A

COMPUTER SYSTEM TRACKING STATION FUNCTIONS

1. Tracking station management and operation control. The function of tracking station management and operation control is primarily an off-line function and involves the performance of the "bookkeeping" and scheduling chores of station management. The major program routines to be performed are the following:

   (a) Pass scheduling. This program produces a "PERT" type chart for each spacecraft pass which the station is to support. This chart details all events and activities which should be performed and the expected time of performance. The chart list turn-on times for all equipment, prepass calibration and status checks to be performed, any special action to be performed during support of the pass such as the transmitting of pre-programmed commands, postpass status and calibration checks. The output from this program is also to be used by the station status monitoring program for the on-line monitoring of station operation.

   (b) Equipment operating logs. This program maintains an up-to-date operating log of all pertinent equipment within the tracking station. This log can be used for the generation of equipment reliability reports, failure-mode analysis studies and in the general rating of station performance. Inputs to this program are via punched card and the station operating history tape produced by the on-line station status monitoring program.

   (c) Inventory control. This program maintains current inventory records and ordering information on all spare parts and equipment within the tracking station. Current stock, rate of usage, ordering lead-time, etc., are factors which should be included in the program. Input is via punched card (or a special manual data input console). Output is via the line printer. Inventory files and other information are to be maintained on magnetic tape.

   (d) Spacecraft pass support program generator. The program generates and formats all data and routines required by the spacecraft status evaluation and command programs for the support of a given pass. This information is combined with the given project spacecraft support program to produce the required real-time programs to support the pass. Input information is via magnetic tape and punched paper tape produced from TTY or data link communications with the central project control complex. The information includes special data processing, data reduction or compression instructions, spacecraft configuration, status evaluation, limit information and commands to be transmitted. Output would be compiled real-time programs.

(e) Tracking station pass support program generator. This program performs a task similar to the spacecraft Pass Support Program Generator; however, it is concerned with the tracking station monitoring program. The program generates all required information for the tracking station prepass, pass, and postpass programs and produces a final object program to be used to support the pass. In many cases the object program does not change from pass-to-pass for a given spacecraft and therefore the generator program is not required for each pass.

The above functions include the major necessary tracking station management and control functions. The capability of the system to perform additional similar functions is limited only by the capacity of the system and its percent usage for real-time functions and other required off-line uses.

2. Tracking station equipment set-up and test. The tracking station computer system will automatically perform prepass setup and testing of the station equipments.

3. Tracking station status check. Only the tracking station equipment required to be on-line or serving as backup for the current spacecraft pass would be monitored. It is expected that this would total approximately fifty pieces of equipment. Various analog quantities such as Receiver AGC, transmitter power output, etc., are scanned and compared with high-low limits. Digital quantities such as switch position, on-off indicators, etc., are checked for proper operational status. Off-normal points are indicated on the tracking station status display. The time at which a point exceeds the normal operating limits, the point identification, value, etc., is logged on the line printer and also entered on the station history magnetic tape.

4. Control of tracking station equipment. This function provides real-time control of tracking station equipment during a spacecraft pass. This program operates in conjunction with the status monitoring routine described in the previous paragraph. Any equipment exceeding the normal operating limits is automatically controlled to return within limits, if possible. The status monitoring routines provide the inputs for this program.

This program controls the automatic turn-on or turn-off of selected equipment at pre-specified times during the pass. It also controls automatic switch-over to backup equipment if a catastrophic equipment failure should occur.

5. Pass simulation and tracking station checkout. The objective of this function is to simulate a spacecraft pass for the purpose of checking the operation, calibration and overall performance of the tracking station.

   Typically, this function is accomplished in the following steps.

   (a) Perform tracking station setup and control as described and check for proper operation and calibration of equipment.

   (b) Drive the tracking and telemetry antennas to lock on the collimation tower. Check for proper pointing.

   (c) Turn on the test transmitter to simulate the spacecraft beacon and telemetry transmission. Check signal strengths, calibration, and operation of telemetry and tracking station.

   (d) Test operation of command transmitter by sending typical commands to the command system.

   (e) Simulate PCM telemetry input from magnetic tape for checkout of computer program.

   When sufficient pre-pass time is available, the pass simulation would be an ideal method for pre-pass checkout of the station. The function would also be useful for "tuning up" station operation for support of a new type spacecraft prior to launch.

6. Pre- and post-pass communication check. In order to reliably communicate spacecraft and tracking station status data to the central station and NETCON (or OPSCON) all communication links between the tracking station and these destinations should be checked immediately prior to and after each pass. The links will be checked by transmitting test messages between the tracking station and the central location.

7. Spacecraft position determination from orbital elements. The function entails computing predicted orbital positions for a given spacecraft from the orbital elements supplied by GSFC. The orbit generator used in computing the predicted positions is a modification of simple Keplerian motion and has

been previously performed on a small computer. The orbital elements are usually updated each week based upon tracking data. The orbital calculation must be performed for each spacecraft pass to be supported by the tracking station.

The output of the calculations are the predicted positions of the spacecraft with respect to the tracking station at the appropriate intervals.

8. Telemetry decommutation. The purpose of this function is to decommutate the PCM spacecraft telemetry data in order to provide an ordered set of data prior to processing. This function is not intended to replace the currently installed PCM equipment utilized for signal conditioning and frame word synchronization.

9. Data compression. Data compression consists of selecting the minimum number of data points to be transmitted necessary to reconstruct, within a specified tolerance of error, successive values of the data. The amount of compression is a function of the data compression algorithm(s) employed and the input data characteristics. Typically, data compression ratios of 10 to 1 or more may be obtained.

10. Quick-Look spacecraft evaluation. One of the functions of the tracking station computer system is to provide real-time quick-look spacecraft evaluation. The evaluation involves monitoring the telemetered data from the spacecraft and evaluating the spacecraft configuration, performance and experimental data. This function does not normally include processing of experimental data other than that required to determine the operational status of the experiment itself.

    The evaluation is performed by comparing the spacecraft configuration with the desired configuration. Limit checks are performed on selected data points and the performance of the spacecraft subsystems such as attitude and control, power supply, telemetry, etc., evaluated. Special displays and printouts of requested values, out-of-limit quantities, spacecraft malfunctions and configuration are provided.

11. Spacecraft command generation and verification. The purpose of this function is to generate spacecraft commands in the required format, to initiate the transmission of the commands and to verify their reception by the spacecraft.

    The commands may be initiated in several ways: they may be transmitted to the tracking station from the central station before the pass to be relayed to the spacecraft at a designated time during the pass; they may be generated in real-time at the central station for immediate transmission to the spacecraft; they may be inserted manually via a command console in the tracking station; they may be automatically generated as a function of telemetry data received from the spacecraft.

12. Generation of spacecraft tracking data. The purpose of this function is to record time and axis positions of the tracking antenna. This information will be used at the central station for refining and updating the orbital elements calculation. This functional program will be integrated with the antenna control program, because of the close similarities in the data input required and the timing.

13. Fly-by test support. The purpose of this function is to support the fly-by test operation by computing the antenna pattern in real-time from telemetry data transmitted to the tracking station by the aircraft performing the test.

14. Experimental data-processing. Real-time processing of experimental data at the tracking station may be a requirement for some projects, particularly during the first few days or weeks after launch.

    The type of processing required is difficult to predict however it is assumed to be statistical in nature.

15. Station display. This display will supply the station operating personnel with the necessary equipment configuration and status information. The operator will control the level of detail to be displayed.

APPENDIX B

AUTOMATED MULTIFUNCTION RECEIVER

PURPOSES

1) To serve as a universal receiver in order to eliminate requirements for a multitude of different special purpose receivers. This will simultaneously eliminate the attendant problems of stocking and procuring parts from multiple sources, thus minimizing attendant difficulties in bookkeeping, lead time, cataloguing, filing and scheduling.

2) To fulfill all receiver requirements that serve to assist the station functions of satellite tracking, ranging, and data acquisition.

FUNCTIONS

1) Receive RF signal in the assigned spectrum, and to retrieve the information for the following purposes:

   a. Telemetry - data on the desired parameters to be investigated during each experiment.

   b. Ranging - information to be processed for the determination of satellite distance (range).

   c. Autotrack - retrieve from the RF signal the information required to develop the error voltages in order to steer (position) the antenna in response to the change in spatial position of the desired satellite.

   Operation - to fulfill the above requirements, different configurations must be employed at different times. Thus, different experiments require the use of different portions of the spectrum and different bandwidths. Certain applications require phase locked loop operations under some conditions and noncoherent operation at other times. In addition, each channel must be able to perform the functions of tracking and telemetry as well as being interchangeable in minimum time. The receiver must be organized in modular form, and all receiver operations, including configurations, must be controllable by digital means from a computer, or from an operator console. Thus, gain adjust, BW, mode of operation, AGC type and response speed, and others, can be controlled by the computer by digitally coded commands.

INPUTS

1) RF energy in a predetermined band of frequencies, with modulation information for use in ranging, autotrack, and for telemetry data.

2) Synthesizer frequencies.

3) Power

4) Timing to logic blocks.

OUTPUTS

1) Telemetry baseband

2) Error signals

3) Presentations

Definition of Terms Used in the Development of the Automated Ground Station.

Decision - Resolution adopted by a machine or an operator oriented toward organization of an electronic complex. The resolution might be a response to indications emanating from the complex, or to rescheduling requirements. Some decision could be made to change the operating level of an amplifier, to change the AGC response speed, change mode of operation, etc.

Control - Action taken by a machine or an operator to command or instruct the equipment as to how or when to perform its functions, or to implement a decision.

Operation - Actions performed by the equipment to discharge its functions, e.g. amplification, development of AGC, mixing, demodulation, etc.

Status - Indications of operational condition of the equipment, i.e., standby, busy, operational, not operational, marginal, etc. To determine status, tests must be conducted, such as calibration, simulation, measurements (waveshape, frequency, bandwidth, etc.).

Presentation - Indications of actual equipment operation. Status can be included, as well as control actions taken and decision implemented.

Timing	- Sequencing of presentations, operations, outputs for assimilation by the processor, input commands from the processor and calibration equipment.
Equipment	- Subsystems than can perform basic station functions. Included are receivers, synthesizers, exciters, transmitters, timing sources, etc.
Machine	- Processor unit and intimately associated devices such as multiplexers, memory devices, buffers, etc.
Operator	- Human element in the network.

Functional Requirements Chart

Equipment	Automated Multifunction Receiver
Document Data..................	September 1967
Equipment Availability Data........	September 1970
Equipment Responsibility..........	John W. Bryan, Code 523 x 5450
Document Status.................	Equipment in conceptual design stage, charts should be updated upon contract award (October 1967)

Definition of Abbreviations

ISL	- Interconnection switching logic
BW	- Bandwidth
PLTM	- Phase lock tracking mode
NPLTM	- Non phase lock tracking mode
Av	- Availability mode
P	- Prepass readiness mode
A	- Acquisition mode
T	- Tracking mode
Pp	- Past pass calibration mode
NA	- Information not available presently

The reference columns opposite each function indicate other functions directly related. For example, in the Decisions table, the P functions (presentations) referred to are those presentations which are used as aids in making decisions.

TABLE D DECISIONS FUNCTIONS

9/1/67

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
1	Sum channel selection	Assignment of particular receiver to a frequency band.	Operations plan	106	All		1 34				Av
2	Error channel selection	Same as 1 above	Operations plan	107	All		2 34				Av
3	State selection, 1 of 8	Program, selection of type of operation, i.e., Telemetry and Autotrack, Telemetry and ranging, etc.	Governed by the mission requirements	106 107	All		3				Av
4	Circuit block selection	Program selection of appropriate circuit blocks to obtain desired configuration for operation in prescribed state.	State of operation, availability	106 107	All		3				Av
5	Frequency selection, 1 of 5	Program selection of VCO operating frequency.	Channel selection, see D1	106 107	10		4 5 6 7 23				Av
6	Pre-detection bandwidth, 1 of 8	Program or operator selection of filter network.	State, mission, phase of operations, operator judgment, presentations	106 107	4		8	4 8 11 16	3		Av
7	Gain control method selection, 1 of 2	Program or operator selection, AGC or manual gain control.	Mission, operator judgment, presentations	106 107	11		10	4 8 11	1		Av

TABLE D DECISIONS FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
8	AGC type selection, 1 of 2	Program or operator-coherent, non coherent.	Mission, operator judgment, presentations	106	11		14 25	8 11 12	1 5		Av
9	AGC level change	Program or operator. Change of receiver gain.	Presentations, operator judgment	106	11		12	4 8 11 12 16	5 7		
10	AGC speed change, 1 of 4	Program or operator. Change of speed of reaction of receiver gain to a change in received signal. strength.	Presentations, operator judgment	106	11		11	8 11 12 16			P
11	Manual gain change	Program or operator. Change of receiver gain.	Presentations, operator judgment	106	6		13	8 11 12			P
12	Tracking mode selection, 1 of 2	Program or operator. Selection of either phase lock or non phase lock operation.	State, mission, presentations, operator judgment	106	8		14	4 8 16	5 7		Av
13	PLTM primary loop noise BW selection, 1 of 7	Program or operator selection of filter network.	Mission, presentations	106	4		15	8 11 12			Av

TABLE D DECISIONS FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
14	PLTM acquisition mode selection, 1 of 3	Program or operator selection of either manual search, manual acquire, or automatic acquire.	Mission, presentations, operator judgment	106	10		16 17 18 19 20 21	4 8 11 12 16			Av
15	PLTM demodulator type selection	Program selection of either AM, PM, or coherent PM.	Mission	106	8		22		7		Av
16	PLTM secondary loop noise BW selection, 1 of 7	Program or operator selection of filter network.	Mission, operator judgment	106	4		15	8 11 12	7		Av
17	NPLTM operation mode selection	Program or operator selection of either manual, AFC, or fixed frequency mode of operation.	Mission, operator judgment	106	9		24		6		Av
18	Receiver output voltage change	Operator selection of output network.	Presentations, operator judgment	106	6		27 30	16			P,P
19	Error channel input level change	Operator selection of input network.	Presentations, operator judgment	107	8		28 31	13 16	2 5		P,P
20	IF output selection, 1 of 2	Operator selection of monitor point.	Determined by test	106 107	5		29				P,P

TABLE D DECISIONS FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
21	Analog AGC output selection, 1 of 3	Operator selection of monitor point on individual channel; horizontal, vertical, combined.	Test	106	8		47				P,P
22	Binary AGC output selection, 1 of 3	Same as C22.	Test	106	8		48				P,P
23	Display selection, 1 of 18	Operator selection of receiver test points.	Test	106 107	All		35 36 37 49				P,P
24	Calibration Instruction, 1 of 6	Operator selection of test.	Test	106 107	All		31 32 33 38 39 40 41 42 43 45 46				P,P
25	Computer Instruction, 1 of 14	Operator selection.	Test	106 107	All		39 44				P,P
26	2nd IF BW selection, 1 of 5	Program selection of BW filter.	State, mission	106 107	4		9				Av

TABLE C CONTROL FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
1	Sum channel selection	Program initiates connection of inputs and outputs.	Determined by operations plan	106	All	1					Av
2	Error channel selection	Program, same as 1 above.	Operations plan	107	All	2					Av
3	Circuit block connection	Program initiates connection of circuitry block by means of ISL.	Determined by state	106 107	All	3 4					Av
4	Operating frequency selection, 1 per sum channel	Program initiates connection of required BW filters. Also, controls application of proper voltage to the frequency determining network of the VCO.	Channel selection	106 107	10	5					Av, P
5	Center frequency stepping	Program or operator through program. Control of circuitry control logic to apply discrete voltages to the frequency determining network of the VCO.	Determined by presentations (P8)	106	10	5					P,A,T
6	Variable bandwidth selection, 1 of 3	Program or operator through program. Operation of circuitry control logic to set the limits of the variable voltage applied to the VCO during continual frequency tuning. ±300 kc; ±15 kc, intermediate BW.	Determined by state presentations (P8, P11, P12)	106	10	5					Av, P

TABLE C CONTROL FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
7	Variable frequency tuning	Program or operator by manual means. The program operates the circuitry control logic to apply the proper voltage to the frequency determining network of the VCO.	Determined by state, presentations (P8, P11, P12)	106	10	5					P,P
8	Pre-detection BW selection	Program controls the ISL to connect the appropriate filter network.	Determined by the state mission, or the phase of operation (stage)	106 107	4	6		4 8 11 16	3		Av,P
9	Second IF BW selection	Program, same as 8 above.	Same as 8 above	106 107	4	27					Av,P
10	Gain control method selection	Program selects either AGC or manual by operating the ISL to connect the appropriate circuit blocks.	Determined by mission, presentations (P4, P7, P8), or operator judgment	106	11	7		4 8 11	1		Av,P
11	AGC slope adjust	Program selects 1 of 4 by control of the ISL to connect appropriate changing rate networks. The operator can control through the program.	Determined by mission or operation judgment	106	11	10		8 11 12 16			Av,P

TABLE C — CONTROL FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
12	AGC level adjust	Program or operator through the program.	Operator judgment	106	11	9		4 8 11 12 16			P,A,T
13	Manual gain control adjust	Operator, adjustment of potentiometer.	Operator judgment	106	6	11		8 11 12			P,A,T
14	Tracking mode selection	Program or operator through program. Selection of PLTM, NPLTM by the ISL.	Mission, operator judgment	106	8	12		4 8 16	5 7		Av, P
15	PLTM BW selection	Program or operator through program. Control of ISL to connect desired filter networks.	Mission, phase of operation, operator judgment	106	4	13		8 11 12			Av,P
16	PLTM Manual search mode selection	Program or operator through the program. Control of ISL to connect the appropriate circuit blocks.	Mission, presentations (P8)	106	10	14		4 8 11 12 16			Av,P
17	PLTM Manual search phase lock loop disable	Operator - control of ISL to disconnect circuit blocks.	Phase of operation, presentations (P7,P8)	106	8	14		4 8 11 12 16			P,A

TABLE C CONTROL FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE							
				IWC	O	D	C	P	S	I	MODE
18	PLTM Manual acquire selection	Program or operator through program. Control of ISL to reconfigure lock loop.	Mission, presentations (P7, P8)	106	10	14		4 8 11 12 16			Av,P
19	PLTM automatic acquire selection	Program - selection of PLTM operation.	State, mission	106	10	14		4 8 11 12 16			Av, P
20	PLTM "sideband unlock" actuate	Operator - control of ISL to momentarily disable phase lock loop.	Presentation (P9)	106	10	14		4 8 11 12 16			A
21	PLTM "search memory" deactivate	Program or operator-control of ISL to disconnect appropriate blocks in the VCO programming circuit.	Operator, presentations (P7, P8)	106	10	14		4 8 11 12 16			A
22	PLTM demodulator selection	Program or operator through program. Control of ISL to connect appropriate circuit blocks to obtain any one of three types.	State, mission	106	8	16			7		Av, P

TABLE C CONTROL FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
23	NPLTM manual frequency stepping	Operator - manual application of discrete voltage steps to frequency determining network of VCO	Presentations (P4), operator judgment	106	10	5					P,A
24	NPLTM selection	Program or operator through the program. Control of ISL to connect appropriate circuit blocks to obtain one of three modes of operation: manual, AFC, or fixed frequency.	Phase of operations, operator judgment	106	10	18			6		P,A
25	NPLTM demodulation type selection	Program or operator, same as C24.	Mission, presentations (P14)	106	9 10	8		8 11 12 16	1 5		Av,P, A
26	Receiver autotrack output adjust	Program or operator through program. Control of ISL to connect the desired attenuator circuit blocks.	Presentations (P13), or operator judgment	107	NA	19		16	5 7		P,T
27	Error channel input level adjust	Program or operator through program. Same as C27.	Presentations (P13), or operator judgment	107	NA	20		13 16	2 5		P,T
28	IF output selection	Operator control of ISL to access desired circuit monitor point, 1 of 2.	Depending on tests	106	5	21					P,Pp
29	TM output level adjust	Operator control of ISL to connect the desired attenuation blocks.	Presentations (P4), operator judgment	106	6	19		16	5 7		P,T

TABLE C CONTROL FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE							
				IWC	O	D	C	P	S	I	MODE
30	Autotrack calibration input signal adjust	Calibration program control of calibration equipment circuitry control logic.	Calibration equipment must be automated	107	NA	25					P
31	Pre-detection BW calibration input frequency selection	Calibration program control of cal. equpt. instrumentation circuitry to select the appropriate instrument and its setting, and to control its operation.	Calibration equipment must be automated	107	NA	25					P
32	Calibration input signal level adjust	Same as C32.	Calibration equipment must be automated	NA	NA	25					P
33	Manual control channel selection	Operator through program - control of ISL to connect the selected receiver to the operator's console.	Operator selection	NA	NA	1					Av
34	Line diagram presentation	Program - determination of ISL switch positions.	Operator command	106 107	All	24					P,A
35	Line diagram portion presentation command	Same as C35.	Operator command	106 107	All	24					P,A
36	Parameter display command	Program - sensing of ISL state and programmed values.	Operator command	106 107	All	24					P,A
37	Calibration command, 1 of 6	Calibration program control of calibration equipment switching logic.	Operator command	NA	NA	25					P,P

TABLE C CONTROL FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
38	Diagnostics command	Test program - control of calibration equipment ISL.	Operator command	NA	NA	25					P,Pp
39	Calibration input frequency selection	Calibration program control of calibration equipment instrumentation (Same as C32).		NA	NA	25					P,Pp
40	Carrier and subcarrier injection (bit error vs. S/N calibration)	Calibration program - same as C32.		106	2	25					P,Pp
41	Subcarrier module command	Calibration program - same as C32.	Upon detection of P7	NA	NA	25					P,Pp
42	Input frequency variation	Calibration program - same as C32.		NA	NA	25					P,Pp
43	Module disconnect	Test program - control of receiver ISL.	To conduct isolated module tests	106 107	All	26					P,Pp
44	Signal input point selection	Test program - control of receiver ISL to access test points.	To conduct subsystem tests	106 107	All	25					P,Pp
45	Input signal selection	Test program - same as C32.		NA	NA	25					P,Pp
46	Analog AGC output selection, 1 of 3	Test program, control of receiver ISL to access test points.		106	11	22					P,Pp
47	Binary AGC output selection, 1 of 3	Same as C47.		106	11	23					P,Pp
48	Display selection, 1 of 18	Operator through program - control of ISL	Test	106 107	All	24					P,Pp

TABLE P PRESENTATIONS FUNCTIONS (Operator Console) 9/1/67

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
1	Phase lock mode	Lamp in operator console, activated by ISL. Denotes receiver configured for phase lock operation.		106	10						
2	Non phase lock mode	Lamp, operation console. Receiver configured for non phase lock operation.		106	10						
3	Manual search	Lamp, operator console. Denotes that the phase lock loop has been disabled, and the VCO is set for manual tuning.	Also input to processor (see I-1, presentations)	106	10		14 17				
4	Combined AGC	Meter, operator console, driven by analog AGC voltage, +3 to -3V DC.	Input to processor (see I-2, presentations)	106	4 7 8 10 11	6 7 9 12 14	8 10 12 14 16		3 1 5		P
5	Manual acquire	Lamp, operator console. Signifies that the phase lock loop is in operation, the VCO is tuned manually.	Input to processor (see I-3, presentations)	106	10		14 18				P
6	Automatic acquire	Lamp, operator console, the phase lock loop is in operation, VCO tuned by program.	Input to processor (see I-4, presentations)	106	10		14 19				P
7	Loop lock	Lamp, operator console. Phase lock loop has acquired and is tracking.	Input to processor (see I-5, presentation)	106	10						

TABLE P PRESENTATIONS FUNCTIONS (Operator Console) 9/1/67

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
8	Loop non lock	Lamp, operator console. Phase lock loop has not acquired.	Input to processor (see I-6, presentations)	106	4, 6, 8, 10, 11	6, 7, 8, 9, 10, 11, 12, 13, 14, 17	8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 25	11	1, 3, 5, 7		P,T, Pp
9	Sideband lock	Lamp, operator console. Lock loop has acquired an erroneous signal.	Input to processor (see I-7, presentations)	106	10						P,A, Pp
10	Search memory on	Lamp, operator console. Loop has dropped lock, VCO is searching.	Input to processor (see I-8, presentations)	106	10						P,A, Pp
11	Lock condition (aural)	Audible loop product tone, connected by receiver ISL to speaker amplifier in operator console. Qualitative indications of proximity to acquisition.		106	4, 6, 8, 10, 11	6, 7, 8, 9, 10, 11, 12, 13, 14, 17	8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 25	8	1, 3, 5, 7		P,A, Pp

TABLE P PRESENTATIONS FUNCTIONS (Operator Console)

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
12	Loop condition (Lissayous)	CRT on operator console, connected by ISL to receiver test point. Indication of the state of the phase lock loop.		106	4 6 8 10 11	8	11 12 13 14 15 16 17 18 19 20 21 25		1 5 7		
13	Tracking error voltages	Meters on operator console, 1 per channel, horizontal and vertical. 0 to ±10 V max, output of tracking receivers.		107	8	20	28 31		2 5		P
14	Spectrum display	CRT display on operator console connected by receiver ISL to monitor points. Frequency amplitude plot.	As applicable	106 107	5						P
15	Line diagram	CRT on operator console, inputs from processor. Configuration block diagram.		106 107	All						P

TABLE P PRESENTATIONS FUNCTIONS (Operator Console)

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
16	Circuit parameters	CRT on operator console, inputs from processor: ISL state.	Input to processor (see I-10, presentations)	106, 107	Au	6, 8, 9, 10, 12, 14, 19, 20	8, 11, 12, 14, 16, 17, 18, 19, 20, 21, 25, 27, 28, 30, 31		1, 2, 3, 5, 7		P

TABLE I PRESENTATIONS FUNCTIONS (Processor Interface)

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
1	Manual search	Phase of locked loop operation; the receiver automatic locking mechanism has been disabled, and the search operation is under operator control, by manually tuning the VCO.	See 3 of Presentations	106	10		14 17	3			P
2	Combined AGC	Receiver response to signal - the processor must monitor this quantity constantly to determine whether other controls must be exercised, such as a different loop noise BW, etc.	See P4	106	4 7 8 10 11	6 7 9 12 14	8 10 12 14 16	4			P,T
3	Manual acquire	Phase lock operation - VCO tuning is under operation control, and the receiver will automatically lock.	See P5	106	10		14 18	5			P,A
4	Automatic acquire	Normal phase lock operation by program control.	See P6	106	10		14 19	6			P,A
5	Loop lock	Processor must be made aware, to stop the search operation.	See P7	106	10			7			P,T
6	Loop non lock	Normal procedure until loop lock is in effect.	See P8	106	10			8			P,T

TABLE I PRESENTATIONS FUNCTIONS (Processor Interface)

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
7	Sideband lock	The receiver has acquired an erroneous signal. The computer must be made aware in order to disable the locking mechanism momentarily.	See P9	106	10			9			P,A
8	Search memory on	Loop lock drop has occurred, the VCO programming circuit has started a search operation.	See P10	106	10			10			P,A
9	Tracking error voltages	Output of tracking receiver - the processor should be able to sense an abnormal condition and initiate the appropriate corrective action, i.e., change mode, substitute components, etc.	See P13	107	8	20	28 31	13			P,A
10	Circuit parameters	The processor must have access to these for operator console display on demand.	See P16	106 107	All			16			P,A

TABLE S STATUS FUNCTIONS 9/1/67

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
1	AGC output voltage	Obtained by means of the calibrator program - the processor exercises control of the ISL in the calibration/test equipment in order to connect input and output test points in the receiver to the calibration instrumentation, and to adjust the output networks of the instruments. Range - from +3 V to -3 V over input - range from -158 dbm to -25 dbm. Acceptable limits unknown for the present.	Very important indication of receiver sensitivity. Accuracy of measurement essential. Limits of accuracy unknown.	106	11	7 8	10 38	4 8 11	5		P,Pp
2	Error output voltage	Calibration program, same as 1 above. Measured against degrees off boresight. Acceptable limits of response not available.	Indication of autotrack receiver performance. Accuracy of measurement essential. Accuracy limits not available.	107	8	20	28 31 38	13 16			P,Pp
3	Pre-detection BW measurement	Calibration program, same as 1 above. Measured at the 1 db points, for BW values of 10, 30, 100, 300 kc, and 1, 3, 10, and 30 Mc.	Indication of BW filter performance (frequency response.	106 107	4	6	8 32 38	4 8 11 16			P,Pp

TABLE S STATUS FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
4	Noise figure measurement	Calibration program - same as 1. Limit, 8 db. Indication of receiver noise.	Mainly mixer noise	106 107	2		33 38				P,P
5	Receiver gain measurement	Calibration program, same as 1. Indication of overall receiver amplifier gain. Acceptable limits not available.		106 107	6 8 11	6 8 9 11 12 19 20	12 14 25 27 28 30 31 33 38	4 8 11 12 13 16	1		P,P
6	Operating frequency measurement	Calibration program, same as 1. Indication of VCO performance and tracking accuracy, stability, trends, speed of response, bandwidth control.	The accuracy of the monitoring equipment must be several orders higher than measurement limit.	106 107	9 10	18	4 5 6 7 24 37 38 40				P,P
7	Bit count error	Calibration program, same as 1. Count of data bits last against input signal strength. Indication of phase lock loop tracking accuracy, response speed, and stability. Determines min. acceptable signal value for pre-determined acceptable bit count error. Limits not presently available.		106	4 6 8 11	9 12 16 17 19	12 14 15 22 27 30 33 41 42	4 8 11 12 16			P,P

TABLE I CONTROL FUNCTIONS (Processor Interface)

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE							
				IWC	O	D	C	P	S	I	MODE
1	All controls	All receiver controls are performed by means of the processor. Whether programmed or operator-initiated.	See Controls Table								

TABLE O OPERATIONS FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
1	Block interconnection switch actuation	Program control of ISL to connect required circuit blocks for desired configuration. This is determined by the mode, mission or operator judgment.		106 107		1 2 3 4 24 25 26	1 2 3 35 36 37 44 45 49	15			P
2	Mixing • VCO controlled-phase lock operation • Fixed frequency controlled-open loop operation	Mixer circuitry - universal type mixer.		106 107		1 2 3 4 24 25 26	1 2 3 35 36 37 41 44 45 49	15 16	4		P
3	IF selection	BW filter selects one out of the mixer products, passes only the desired frequency and a band of frequencies about it. Two IF's, 150 Mc and 18 Mc.		106 107		1 2 3 4 13 17 24 25 26	1 2 3 35 36 37 44 45 49	15 16			P

TABLE O OPERATIONS FUNCTIONS 9/1/67

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
4	BW shaping	BW filter passes only the desired band of frequencies with nominal attenuation. Values depend on function, i.e., pre-detection, loop noise, etc.		106 107		1 2 3 4 6 17 24 25 26 27	1 2 3 8 9 15 35 36 37 44 45 49	14 15 16	3		P
5	Amplification	Flat gain wideband amplifier. Gain determined by design, value not available.		106 107		1 2 3 4 21 24	1 2 3 29 35 36 37 44	4 15 16	5		P
6	IF gain control	Voltage controlled gain amplifier, AGC or manually applied voltage.	Characteristics presently not available	106 107		1 2 3 4 11 19 24 25 26	1 2 3 13 30 35 36 37 44 45 49	4 15 16	5		P,A

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TABLE O OPERATIONS FUNCTIONS

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ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
7	Optimal pre-detection combining	Combiner circuitry. AGC controlled to algebraically add individual signal to noise power ratios (horizontal polarity and vertical polarity signals).	Characteristics presently not available	106 107		1 2 3 4 24 25 26	1 2 3 35 36 37 44 45 49	4 15 16			P,A
8	Demodulation - derivation of DC voltage proportional to the following, for phase lock loop operation	Phase detection circuitry.	Used for control of VCO	106 107		1 2 3 4 12 16 22 23 24 25 26	1 2 3 14 17 22 35 36 37 44 45 49	1 2 3 4 5 6 7 8 9 10 11 12 15 16	6 7		P,A
	• ϕ-difference between signal and reference phases	Phase detector circuitry. Controlled by synthesizer derived reference signal.	Used when signal carrier not detectable								
	• Coherent ϕ-difference between signal carrier and reference phase.	Phase detector circuitry, controlled by synthesizer derived reference signal.	Used when signal carrier is detectable								
	• AM-rectification of signal peaks	Diode demodulator circuitry.	Used in lieu of ϕ detector under certain conditions of operation.								

TABLE O OPERATIONS FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
9	Demodulation - derivation of DC voltage proportional to the following, during open loop operation • Coherent ϕ - see 8 above. • AFC - difference between signal and discriminator nominal center frequency	 See 8 above. Discriminator circuitry.	Used for control of VCO See 8 above Used for frequency modulation operation	106 107		1 2 3 4 18 24 25 26	1 2 3 25 35 36 37 44 45 49	1 2 3 4 5 6 7 8 9 10 11 12 15 16	6 7		P,A
10	VCO control - frequency control • stepped - center frequency • continual variation of VCO frequency	 ISL - application of discrete voltage values in a programmed sequence. VCO programming circuitry - application of predetermined variable voltage to the VCO frequency determining circuitry.	 During the search phase During the search phase	106		1 3 4 5 14 24 25 26	1 2 3 4 5 6 7 16 18 19 20 21	3 5 6 7 8 9 10 15 16	6		P,A

4

TABLE O OPERATIONS FUNCTIONS

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
10 (cont)	• BW control	VCO programming circuitry establishes variable voltage limits to sweep the VCO frequency: ±300 kc, ±15 kc, intermediate.					23 24 27 35 36 37 44 45 49				
	• Search memory	VCO programming circuitry applies a predetermined voltage waveform to the frequency determining circuits to continue sweeping the same direction and at the same rate as when	Used when loop drops lock								
	• Acquisition - VCO output in step with the signal carrier phase	VCO programming circuitry stops the frequency sweep, and applies infinitesimal correction to VCO by demodulator derived DC.									
11	AGC		Used for gain control, optimal combining	106		1 3 4 7 8 9 10 24 25 26	1 2 3 10 11 12 35 36 37 44 45 47 48 49	4 16	1 5		P,A
	• development	Demodulator detection circuitry.									
	• level regulation	ISL - correction/disconnection of attenuator block.									
	• speed regulation	ISL - connection/disconnection of charging networks.									

TABLE I INPUT FUNCTIONS (To Receiver)

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ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
1	Telemetry and/or Ranging signals	Received from antenna, via remote mixer and multicoupler. RF energy, from -158 dbm to -25 dbm, in the following bands.		106							
		648 to 652 Mc	Up converted from 135 to 139 Mc								
		645 to 655 Mc	Up converted from 400 to 410 Mc								
		600 to 700 Mc	Down converted from 1435 to 1535 Mc								
		645 to 655	Down converted from 1700 to 1710 Mc								
		600 to 700	Down converted from 2.2 to 2.3 GC								
2	Autotrack Signals	Same as 1 above, 600 to 700 Mc		107							
3	Local Oscillator signal	Reference signal from HP5105/ 5110 B synthesizer, GFE.	Stable, accurate RF source	NA							

TABLE I INPUT FUNCTIONS (To Receiver)

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
4	Power	From station AC lines		NA							
5	Timing	From station clock. Used to clock the receiver logic circuitry		NA							
6	Control signals	From processor, via interconnection switching logic and circuitry control 2 logic used to configure connect isolate recorder.		106 107							

TABLE I OUTPUT FUNCTIONS (From Receiver)

ITEM	PURPOSE	DESCRIPTION	REMARKS	REFERENCE IWC	O	D	C	P	S	I	MODE
1	Telemetry and Ranging data	Telemetry baseband from 0 to 2.0V rms. Ranging output at -60 dbm ±2 db. Spectrum not available. From second mixer to external demodulator.	Spectrum not available	106	2						
2	Tracking error voltages	DC, from less than 0.2V to ±10V max. Drift less than 0.1V for 24 hrs. with 0 input. Deviation less than 1.5 db from linear with linear variation of input from 10 to 35 db below sum channel. From autotrack receiver demodulator.	Response values not available (output vs. input)	107	8						
3	Presentations	From receiver component modules to the processor data base and the operator console.	Used as aids in decision making by processor or operator. See Interface (presentations) table.	106 107	All						

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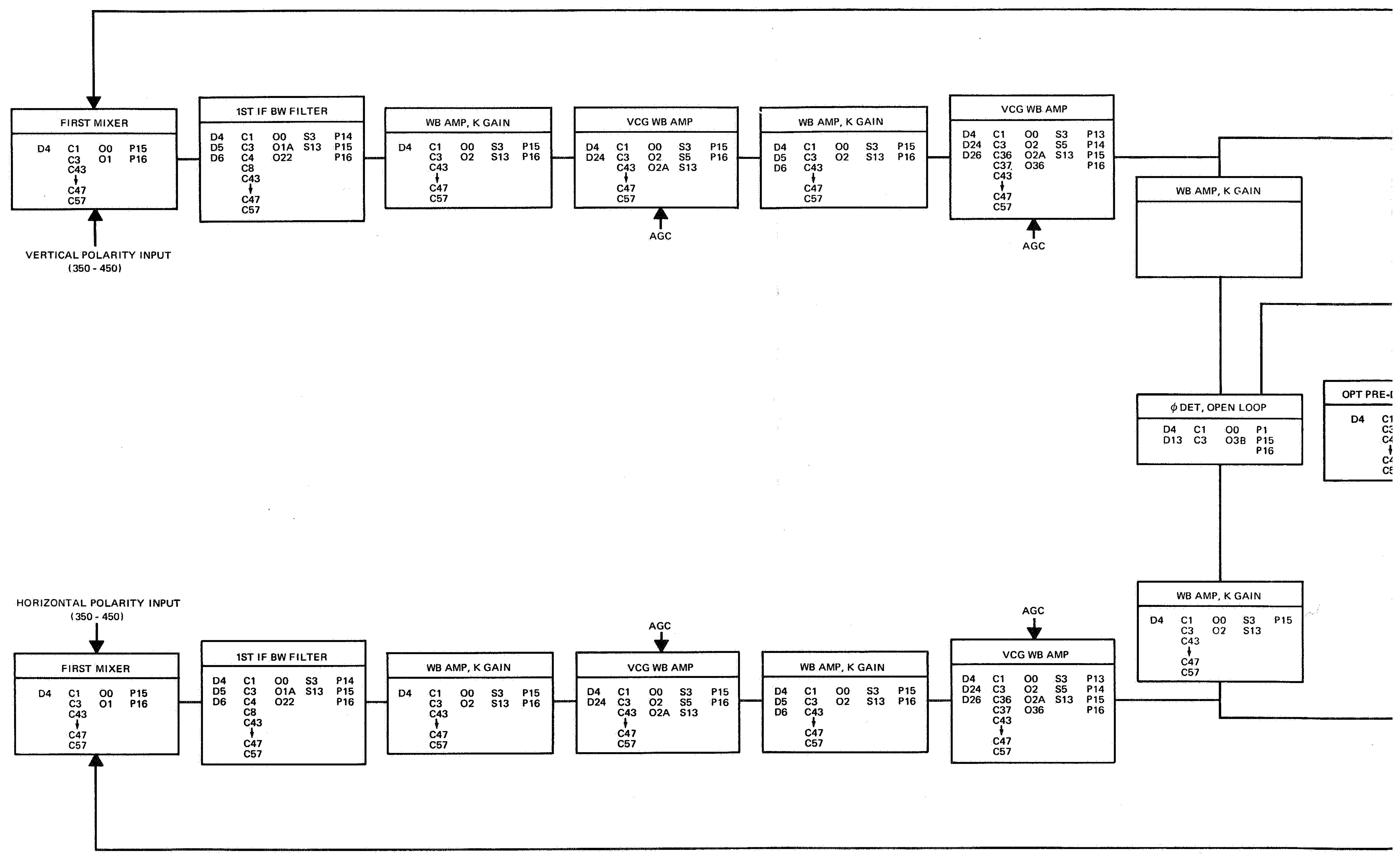

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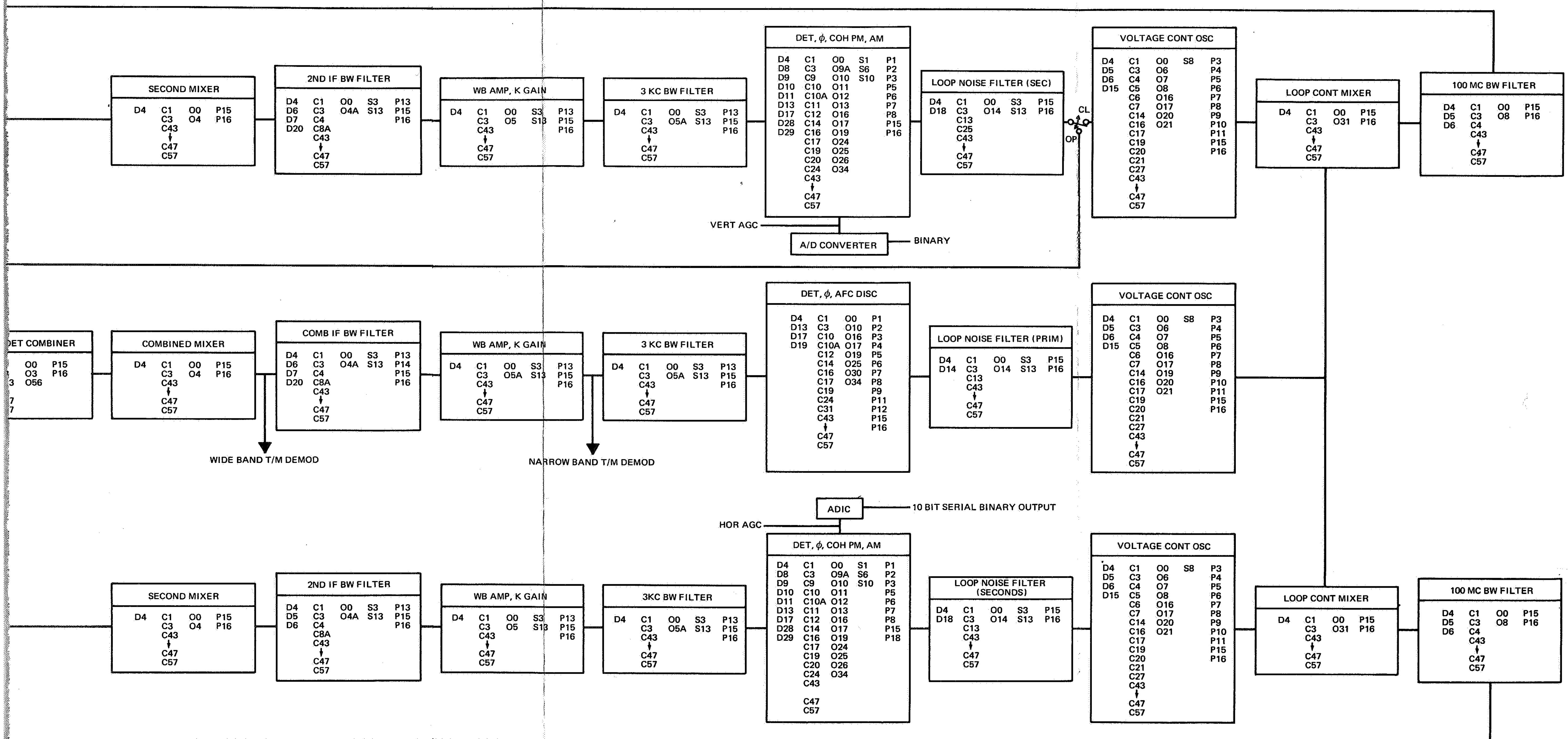

Figure 5. Automated Multi-Function Receiver Block Diagram (Sum-Channel) Telemetry