X-571-64-259

TM X-55071

NASCOM REAL-TIME SYSTEM

AUGUST 1964

NASA

GODDARD SPACE FLIGHT CENTER

GREENBELT, MARYLAND

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER

GSFC 490
ELECTRONIC DATA SWITCHING CENTER INSTALLATION

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FOREWARD

In 1958 the National Aeronautics and Space Administration established a world-wide communications network which was used to successfully funnel the radar and telemetry data to the Goddard Space Flight Center computers, as well as the Cape Kennedy (Cape Canaveral) computers, to support the early space missions, especially the Project Mercury manned flight series. The network was based entirely on teletype speed transmission in the 60 to 100 word per minute range. By 1962 it was recognized that the missions were becoming more frequent, more complex and would involve high speed data sources outside the Continental United States which the slow speed teletype network could not service. Therefore, a modernization program was initiated with the intent of establishing a system of high speed solid state switches stratigically located to provide the highest degree of automation; allow the use of a minimum of expensive long haul high speed circuits and give the network a real-time communication capability to stay abreast of the future projects including Gemini and Apollo.

The GSFC was the first switching center to undergo the modernization process. A Univac 490 Real-Time Switching System was chosen for the main switching functions and was installed during the month of December 1963. An extensive study of the network requirements had been in progress for approximately one year preceeding the equipment installation. These requirements were interpreted into the programmable 490's and in March 1964 the system went into operation. Following is a description of the system as it is in present operation.

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1.0 SYSTEM ARRANGEMENT

In order to accommodate the network requirements it was determined that the following equipment was best suited for the job (see FIGURE 1). It consisted of the following:

2 - Univac 490 Real-Time Central Processors with 16K core
2 - Univac FH 880 Magnetic Drums
6 - Univac IIIC Tape Servos
1 - Univac 1004 Card Processor

A system of input multiplexing of the data circuits was chosen because of the large number to be serviced. Each circuit enters the system through its individual line terminal which is a Univac CLT (one character buffer). Both the five level baudot code and the eight level ASC II codes are being used in the Center. When a circuit becomes busy and an input buffer has received a complete character, a series of interrupts are triggered in the logic of the 490 Central Processor. A multiplexer has been assigned an address in the main core of the 490 CP for that character and it is brought into the system. The CLT is then ready for the next character. The transfer is accomplished in a total of 20 micro-seconds which is much faster than the input circuits can operate. This rapid scan time of the multiplexer insures that all inputs will be serviced in a real-time mode, even when they are all busy at the same time.

At the present time, each multiplexer occupies one of the 14 channels into the Central Processor core; therefore, four channels are used to service the four multiplexers. Each multiplexer has the capability to service 32 data inputs or circuits in a full duplexed mode for a total of 128 circuits. This is by no means the capacity of the system, as the multiplexers can be cascaded onto each other should the network grow to that extent. In a peak load condition with all circuits busy at 100 wpm speeds, each input would necessarily be serviced each 1000 micro-seconds. It requires 20 micro-seconds for each busy CLT or a total of 1000/20 or 50 busy circuits maximum for each channel. Assuming a logical 25 percent loading of the circuits at any particular time would allow 4x50 = 200 circuits per channel, which is more realistic when thinking in terms of total capacity.

As stated before, each CLT has been assigned its own small area of core in the Central Processor where incoming data is stored for that particular circuit. This is one of the more important features of the 490 Central Processor for this application in that it requires no internal machine cycle time to service the inputs and outputs once the input or output mode has been established. The data is stored in its own location within the Central Processor under control of programmed hardware.

Once inside the CP the data is packed into five character words and transferred to the FH 880 drum in a location which is remembered for future use. When sufficient characters have been received to completely identify the sending and receiving addresses, the receiving circuit is status checked. If available, the message is sent in real-time as it comes in. If not available, a notation is made in the "things-to-do" table and at the first opportunity the message is sent and the notation is removed from the "things-to-do" table.

The data is not removed from the drum at this time as there are several uses for it in other programs. It must be logged, journalized, stored for future reference or recall, and so forth. In order to provide a system of indiscriminate sending and receiving messages into an on-line device, systematic layout of the drum was designed as follows: It was divided into five time frames of eight hours each. These time frames are somewhat related to five rotating sections on the drum, each section containing a complete eight hours of traffic. At the end of eight hours, of traffic on section 1, section 2 is used for the next eight hours; section 3 and 4 utilized next in turn. However, when section 4 is being filled, a comparative search is made of section 1. Any message found to have been sent is transferred to tape and erased from the drum. Any message which is found not to have been sent is transferred to section 5 of the drum and all references to the drum address of this message are changed to the new location wherever it might be stored in memory such as in the "task" table. This procedure insures that one section of the drum is always available for new traffic in advance of the filling of the last section to insure that a saturated condition cannot exist on the drum.

The output of data from the drum, through the Central Processor core, through the multiplexer and to the correct CLT is a reverse of the input cycle. The message is retrieved from the drum, unpacked from the 5 character words and placed in the correct output buffer for transmission to its destination. The output mode is established between the CP and the CLT and the message is sent, character by character to the receiving site.

A representative sample of the CLT and multiplexer is shown on FIGURE 2 and the equipment arrangement is shown on FIGURE 1.

2.0 SYSTEM FEATURES

The 490 system of traffic switching accepts inputs and outputs the same way as other teletype networks, except that once the message is entered into the 490, it is read, interpreted, directed, corrected, if necessary, and sent to its destination automatically providing enough information is received to determine the addressee(s). If a trouble condition exists in a message, it is interpreted by the programs and a print-out which states what is wrong with the message, is sent to the proper service equipment. These print-outs are called Advisory Messages which call for some action by the responsible person. The print-outs call attention to such things as:

a. Invalid SOM (start of message)
b. Invalid Precedence
c. Invalid EOM (end of message)
d. Message Sent
e. Message Held (with drum address)
f. Garbled Message

These features are all designed to help the operations personnel service the network. There are also many side benefits which are primarily of more interest to the engineering planning and analysis personnel. Many of the basic parameters for network engineering and analysis have been incorporated into these programs, such as:

a. Message Count
b. Word Count
c. Busy Circuit
d. Traffic Backlog
e. Circuit Outage
f. Circuit Assurance
g. Network Utilization
h. Transmission Errors
i. Network Loading

These parameters are built into the programs and can be recalled in any desirable form. They are mostly associated with the slow speed TTY circuits, but in the very near future the center will be switching high speed circuits. Different techniques are required for the necessary handling of these new circuits. They require different programs in order to identify various parts and pieces of messages, as well as different parameters which are covered by the data.

High speed circuits are to be used to carry traffic between the major NASCOM switching centers, and also to connect to the various computers at GSFC and outlying locations. The center will connect to three IBM 7094's in the installation, with a transfer rate of 40.8 kilobits per second. Each computer in the system presents a new and different set of interfacing programming problems.

The 7094 interfacing programs are required to accept the regular NASCOP formats and perform the necessary message accounting. With the knowledge and familiarization of the 7094 functions we are progressing on these programs.

There are plans at GSFC for interfacing other computers which do not conform to the 7094 type of task. These are ultra-high-speed computers which will be used for data reduction associated with the various scientific satellites such as Nimbus, Tiros, Relay, SYNCOM, and so forth. The 490's will be required to store data for varying lengths of time and on pre-arranged schedules send this data to the using computers at very high speeds. New techniques are needed for these tasks as the requirements are finalized. New types of data handling programs are being investigated which will assure better reliability.

3.0 SYSTEM DESIGN

The basic premise for the application of the 490's to the NASCOM network was 100 percent reliability and a flexible input handling technique. The reliability is assured by using two 490's in the system, either of which can perform the complete switching job, and also execute the important programs in such a manner that only solid state circuitry is involved in the switching chain. Although a 1004 Card Processor and tape servos are a part of the overall 490 system, only the main frame logic and core storage plus an FH880 Magnetic Drum are used in the main switching chain. As long as one main frame and one drum is operable, the system can perform its basic job of switching the traffic. The system can remain in this status for extended periods of time under emergency conditions.

Flexibility of inputs has been achieved through an intensive programming effort coupled with a communications oriented processor. To achieve the most flexibility in the system, a study of other networks was necessary. In some cases involving the other networks studied it was found that strict adherence to pre-planned formats, message lengths, acceptance times, and so forth is required; otherwise, the messages are not accepted. In other cases, polling of input circuits determines when a message will be accepted. This imposes varying degrees of restrictions and regulations on the operators in the field and will not support a real time network as used in NASCOM.

The 490's in this system are programmed in such a manner that all inputs are accepted without restriction in real-time. There is a recognized format which is thoroughly covered in the NASCOP operating manual. Any input will be accepted and forwarded by the 490 programs regardless of any non-conformance to the recommended format, but such non-conformance is noted on the intercept position. In some cases, insufficient information may exist to determine the addressee, therefore, making it impossible to forward the message. This situation has been given consideration, and a notation at the intercept position will state that the message is being held. It will also state the drum address where the message is stored, enabling it to be recalled for any required action by the operator at GSFC.

4.0 WORKING PROGRAMS

Instructions are grouped together to form individual programs which perform their specific job. Some of these programs are long and complicated (validation), while others are short and quite simple (various advisories). Each has its place in the overall picture and is called upon to act when it has a job to do. For example, the advisory to inform the service area of an excessively long message (which could indicate a stuck tape or an open circuit) is only called upon when this situation arises. The input program, on the other hand, is involved with every character entering the 490. The assignment of the programs, when they are needed, is under the direct control of the Executive Program, "COMEX."

4.1 Comex

In order for the system to be in a position to perform at maximum efficiency in a real-time mode, an overall supervision of the individual jobs to be accomplished is required. There are a myriad of details involved in supporting a network such as NASCOM and each of them must be performed as soon as possible, however, only one job can be performed at a time (an exception to this is simultaneous input and output). Also, some jobs are more important than others. For example, it is much more important in relation to machine time to service a busy input than it is to write a message on tape for use some time in the future. The message is available for transcribing for many hours, but the input would be lost in, say 100 milliseconds, even less on a high speed input.

A parable to the comex control or executive system is the "job jar" which is present in many households. A jar is kept in the house and as tasks present themselves, a notation on a slip of paper is placed in the jar. Whenever time presents itself, a task slip is taken from the jar and assigned to the person responsible. This process continues until the jar is empty. In fact, in an efficient arrangement, there should never be more than one task in the jar at any particular time. Experience shows, however, that this is not the case.

In the 490's, with the many tasks to be accomplished, approximately 50 individual worker programs have been written, each with its own specialty. One inputs the data, one outputs, one packs the characters, one stores to the drum, etc. Comex, as master of the "job jar" assigns the tasks to the responsible worker program. Upon completion of the tasks, the worker program erases the task from the task table and returns control of the system to Comex. Many times completion of the task involves parameters which are beyond the control of the worker program. For example, transmitting a multiple address message to all addresses at the same time requires that all of the circuits involved are idle at that time. Sometimes this is not the case. Therefore, the worker program must send the message to the addressees whose circuits are available and make a notation or "job-slip" for those remaining. The notation is placed on the 490 "task-table" (job-jar) with an associated priority. When time presents itself, and it does in the 490, the worker program checks the circuits again for availability. If the job is completed the task slip is erased. If not, it is left on the task table.

Comex always knows where a worker (program) is located. When Comex checks the task table, the task is assigned to the address which is associated with the task. In other words, reverting to the household job-jar, if the pipe is in need of repair in the basement, the task slip is sent to the basement. If the leak were in the kitchen, the slip would be sent there, etc. In the 490's, the responsible program is always at the correct location and prepared to act.

Comex devotes the majority of attention to inputs and the remaining time is spent on the myriad of details involved in the servicing of a message through the network. For the most part, the decisions made by the 490 are hidden deep inside the various programs, but the results of the decisions are readily apparent. They are covered in this report under "System Features."

5.0 NEW PROGRAM IMPLEMENTATION

The most strict control possible is maintained to insure that any change to the programs does not adversely affect the operation programs. This control consists of verification, test, and simulation methods. When a change is made on any of the circuits, sites, or NASCOP procedures the detailed requirements are submitted to the programming group. The task is assigned to a specific programmer for implementation.

Upon completion of the coding, assembly and debugging, it is given to another programmer for his verification and concurrence. It is then submitted to the programming analyst to assure that the change will actually perform and will integrate into the total system. At that point, the change will be made on a simulated off-line basis in the back-up 490 system. It is run for the required period of time and the results are analyzed from an individual program basis and system basis to re-assure that none of the important information storage locations have been inadvertently modified. When everyone concerned has agreed that the change is valid, it will be incorporated into the system programs for on-line operation. This system of documentation will insure that the most minor network change will not cause a series of events which would disrupt the operational programs.

Along with the actual work, a filing system is kept on magnetic tape. This file lists all the pertinent information concerning the individual circuits and also contains the actual configuration of the various modules which are used by the 490 to describe the individual circuit parameters. Its main use is to keep an up-to-date network file as it actually exists. When a circuit parameter changes, and the program is modified accordingly, this file is printed on the 1004 either in whole or in part. A complete network print-out may be taken at any time and varied as to particular needs. All modifications to the circuit parameters are made from this master file; when the modification is finally incorporated into the NASCOM system programs, the file is up-dated also. A system of verification by program, insures that there are no errors in re-storing the up-dated file back onto the tape. These verification programs are covered in this report under 'Utility Routines."

6.0 CONSOLE OPERATION

Prime function of the control console is to activate and initiate a worker program held in memory. This is done by manual key or via a 35 ASR. The console has the capability to perform various functions, such as:

a. Open and close stations
b. Set stations operational or non-operational
c. Set or clear alternate routing indicators
d. Circuit status reports
e. Reset channel numbers
f. Initiate message recall
g. Request specific table listings
h. Initiate alternate routing
i. Initiate normal and emergency transfer of control from one processor to the other
j. Restart validation

A standard format must be observed when addressing the CP via the 35 console. All characters keyed into the CP will be disregarded until a start of message function ($) is received. It is necessary to give information to activate a particular program following the SOM. The information must be in the form of 3 alfa character identification code which describes the function to be performed. This code may or may not be followed by elucidating parameters. Following these parameters is an optional 3 alfa character code which is significant only with particular entries. Arguments may be present and must follow in an alfa-numeric sequence (A-Z, 0-9) or will be rejected. Upon completion of all necessary entry information, an end of message (".") must be sent; then the CP will take action on the request presented.

Each entry will generate a disposition message. This message gives the current derived time from the day clock, the function identification code and a message acknowledgment which indicates the entry was made or an error response which states why the entry was rejected.

The console has the ability to backspace and delete the last character entered. Three consecutive backspaces will terminate the message being entered.

7.0 SERVICE AREA

The service section plays an important role in the operation of the Communications Processor 490 Real-Time System. Although messages are not held, according to a recent survey, 15 per cent of all incoming traffic will go to the service area. The service area section consists of the following:

a. Four teletype Model 28 RO's
b. Four teletype Model 28 ASR's

Two Model 28 RO's are used for Journal Listings. There are two types of Journal Listing; normal and recall. These two RO's are on rotary; if one is busy you can use the other. If necessary, everything which is received on the RO's can be put on tape for future use. The information appears on the normal Journal Listing as input channel designator, input channel letter, input time word and date, output channel designator, output channel letter, output time word and date, the Julian date, the internal message number and the entire message heading to the first letter Z. The information appears on Recall Journal Listing as input channel designator, input channel letter, input time word and date, output channel designator, output channel letter, output time word and date, the date, internal message number, recall request message, supplement heading letters Z and original message heading letters Z.

The other two rotary RO's are used for Communications Processor generated Advisory Messages. Most of the messages received on these RO's will not require immediate action for they are primarily for information purposes and will not be numbered, journalized, or stored. There are two types of discrepancies and operational messages directed to non-operational stations. The advisory informs operating personnel that no other errors are involved in the message, and the message is forwarded to all addresses. The information as it appears on the RO's is; input channel and letter designator, input date-time word, invalid channel number, last valid number received, an operational message directed to a non-operational station, input message through the first double line feed.

Two Model 28 ASR's on rotary are used for intercept traffic. All messages on these machines are available for normal recall from the drum. They are also recorded on tape, but are not available for recall from the tape because no journal entries are made for this traffic. All messages of the type which require action on the part of switching center personnel appear on these ASR's. All traffic directed to intercept by the validation routine is placed on a common queue for delivery to the intercept position. Some of the station discrepancies that cause the CP to generate a message to the Intercept ASR's are:

a. Invalid channel number
b. Invalid start of message
c. Invalid precedence
d. Invalid routing indicator
e. Operational traffic to non-operational station
f. Invalid end of message

The print-out on the ASR is; input channel and letter designator, input date-time word, and type of error followed by sent or held. When the message is forwarded with an error in the precedence or routing indicator, the station to which it is sent is listed following the word SENT. When the message is forwarded with an invalid start of message or operational to non-operational error the word SENT is present but not the station listing. When the error is an invalid channel number without last valid number received, the word HELD is present and no stations are listed, but the drum address where it is stored, and the input message through the first double line feed does appear.

If there is an invalid end of message on a line other than GSCP, the message is sent to the intercept ASR, the end of message (FIGS H LTRS) is inserted at the end of the message and action is taken for a valid ending.

Another Model 28 ASR is used for all traffic addressed to GSPA. It is available for normal recall from drum or tape.

The last Model 28 ASR is used for all transmitted traffic originated from GSPA; this includes intercept traffic corrections and is also available for normal recall from drum or tape.

Intercept corrections use VALIDATION, and FIX-IT routines. The VALIDATION routine validates the routing indicators, when it gains control from the FIX-IT routine, and lists the drum address of the supplementary heading on the proper output queues. The FIX-IT routine utilizes the supplementary heading and drum address (supplied in a message from GSPA to GSCP) to forward previously intercepted messages to their proper addresses.

8.0 FACILITIES CONTROL INTERFACE

8.1 CP Access to Distant Stations

8.1.1 Multiplexing - Communications transactions are handled by the CP on a character multiplexing basis. Character multiplexing is defined as one character being sent to the CP from one communications line terminal (hereafter referred to as CLT) before control is sent to another active CLT for a one character transmission. Some CLT's being of a higher priority due to character speed, are sampled by the multiplexer more frequently than others. One communications multiplexer accommodates up to 64 CLT's, and another CLT accommodates one communications line in one direction. CLT requirements for various types of circuits are:

a. Full duplex - 2 CLT's ... 1 send and 1 receive
b. Half duplex - 2 CLT's ... 1 send and 1 receive
c. Simplex - 1 CLT ... (either direction)

The switching speeds of the Multiplexor and the CP offset the possibility of lost characters.

8.2 Basic Circuitry

Each CLT termination "appears" in a set jack corresponding to its associated circuit at the Facilities Control Board. Each CLT is operated directly by the DC loop and associated keying.

A patch cord inserted into the CLT jack, "physically lifts" the CLT from the circuit; thus, disabling that particular leg of that particular circuit.

All CP associated teletype equipment also "appears" on the Facilities Control Board on jacks and are "hard wired" directly to the CLT's which service them.

8.3 Communications Interruptions

Generally, communications interruptions fall into the following two categories:

a. In-house troubles
b. Communications path failures

8.3.1 In-house troubles - Generally, in-house troubles are due to equipment failures. At the GSFC, these equipment failures fall into two categories. These categories are:

a. CP associated equipment
b. Teletype and associated equipment

Once it is determined that there is an apparent in-house trouble at GSFC, the Facilities Controller must test to determine the source of trouble. This requires close coordination between the Facilities Controller and the maintenance forces of the Western Union and the Telephone Company, as well as the CP engineer.

Certain equipment patching may be implemented to restore service to CP associated teletype equipment. This is done by patching a spare teletype machine into the CLT which normally services the affected teletype equipment. A defective CLT also may be patched to another currently unused CLT, pending restoration of the affected CLT. However, due to the physical wiring relationship of each circuit to its associated CLT, it is imperative that this change be implemented in both the CPCC/490 area and at the Facilities Control. All other CP associated equipment failures must be handled by the CPCC operator and the Univac engineer.

8.4 Circuit Assurance

Circuit assurance functions are conducted by the CP which are very similar to those functions now performed manually. The CP, however, queries stations on an incessant basis rather than at random.

Each station that is equipped with circuit assurance answer-back equipment is tested and if the resulting reply is incorrect, or if there is no reply at all, the CP continues to test this station until it gets a good reply or until it queries the station five times without a good reply. At the time the circuit is tested five times without receipt of a good reply, the circuit assurance program within the CP considers this circuit to be out of service. The CP then takes the appropriate action to insure that no further traffic is sent to this station and alerts the Facilities Control with a message stating the following:

a. Time
b. Station
c. "CA Report"
d. Number of "no replies"
e. Number of "garbled replies"

8.5 Facilities Control Advisory Monitor (VLAQFACS)

8.5.1 Purpose - The Facilities Control is equipped with a Model 28 RO which is utilized by the CP to automatically inform the controller of garbled/open circuit and circuit assurance reports.

8.5.2 Circuit Garbled/Open - If a circuit begins garbling or goes at random, the CP informs Facilities Control on VLAQFACS as follows:

a. Station
b. Current time
c. Print-out of garbling/open

9.0 UTILITY ROUTINES

As the NASA Communications Processing System expands, many recurring services to the CP's may be performed more efficiently by designing the various utility routines needed for their execution. In this manner, responsibility for the correct completion of these tasks is transferred from the console operator to the CP. The need for many routines can be foreseen at present and several of the applications are listed in the following paragraphs.

9.1 Tape to Drum

This routine loads a fixed format tape into a designated drum address in one of the following methods:

a. With a compare of present contents
b. Direct load without compare of present contents

Format xxxxxxxxxxxx yyyyyyyyyy zzzzzzzzzz

a. x = drum address
b. y = present contents of drum at this address
c. z = new contents to be entered

* If no compare of present contents is required, second word (y) would be deleted when making tape.

The Program Tape to be loaded is mounted on a servo and read into the core and started. The operator than makes a console entry designating a compare or no compare load. If no compare is requested, the tape is loaded to the drum and the routine closed out. If compare is requested, the content of the drum address is compared to the tapes present content and, if equal, enter new contents. If present contents do not compare, the routine sends the content of the drum to the console for a decision on making the change to this address. After all changes on tape are made, the program will close out.

9.2 Tape to Core

The routine is the same as tape to drum except the change affects the core only and is lost by bootstrapping the CP.

9.3 Type-Out Counters

Routine counters are placed on a routine-contained list and their contents printed on console at a designated time, or whenever requested. Typeout on console is in a format similar to the one below.

Format wwwww is xxxxx was yyyy dif zzzzz

a. w = counter name, number, or address
b. x = present contents in octal
c. y = contents when last requested in octal
d. z = difference in decimal

9.4 Octal to Spurt

This is a conversion routine for tape stored routine which converts machine instructions to a XS-3 coded spurt equivalent and stores in a buffer for output to the 1004 printer.

9.5 De-bugging Aid

This is a routine which interlaces with a designated program that is in a process of being de-bugged. This routine has the ability to save specific registers and other relative information during the occurrence of a designated set of circumstances within the program being de-bugged.

10.0 MODULE AND CIRCUIT INVENTORY RECORDS

The growth of the NASA Communications Processing System necessitates many equipment and programming changes and a flexible method of establishing and maintaining an inventory of these changes has been devised.

The variety of records that are required seemed to eliminate the possibility of a fixed word count and format. The Module and Circuit Records are outlined below and any additional records of this type will follow a similar format.

10.1 Module Record

All permanent on-line module information is duplicated on magnetic tape. This information, preceded by certain processing program requirements, is the basic module record. One tape block contains one record. The following example is the present format for the variable length module record:

a. first word: number of words in module; ESI number
b. first word plus 1: base address; spare
c. first word plus 2: first data word
d. first word plus N: last word*

* First word plus two through word plus N will be variable according to module length.

This record serves as an inventory of all modules and their current assignment. Maintenance to these records are frequent and for this reason simplicity in design was stressed.

A Module Record Maintenance Routine reads one tape block, identifies the ESI number, makes the necessary change to the record, and rewrites the new record on a new tape. In event there are no changes to be made, it is written on the new tape "as is" and the next tape block is read into the core.

A Module Record List Program reads a block, converts all information to be printed on the 1004 card processor printer to XS-3 cord, packs the output buffer in the format required, and gives control to the printer routine.

10.2 Circuit Inventory Record

The Circuit Inventory Record contains all information relative to an individual circuit. The information is stored on magnetic tape; one record per tape block. Some of the requirements are listed below:

a. Circuit number (or record number)
b. Routine
c. Drops
d. Carrier
e. Associated project (if any)
f. Line speed
g. Date of service
h. History
i. Part time or full time
j. Associated equipment
k. FDX, HDX, Simplex

The records are maintained for report reference, and as an inventory of stations and equipment associated with each circuit.

The accessing programs read one tape block into a designated core area and identifies the circuit being processed. Report programs retrieve needed information from the record, process it and read the next tape block. Record up-dating programs make necessary changes, if any, and re-write the block on a new tape. Processing programs do not write on the input tape, for new tapes are made when changing record information.

11.0 METHODS OF TESTING

11.1 Format Line Concept

To conform with NASCOP, errors are selected by format line; that is, SOM, routing line and so forth. Each line is broken into a series of probable errors which may be encountered in a normal teletype message. Although each error is pre-conceived and placed in logical sequence; it is impractical, if not implausible, to generate an error to simulate all possibilities in advance. Experience in operating the system brings to light new error combinations continually.

Errors, which were selected on a past experience basis as typical, were adopted as a practical means of evaluation. The most common error being extra "letter functions" which are inserted at the beginning of the message to provide a leader to accommodate the tape transmitter.

11.2 Mixed Combinations

Mixed combinations are designed to achieve error results which are not achieved by single format line errors. These combinations when properly synthesized create special conditions such as "misrouting" or "held for validation."

Message identification is obtained by several means. To eliminate identification by means of serial progression from full identification to no identification is a method to determine the message delivery cut-off point.

11.3 Radar and Telemetry Format

A "JJ" identifier in the SOM of a message denotes telemetry or radar data. An attempt is made to disguise this identifier by adding extra letters or leaving one of the J's out.

Header identification is gradually eliminated until no identification is present. This is to test at what point JJ data would be lost because of garbled headers.

11.4 Service Forward, Message Recall and Set Count

The numbering sequence and other characteristics preclude any pre-conceived fixed messages; however, the format to be used, with examples, is pre-cut. The teletype tape for each test is cut just prior to the testing cycle.

11.5 Master Tape Log

The master log is a serial listing of the teletype test tapes. It is composed of numbers and letters relating to teletype format lines, that is, format line 1A, 1B, 1C ... format line 2A, 2B, 2C ... and so on. Also, each category such as JJ Data and Mixed Combinations is listed as JJ1, JJ2, JJ3 and MC1, MC2, MC3 ... respectively. Each serial number is referenced to a particular error which has been pre-conceived. This numbering system is open-ended to facilitate additional listings where applicable.

11.6 Test Folders

The test folder has a number corresponding to a serial number in the master log. Each folder contains a master test tape, a "hard copy" of the message on the tape, and a data sheet to annotate test results. The master test tapes are standard five level, clear hole, mylar tapes. A useable test tape may be cut from the master, always maintaining the master as a permanent record. An envelope is affixed to each folder which contains the master tape.

The text of the "hard copy" explains the type of error which is encountered when utilizing the enclosed test tape associated with the message.

The test results are in the form of notations regarding significant information about the characteristics observed during the testing period. These results may be a basis for change in the future operating techniques or format.

11.7 Progress Reports

Progress reports are submitted weekly summarizing the various stages of completion. The intent of each report is to disseminate information among cognizant personnel, concerning the testing and documentation phase.

11.8 Test Run Results

Folders are made that contain the input/output information (receive side and send side) with any intercept or advisory messages which may have been generated. The tests are listed by run numbers relative to each format line.

11.9 Adapting Tapes to Program Debugging

The beginning conditions as set forth in the Univac Systems Manual are programmed to achieve the original requirements. Each tape, when related to program evaluation, is used to check a specific function. Program errors may be detected when a tape fails to be processed correctly.

11.0 Program Analysis

In some cases tape errors have generated conditions which were unusual or which were not postulated. These errors provide the impetus for program changes, and new programming concepts may be formed as a result of these simple or compound errors.

11.11 Adapting Tapes to Operational Debugging

The system input and output is simulated with several ASR-28's. One teletype is chosen as a "send side" and another is chosen as the "receive side." As each tape is sent, the receive side "hard copy" is evaluated along with any service messages which are generated by the CP and is compared with the send side. When an entire group of error tapes clear the CP and are correctly forwarded, the operational conditions are satisfied.

12.0 490/7094 INTERFACE

The 490 is a replacement switch for the 83B2 (AT&T) switch which was installed to direct radar teletype to the 7094's, and to direct text teletype from the 7094's to the operating sites in support of the Mercury Manned Space Flight Missions. A total of 14 incoming and three outgoing teletype circuits are involved. These circuits are a mixture of 60 wpm and 100 wpm.

During non-mission periods, the circuits are used for network checking and routine messages.

The old interface was a manual "patch cord." A one-for-one situation which passed all traffic on the circuits to the 7094's. To be able to use these circuits to support other missions not involving the 7094's, a means of directing traffic was needed. The 490 provides the directing ability, and the message header provides the direction of the message.

Interfacing in the new manner brought with it several problems, as follows.

12.1 Reliability

To provide 100% assurance that all radar data is received by the 7094's, all data formats plus any message which is in such a distorted state that it cannot be recognized as a valid text message is routed to the 7094's.

The 490 programs do not examine the text of these messages, but the 7094 programs do perform checks to insure proper data. Therefore, text messages will be rejected by the 7094's.

12.2 Compatibility with existing equipment

The existing inputs to the 7094's is through an IBM 7261 S/P converter, 7281 channel multiplexer and into the 7094 core buffers. Both 60 wpm and 100 wpm channels are installed in the 7281. To debug the interface programs, we use the same speed output from the 490. Other wise a lengthy re-alignment would be necessary each time we tried to debug.

12.3 Formats-Incoming

Two routing indicators are assigned to the 7094's for text type traffic. The original radar routing indicator, consisting of two J's (JJ) is retained.

12.4 Formats-Outgoing

The 7094's and any other originator of messages in tha t area were given an instruction manual which details the formats to be used in the NASCOM network.

12.5 Message accounting

The 490's are programmed to maintain a message accounting for all messages entering the network. This requires the originator to generate a sequential number for every message. The matter of the sequential number posed a serious problem to the programmers of the 7094's. There are three 7094 computers involved and anyone of them can transmit at any time. Therefore, to generate a sequential number for each message would involve up-dating all computers each time a message is sent. There are several 7094 programs involved also which would necessarily be initialized to the present message count.

It should be noted that a message received out of sequence will not restrict if from being transmitted to the receiving station, but only causes an advisory message to be generated by the 490 explaining the situation, plus, intercepting the complete message for remedial action. In the case of the 7094's, all traffic would be intercepted from the time of the first non-sequential number received.

To offset this, the 490 is programmed to accept a "set count" message. Upon receipt of this message the 490 initializes the message count of the originator to zero. Therefore, each program used in the 7094's need only generate a set count message and start all messages at zero count, which solves the problem of synchronizing a counter in three computers.

12.6 Cadfiss

This is a network checking program which has been in existence for some time. It sends a message on each circuit and waits for the answering message, analyses the results and forms a norm for traffic reliability for the network.

As there are no programming checks made on the returned messages to the originator, a one-for-one circuit network is used. When a message enters a particular channel of the 7094 it is assumed to be from that station. This posed a message accounting problem again. To insure the proper return to the 7094's each 490 incoming circuit was assigned a corresponding outgoing circuit to the 7094's. In this way, the 7094 programs are assured that they are receiving the correct returning traffic.

As stated before, the present programs are directed towards our slow speed teletype traffic. While very important, these circuits are relatively easy to handle when compared to the high speed (1200-4800 baud) data. As we pick up the higher speed circuits, new programs must be developed particular to the needs of the circuit involved and unique to the type of data being transmitted. We believe that these new teletype circuits will be relatively easy to incorporate, for we have considered most factors within the program concept. However, new types of data such as the Digital Command System (DCS) with its partial recall critieria requires a complete new concept of the recall program. It will also be a part of the main operating programs and as stated before, any change to these programs requires the most serious, and comprehensive planning and debugging possible.

We also have several requirements for inventory type programs which furnish us a print-out of any or all of the network at any time. We are presently working on the means for up-dating these programs as new circuits, equipment, and so forth, are added to the network.

Fortunately, the matter of circuit inventory up-dating is automatic with the 490. In the past, we have had no centralized system for listing all of our circuits and an inventory required extensive research and must time. With the 490's, however, every circuit must be connected to a CLT and programmed for in advance. We, therefore, have all of the required information to maintain the complete up-to-date inventory at hand. It requires only an up-dating program to maintain the inventory. There are many other uses for the 490, in this type of "off-line" work and which will present themselves in the future. This is a continuing project and as other uses are found and implemented, this report will be up-dated and the information will be distributed.

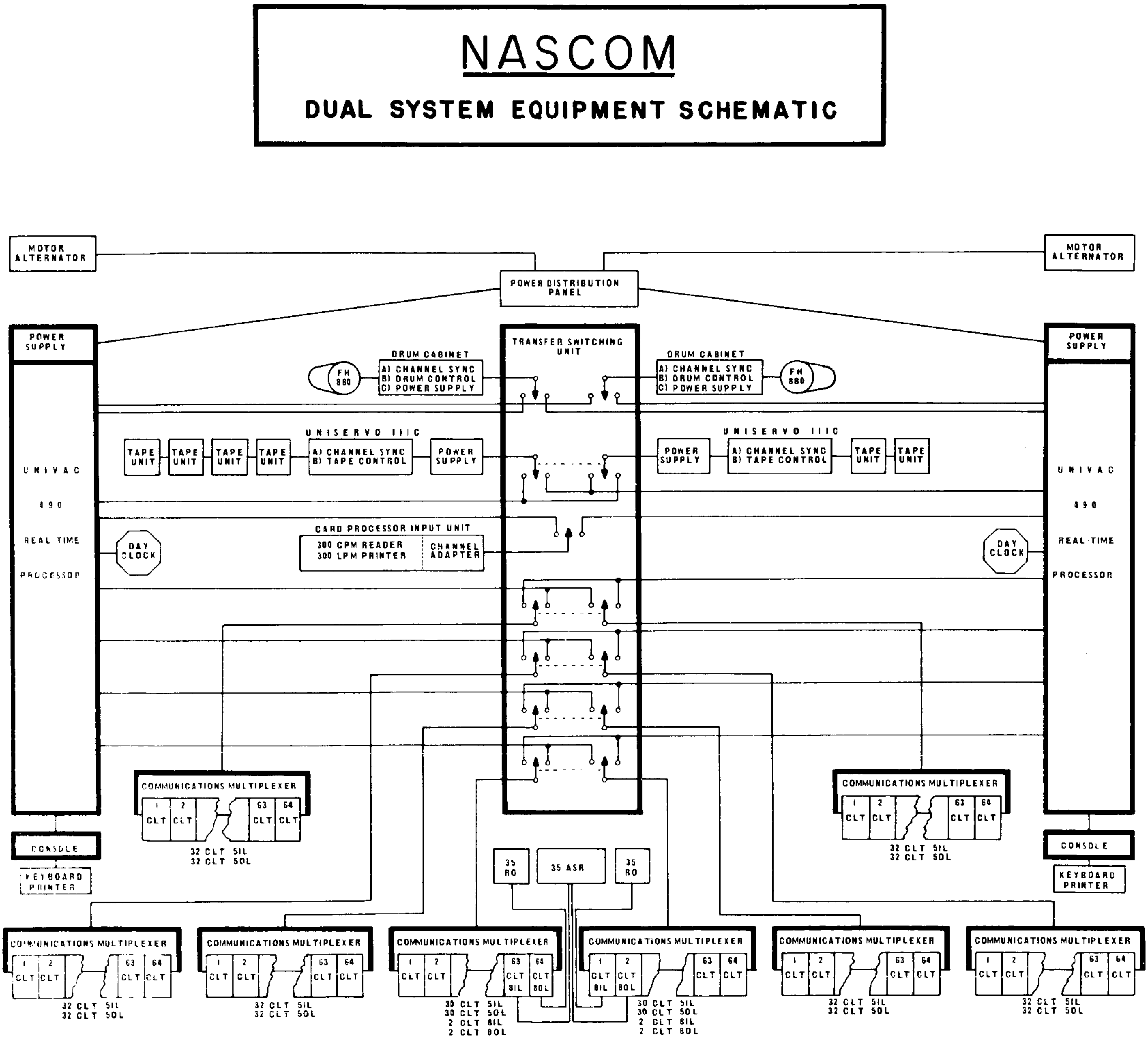

Figure 1. Equipment Arrangement

NASCOM CLT/CIRCUIT MULTIPLEXER ASSIGNMENTS

MULTIPLEXER 1 & 5

(A)	(B)	(C)	(D)		Circuit	Station	Remarks	
00200	0054	00	1	5OL	100 WPMSX →	GSTS	TERMINAL SECTION	(R) CLT's 3-5
00201	0054	01	2	5IL	← 100 WPMSX	GSTS	TERMINAL SECTION	(R) CLT's 4-6
00202	0052	02	3	5OL	60 WPMSX →	GSTS	TERMINAL SECTION	(R) CLT's 1-5
00203	0052	03	4	5IL	← 60 WPMSX	GSTS	TERMINAL SECTION	(R) CLT's 2-6
00204	4042	04	5	5OL	→	SPARE	TERMINAL SECTION	(R) CLT's 1-3
00205	4042	05	6	5IL	←	SPARE	TERMINAL SECTION	(R) CLT's 2-4
00206	4041	06	7	5OL	100 WPMHDX	INTERCEPT/INPUT CP POSITIONS	IN ROTARY	
00207	4041	07	8	5IL				
00210	0051	10	9	5OL	100 WPMHDX	INTERCEPT/INPUT CP POSITIONS	IN ROTARY	
00211	0051	11	10	5IL				
00212	0046	12	11	5OL	100 WPMHDX	GSPA		
00213	0046	13	12	5IL				
00214	4030	14	13	5OL	100 WPMSX →	GSOC	(R) CLT 15	
00215	4030	15	14	5IL	← NS-138***	GCON		
00216	4024	16	15	5OL	100 WPMSX →	GSOC	(R) CLT 13	
00217	4024	17	16	5IL	← NS-307***	JMOJ		
00220	0045	20	17	5OL	NS-005##	GPUT	IN ROTARY	
00221	0045	21	18	5IL				
00222	0043	22	19	5OL	NS-006##	GPUT	IN ROTARY	
00223	0043	23	20	5IL				
00224	4022	24	21	5OL	NS-007##	GPUT	IN ROTARY	
00225	4022	25	22	5IL				
00226	4021	26	23	5OL	NS-750##	GLOG		
00227	4021	27	24	5IL				
00230	0034	30	25	5OL	NS-009##	GSOC	(R) WITH CLT 51 & 52 ON MUX2	
00231	0034	31	26	5IL				
00232	0032	32	27	5OL	NS-013#	GNET	(R) CLT's (29-30), (31-32), (61)	
00233	0032	33	28	5IL				
00234	4014	34	29	5OL	NS-015#	GNET	(R) CLT's (27-28), (31-32), (61)	
00235	4014	35	30	5IL				
00236	4012	36	31	5OL	NS-016#	GNET	(R) CLT's (27-28), (29-30), (61)	
00237	4012	37	32	5IL				
00240	0031	40	33	5OL	NS-025##	GOSI		
00241	0031	41	34	5IL				
00242	0026	42	35	5OL	NS-100#	GHNJ		
00243	0026	43	36	5IL				
00244	4011	44	37	5OL	NS-104#	GNTP (F)	GALA	
00245	4011	45	38	5IL				
00246	4006	46	39	5OL	NS-105#	GFLD		
00247	4006	47	40	5IL				
00250	0025	50	41	5OL	NS-108##	GQUI		
00251	0025	51	42	5IL				
00252	0023	52	43	5OL	NS-109##	GAGO		
00253	0023	53	44	5IL				
00254	4005	54	45	5OL	NS-111##	GAPU	GAQU, GVIL	
00255	4005	55	46	5IL				
00256	4003	56	47	5OL	NS-117#	GBPT		
00257	4003	57	48	5IL				
00260	0016	60	49	5OL	NS-118#	GYRS		
00261	0016	61	50	5IL				
00262	0015	62	51	5OL	NS-121#	GACQ	GWBC, GSWB (F)	
00263	0015	63	52	5IL				
00264	0070	64	53	5OL	NS-125**	GSPE		
00265	0070	65	54	5IL				
00266	0064	66	55	5OL	NS-126#	GBEN		
00267	0064	67	56	5IL				
00270	0013	70	57	8OL	SPARE	CPCC		
00271	0013	71	58	8IL	SPARE	CPCC		
00272	0007	72	59	8OL	100 WPMSX →	35RO	COMMUNICATIONS PROCESSOR CONSOLE CONTROL	
00273	0007	73	60	8IL	← 100 WPMSX	35ASR		
00274	0062	74	61	5OL	NS-014#s →	GNET	(R) CLT's (27-28), (29-30), (31-32)	
00275	0062	75	62	5IL	SPARE			
00276	0061	76	63	5OL	100 WPMSX →	28RO	FACILITIES CONTROL	
00277	0061	77	64	5IL	SPARE			

LEGEND

(R)	IN ROTARY
*	100 WPMHDX
**	100 WPMFDX
***	100 WPMSX
#	60 WPMHDX
##	60 WPMFDX
#s	60 WPMSX
(A)	ESI
(B)	OCTAL CLT NO.
(C)	PRIORITY
(D)	DECIMAL CLT NO.

MULTIPLEXER 2 & 6

00300	0054	00	1	5OL
00301	0054	01	2	5IL
00302	0052	02	3	5OL
00303	0052	03	4	5IL
00304	4042	04	5	5OL
00305	4042	05	6	5IL
00306	4041	06	7	5OL
00307	4041	07	8	5IL
00310	0051	10	9	5OL
00311	0051	11	10	5IL
00312	0046	12	11	5OL
00313	4030	13	12	5IL
00314	4030	14	13	5OL
00315	4030	15	14	5IL
00316	4024	16	15	5OL
00317	4024	17	16	5IL
00320	0045	20	17	5OL
00321	0045	21	18	5IL
00322	0043	22	19	5OL
00323	0043	23	20	5IL
00324	4022	24	21	5OL
00325	4022	25	22	5IL
00326	4021	26	23	5OL
00327	4021	27	24	5IL
00330	0034	30	25	5OL
00331	0034	31	26	5IL
00332	0032	32	27	5OL
00333	0032	33	28	5IL
00334	4014	34	29	5OL
00335	4014	35	30	5IL
00336	4012	36	31	5OL
00337	4012	37	32	5IL
00340	0031	40	33	5OL
00341	0031	41	34	5IL
00342	0026	42	35	5OL
00343	0026	43	36	5IL
00344	4011	44	37	5OL
00345	4011	45	38	5IL
00346	4006	46	39	5OL
00347	4006	47	40	5IL
00350	0025	50	41	5OL
00351	0025	51	42	5IL
00352	0023	52	43	5OL
00353	0023	53	44	5IL
00354	4005	54	45	5OL
00355	4005	55	46	5IL
00356	4003	56	47	5OL
00357	4003	57	48	5IL
00360	0016	60	49	5OL
00361	0016	61	50	5IL
00362	0015	62	51	5OL
00363	0015	63	52	5IL
00364	0070	64	53	5OL
00365	0070	65	54	5IL
00366	0064	66	55	5OL
00367	0064	67	56	5IL
00370	0013	70	57	5OL
00371	0013	71	58	5IL
00372	0007	72	59	5OL
00373	0007	73	60	5IL
00374	0062	74	61	5OL
00375	0062	75	62	5IL
00376	0061	76	63	5OL
00377	0061	77	64	5IL

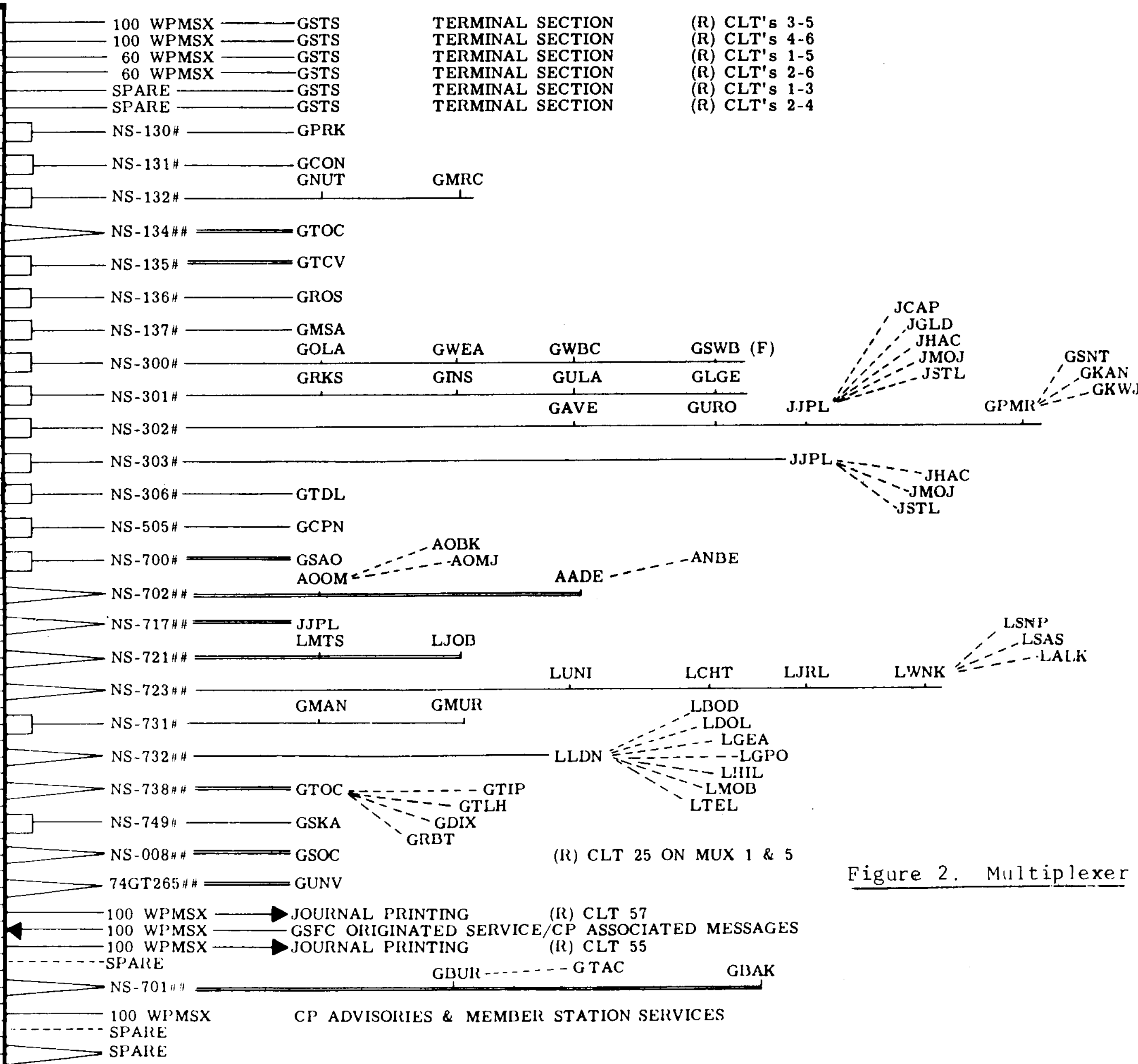

Figure 2. Multiplexer

Footnote (F) Receives only. We number to them, never receive from them.

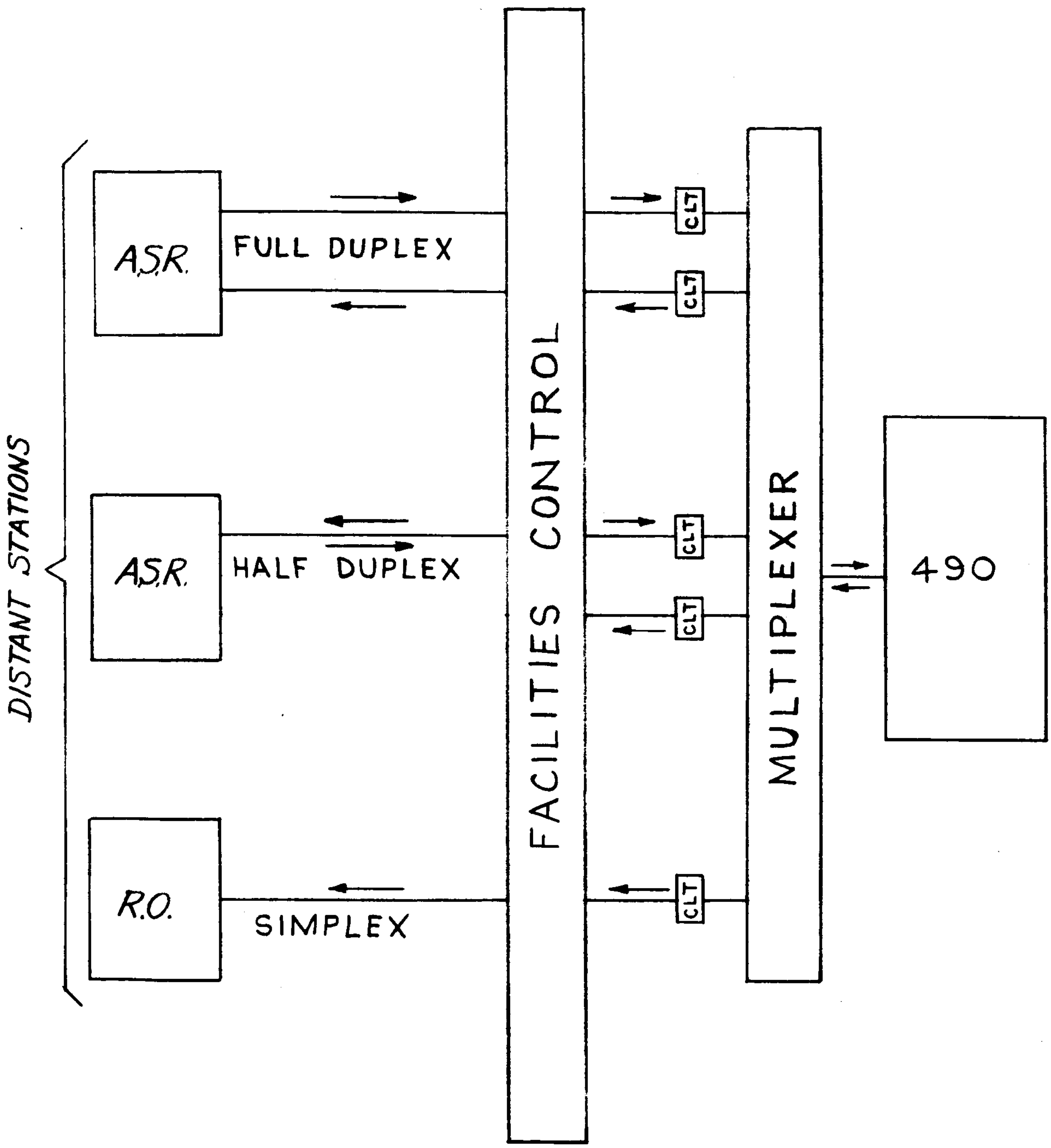

FIGURE 3. FACILITIES CONTROL INTERFACE