SUMMARY

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The Use of a UNIVAC 490

As a Real-Time Message Switching Unit

In order to attempt to explain the operation of the 490 as a real-time message switching unit, a brief description of the NASA Communications Division functions, history and scope is in order.

The NASA Communications Division, of the Goddard Space Flight Center, Greenbelt, Maryland has, as its primary purpose, the responsibility to engineer, operate, and maintain the operational communication systems within the NASA. Operational in this sense means, those communication facilities which are specifically utilized for support of Manned and Scientific Satellites and Spacecraft.

The NASCOM Network has grown from an original system of nine stations with approximately 6,000 circuit miles to its present state of 125 stations
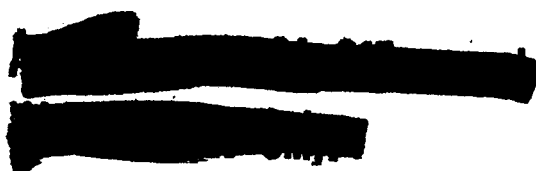
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consisting of over 450,000 circuit miles. Communication links consist of landline, submarine cable, HF radio and even CW. The majority of our stations are served by 60WPM full-duplex teletype circuits. However, we are now in the process of reviewing all circuitry with a look towards high speed transmission where it is economically feasible.

Second generation manned and unmanned spacecraft with the requirement for real-time information flow of command, control and data acquisition and tracking necessitated a communications switching system that could provide complete reliability, versatility and real-time message switching. Another primary factor was economy. Message switching to common user trunk channels was our answer to this.

Previously, three small unsophisticated communication networks were utilized for separate support of Project Mercury, Scientific Satellites and Deep Space Probes. In this system, separate circuits to similar locals were committed full time to a specific system, and were not available for use to support other projects. Our present integrated NASCOM Network makes use of all facilities on a message-shared basis resulting in fewer circuits to areas of remote site consolidation.

The central controlling   of the NASCOM Network is the Primary Switching Center located at the Goddard Space Flight Center. GSFC in turn is supported by smaller "sub-switching centers" located in London, England,

- 3 -

Honolulu, Hawaii, and Adelaide, Australia. All circuitry is hubbed on these sub-switching centers for a consolidated controlled operation.

In early 1963, the NASA Communications Division began preliminary studies aimed at the purchase of a switching system that could provide reliability, versitility and real-time message switching with a minimum amount of human intervention. The requirements for second generation spacecraft and the saturation of our existing systems were prime factors in the decision to automate. At the time of selection of the 490, there were approximately 15 active orbiting satellites being worked by ground stations throughout the world. The impact in the sophistication of Manned Space Flight was felt. The Project Mercury program, successfully supported on the 83B2 system was phasing into more complex missions of Lunar Exploration utilizing sophisticated methods of information flow between the remote site, the spacecraft occupants and the on-board computers.

Final selection and procurement of the system began in June of 1963. In December of 1963, the switching system was installed in its present interim location at the GSFC. Our time-table of on-line operation initially was set for March of 1964. This did not prove feasible, and our on-line operation on a full-time basis began in June of 1964.

The system configuration at Goddard consists of two Univac 490 Central processor units, FH880 drums, IIIC Mag tape units and a 1004 card processor and printer. The system is completely redundant in all respects. It is a basic concept that during all missions, manned or scientific, that a dual system of operation is maintained. One system being utilized as the

on-line or operational system, and the other as a dynamic standby. Both
units receive the same teletype or data signal simultaneously but inde-
pendently. The output of one CP is connected to the outgoing line and the
output of the standby system inhibited. If the active unit would fail, the
standby unit is immediately brought into service. It is not necessary that
a complete unit be switched if only a portion or a component of hardware
fails. By means of a master panel of transfer switches, it is possible to
randomly switch hardware from one system to the other by depressing a
button, e.g., utilizing the FH880 drum normally associated with the A CP
on the B unit, utilizing a Multiplexer B on the A unit, etc. I know all of
you gentlemen are aware of the standard 490 system, however, I might
mention for a moment the communications sub-system. This consists of
two principal elements: Communication Line terminals (CLT's), which
establish the connection of the communication line; and a communications
multiplexer, through which the CLT's deliver or receive data from the
central processor. There are three basic CLT's: low speed (up to
300BPS), medium speed (up to 1600BPS); and high speed (2000 to 4800 BPS).
Above 4800 BPS, a Communications Control Unit (CCU) is used. These
CLT's are adjustable to the speed of the communications line by a clock
change.

Each communications multiplexer has the capability of handling 32
input/output CLT's. At the present time, we have the capability of serving
128 full duplex teletype circuits per CP, and approximately 100 pair of
CLT's are assigned and operating on circuits.

In essence, these CLT's are our interface with the common carrier. The carrier and UNIVAC meet on a Government-owned terminal board.

II. BASIC OPERATIONS

As previously stated, some of the basic precepts were to develop a real-time message switching unit which would provide real-time, reliable communications for both data and teletype messages.

A. TELETYPE

Operations utilizing teletype messages and normally teletype speeds of 60 and 100 WPM make up the bulk of message flow within the NASCOM Network at this time. Operating procedures, prepared by the Communications Operations Branch are specifically orientated towards an operation via a completely automatic switching system. The concept followed was the system, and all operating procedures must be simple, easy to utilize and allow message preparation in a minimum of time. In some network locations indigenous personnel, engineers, technicians and even secretaries are pressed into service as operators.

Message checks are made on each message received by the CP for error detection and message validation prior to onward delivery. Some of the unique features of our operation via the CP are:

1. The ability of simultaneous transmission of multiple address messages to as many addressees as the addressed stations circuits are idle.

2. The use of collective message routine indicators, i.e., one indicator will send the message to a specific pre-assigned group of stations. We have carried this further and have a collective indicator that allows us to send a broadcast transmission, using one collective indicator to all stations served by the CP. These collectives, or special distribution instructions as we call them, are particularly useful during missions. As an example, during SYNCOM III, a collective indicator of "DSEO" was utilized on approximately 98 percent of all messages originated within the Communications Space Craft Control Center, for all SYNCOM ground stations. Another collective indicator DSDL, will route a message to all of the SPACE Tracking and Data Acquisition Network (STADAN) stations.

3. The capability to utilize various speeds, i.e., 60 or 100 WPM circuits at will. The CP will compensate for the speed variation. As an example, the Control Center for SYNCOM C was served by a 100 WPM circuit from the CP, while the majority of SYNCOM tracking stations sending messages in were transmitting at 60 WPM. This is most useful where speed conversion or a sequencing method of operation is necessary.

4. The use of MAG Tape as a permanent message storage medium in lieu of paper tape or copy. Each incoming message is packed on magnetic tape. This eliminates manual message handling, facilitates message retrieval, and reduces the amount of permanent storage space required. It further reduces our operating budget. In the past, all messages were microfilmed and retained indefinitely. Under our present system, all messages are stored on a magnetic tape which has a capability of storing approximately

2.8 million teletype characters. These tapes, as well as our entire operation, are centered around the 24-hour GMT day. At 2400Z daily, the tape is removed, labeled and stored. We are now planning to consolidate or pack 3 to 4 days information on one tape. These tapes also serve the purpose of enabling us to recall messages that may be desired by a remote location after the normal retransmit time a station is allocated has expired. Each message when it is placed on tape, is assigned a unique tape search identifier number. This consists of the julian date and a consecutive number. If a message is required for recall from tape, we simply locate the tape, mount it, send a short message from our service area which, in essence, tells the CP what message to recall and what station to send it to. An entire tape can be searched in approximately 3.5 minutes.

The use of an interrupt message precedence on critical or urgent messages. Messages meeting the criterion established for an URGENT message and carrying a precedence level of UU, will automatically interrupt the transmission of a message (except if it is another URGENT), send the URGENT message, and, restart the interrupted message.

The utilization of a method of providing protected or isolated networks within the CP. By utilizing a combination of precedence levels and routing indicators, specific stations can be grouped or isolated to provide mission support without chance of interruptions or delays by non-mission orientated messages.

An automated check-off of numerical continuity of messages. As in most diversified communications systems, particularly where HF radio and long haul circuits are utilized, it is important that message continuity be

maintained. We utilize a system of sequential message numbers (channel numbers), based on the 24-hour GMT radio day. If a message is received at the CP with an invalid message number, i.e., not the next sequential number, the message is forwarded and an advisory printed out in our service area with the message heading notifying an operator an error has been made. If, when the message is received, and the number is the same or lower than previously received messages, the CP automatically annotates the message with the term SUSDUPE (meaning this message is a suspected duplicate) prior to onward relay. NO message is delayed due to a numbering error.

Numerical continuity with all stations operating on a 24-hour GMT radio day is changed at 2400Z. At this time, stations recycle and restart the new radio day with message number 001. The unwieldly process of manually checking logs, verifying numerical continuity of send and receive ends, etc., has been automated. Stations now send a message to the CP which, when received, verifies and resets to zero the incoming station numbers, assigns a supplementary heading to the received message, sends it to the station as the last number of the old radio day, and immediately resets the output numbers to zero. This process takes approximately two seconds from receipt of the incoming message.

Our basic theme has been to attempt to let the CP take care of as much of the manual portions of message handling as possible and reduce the workload on remote site personnel. The change of number sequence is one portion of this philosophy. Another procedure utilized is the capability of a remote site to request retransmission of messages directly

from the CP. A remote site, upon receipt of a garbled message, simply
addresses a service to the CP and, requests a retransmit of the message
by the message number. The CP will recall the requested message,
attach a supplementary heading to the message using the same precedence
level the station used on his incoming service and retransmit the mes-
sage to the site. This takes approximately two to three seconds from
receipt of message. As we move further down the path of sophistication,
further aids to the handling of messages for the remote stations will be
utilized. Preliminary exploration has begun on the feasibility of an auto-
matic acknowledgment to a site for data transmissions, receipt of URGENT
messages by the CP, etc.

Other features of the system are:

Dual precedence messages - A station may utilize a higher precedence
for action addressees than for information addressees. The CP will queue
and transmit the message accordingly for each precedence level. If a
message is received with a garbled precedence, and one of the two charac-
ters are recognized as a valid precedence level, the CP will forward the
message in order of the recognizable precedence. The one precaution we
have taken in this area is the URGENT precedence level. If a message is
received with one character of the URGENT precedence level and one
other character, the CP will not interrupt a message in transmission to
deliver this message. Rather, it will place it in a position to be the next
message for transmission. If a message is received with a completely
garbled precedence level, it is routed to the service area with an advisory
stating the problem and a notation the message was held.

If messages are received with garbled routing indicators, naturally no delivery can be made. However, if a multiple address message is received and contains valid as well as invalid indicators, the CP will forward the message to the valid indicators and print the message in the service area with an advisory to the operator telling him what stations the message was transmitted to and what the problem is.

A unique end of message pattern, of "figs H ltrs" is used to end each message. The CP recognizes this end of message and proceeds to look for the next incoming message on the circuit. In our original installation, our system was equipped with an "external interrupt" feature which required that no station could pause more than 750 milliseconds. The CP would consider this interruption as an invalid end of message. This system did not prove feasible so we changed to our present method of specifically looking for an end of message pattern. A time extension of the CP allows a station to pause in transmission up to 16 seconds before it assumes an automatic end of message. A preset time is necessary to preclude against the possibility of a station having a hung tape, etc. Stations furthermore, have the capability of "stringing" messages providing at least 20 letters functions are included between each message.

Some interesting operational uses of the CP that are now being programmed are:

1. Direct input/output of data. - Manned Space Flight Stations of the NASCOM Network will be tracking the spacecraft with various types of radar. This radar data is reformatted in an analog to digital converter and forward in real-time to the GSFC Computer Facility where it is utilized

for orbit update, computation of retro-fire times, etc. This data is pre-faced with a start of message pattern "JJ". The data is received and forwarded to the GSFC 7094's in a real time mode. The use of unique directing codes on remote site real-time data outputs provides the capability of immediate transmission from the distant station with no delay in message heading preparation.

2. Digital Command System Data - Remote Manned Space Flight Stations are equipped with units which accept teletype messages, reformat them, and transmit them to an on-board computer in the Gemini Spacecraft. The digital command message which performs this function is an output from the GSFC Computing Complex, forwarded to the remote site via the CP. Certain unique procedures are utilized with the DCS system. Among them are:

1. Holding of a command within the CP until a remote site sends a message to the CP stating he has a valid command. At this time, the CP will forward the next command to the station, and await a validation message on this message. If a validation message is not received, we have the capability of locally validating it in order to allow the next command access to the circuit. If a site receives a command garbled, he has the capability of requesting an automatic retransmit of the entire command message, or, specific lines within the individual command, e.g., if line number 117 of the command was received garbled at the remote site, rather than request a re-transmit of the entire message which is not necessary, he would request a retransmit of line number 117. The CP will recall this specific line, build a message heading, and retransmit the command to the site.

These are a few of the unique operational considerations that are currently in use to support all phases of spaceflight. Briefly some of the other features of the system and operational concept are:

1. Alternate routing of messages simply by a console entry.

2. Circuit assurance and related analysis by-products.

3. Continual circuit viewing and print-outs in our service area and Facilities Control area when circuits are garbling, running open, receiving excessive input, etc.

4. For internal housekeeping, a print-out in our service area of each message heading which contains: the circuit the message was received on, the time the message was received, the time the message was transmitted, the channel and number the message was transmitted on, and, if a delay was experienced in transmission a number from 1 to 5 denoting the reason for the delay. It further contains a tape search identifier - A unique number assigned to each message which allows us to recall messages from tape.

FUTURE PLANS

Our future plans call for the expansion of the real-time switching concept to encompass our sub-switching centers at London, England and Adelaide or Canberra, Australia. Naturally, these units will not be of the magnitude of our primary switching unit at GSFC. The mode of transmission will be high speed. Probably starting with 1200 BPS and increasing the speed as our requirements and traffic loading grow.

Two important factors involved in the automation of sub-switching centers are: Cost reduction - as an example, utilizing an alternate voice/data channel to Australia in lieu of our current 60 WPM teletype channels would amount to a saving of approximately $500,000 per year. Diversification - All voice circuits to our sub-switching centers will be conditions for alternate voice/data. This gives us the capability of as many make good circuits as we have voice circuits appearing at the sub-switching centers.

High Speed Interfacing with the various Orbit determination computing areas of the GSFC. Present plans call for interfacing with the 7094's on an initial interface of __4800__ BPS with an expansion ultimately to 40.8KB transmission rates if necessary. These 94's are used primarily for real-time support of Manned Spaceflight Missions. Other computer interfaces are currently under study with those areas handling scientific satellites, Meteorological satellites, etc.

Problems

Very few problems have been experienced in our operation. Plant and Documentation seem to have been predominant. Our current interim location for example was not designed for the atmosphere required for computers. Consequently, power and air conditioning had to be modified to support the CP. Documentation - Documentation did not keep pace with programming and operational requirements. This is a problem in most areas. We are now in the process of reviewing and updating our documentation to reflect our current operational philosophy.