X-550-66-282

NASA TM X-55707

APOLLO SYSTEMS

N67 18991 | N67 19000
(ACCESSION NUMBER) | (THRU)
30 | 1
(PAGES) | (CODE)
NASA TM X 55707 | 07
(NASA CR OR TMX OR AD NUMBER) | (CATEGORY)

FACILITY FORM 602

JUNE 1966

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

X-550-66-282

APOLLO SYSTEMS

June 1966

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

TABLE OF CONTENTS

N67 18992

3 APOLLO NETWORK 6

6 Carl O. Roberts, Jr. 9

Mr. Roberts is Head of the Manned Flight Systems Engineering Section (MFOD). He is responsible for systems design, engineering, eqiupment specifications, and network qualification of the Manned Space Flight Network for Gemini, Apollo, and other manned programs. Formerly he headed up the Bendix Radio Engineering Support Group at Goddard.

Although the design of the Apollo network followed closely behind the Manned Space Flight Network (MSFN) modification for the Gemini program, many site modifications were necessary to provide Apollo support due to the greater scope of the Apollo program. The Apollo program requires instrumentation for support of the S-I, S-II, S IV-B/IU, Command Service Module (CSM) and Lunar Excursion Module (LEM) stages. Support must also be provided at both orbital and lunar distances. Increased data processing capability is required for processing and displaying significantly larger amounts of information. The ground network requires the capability of processing both Pulse Code Modulation (PCM) telemetry and command data for the CSM, LEM, and S IV-B/IU. In various stages of the Apollo program, both tone (on UHF) and digital [on Unified S-Band (USB) and UHF] command capabilities are required. Also at various stages both USB and VHF telemetry links are required.

To provide support for the Apollo program many significant changes were made to the network data systems:

1. The Unified S-Band System, built by Collins Radio of Dallas, Texas, combines the functions of acquisition, telemetry, command, voice and tracking on one RF link. The use of this system increases the data processing task, but reduces the number of required antenna mounts, transmitters, receivers, etc. This system also includes receiving and ranging equipment designed by the Jet Propulsion Laboratory (JPL) to supply range and range rate information.

2. Stored program PCM telemetry decommutators were specified for the Apollo installations to provide increased data handling capability and

more flexibility. This system is presently being delivered by Dynatronics of Orlando, Florida.

3. Computer-driven alpha numeric displays, built by Raytheon of Wayland, Massachusetts, were selected to provide a greater and more versatile capability to the on-site flight controllers. This system permits the display of printed information and charts of real time data on a cathode ray tube.

4. A general purpose data processing system utilizing 642 B modified computers, manufactured by Univac of St. Paul, Minnesota, is being supplied at each site to drive displays (where required), process telemetry, command and teletype data and to select and format data for transmission to the Manned Spacecraft Control Center (MCC-H) at Houston. This system processes and stores command data received from MCC-H for delayed transmission to the Spacecraft. The data processing system at each site is also connected to MCC-H and Goddard by high speed data circuits. This feature provides MCC-H with the capability of remotely changing data parameters being transmitted to the Control Center and the capability of remotely uplinking data to the spacecraft. Additionally, it provides GSFC with the capability of automated check-out of the network, in detail, in real time.

5. Other miscellaneous data systems are being added to the MSFN for Apollo support. These include TV monitors and scan converters, high speed printers, stored program PCM simulators, VHF predetection diversity combining receivers, and wide band recorders.

Maximum flexibility, through modularity of design, and high reliability, through selected redundancy and use of solid state circuitry, were considered as important factors in the design of the network equipment.

Redundant capability has been provided in the Data Processing System for reliability. Two identical computers have been provided for processing command and telemetry data. An emergency program is being prepared which will enable one computer to process the most essential data for both command and telemetry functions.

Expansion and reconfiguration capabilities have been designed into the major equipments. Most modifications which will be required to the MSFN from mission to mission can be made by software change rather than hardware modifications. Programmable units include the 642 B computers, PCM decommutators and simulators, the console computer interface adapter, and the display system. The flexibility which has been designed into the network systems should enable the MSFN to support a great variety of missions in the future.

N67 18993

UNIFIED S-BAND SYSTEM

W. Paul Varson

Mr. Varson, Head of the Manned Flight Support Office (MFSO), has been in the missile and space program since 1951. As Head of the Technical Staff of the MFSO, he is responsible for the Unified S-Band program and coordination of the efforts of the Jet Propulsion Laboratory in support of this program.

The Apollo program is significantly more complex than either the Mercury or Gemini programs and has consequently presented a corresponding increase in the complexity of the support required from the Manned Space Flight Network (MSFN). For the first time, the network is required to provide tracking and communications to lunar distance which requires incorporation of the unified S-band (USB) system into the network. The existing network is capable of supporting the earth-orbital phases of the mission and will be used for support of the initial Apollo flights while the USB systems are being checked out for the lunar missions.

The USB system utilizes a single carrier frequency in each direction to provide tracking as well as communications with the spacecraft. The interface with the network equipment is the same whether the data comes from the USB system or the Gemini equipment. The unified systems approach was adopted rather than extending the range of the existing network equipment primarily because it was considered to offer a superior technical solution with a minimum of new development. There have been several approaches to the unified systems concept, but perhaps the most thoroughly developed is that used by the Jet Propulsion Laboratory. This system has been employed successfully in support of lunar and planetary programs and, with minor modifications, was applicable to the Apollo tracking and communications requirements.

The design of the USB system is based on a coherent doppler and the pseudo-random range system which has been developed by JPL. A single carrier frequency is utilized in each direction for the transmission of all tracking and communications data between the spacecraft and ground. The voice and up-date data are modulated onto subcarriers and then combined with the ranging data. This composite information is used to phase-modulate the transmitted carrier frequency.

In the transponder the subcarriers are extracted from the RF carrier and detected to produce the voice and command information. The binary ranging signals, modulated directly onto the carrier, are detected by the wide-band detector and translated to a video signal.

The voice and telemetry data to be transmitted from the spacecraft are modulated onto subcarriers, combined with the video ranging signals, and used to phase-modulate the down-link carrier frequency. The received and transmitted carrier frequencies are coherently related which allows measurements of the carrier doppler frequency by the ground station for determination of the radial velocity of the spacecraft. The transponder transmitter can also be frequency-modulated for the transmission of television information or recorded data instead of ranging signals.

The basic USB system has the ability to provide tracking and communications data for two spacecraft simultaneously, provided they are within the beamwidth of the single antenna. The primary mode of tracking and communications is through the use of the PM mode of operation. In addition to the primary mode of communications, the USB system has the capability of receiving data on two other frequencies for the transmission of FM data from the spacecraft.

The tracking and communications with the spacecraft during the lunar missions will be provided by three primary deep-space facilities, employing 85-foot antennas, spaced at approximately equal intervals of longitude around the earth to provide the continuous coverage of the lunar missions. Three of the JPL Deep-Space Instrumentation Facilities (DSIF) located at approximately the same locations will be equipped to also support the lunar missions. Each of these facilities, both the primary and backup stations, will be equipped to track and provide communications with both the Lunar Excursion Module (LEM) and the Command Module simultaneously.

In addition to the 85-foot stations, a number of other stations employing 30-foot antennas are also required in the network. These systems are needed for launch coverage, in-flight checkout of the spacecraft, to fill gaps in the coverage of the three lunar stations, and to provide instrumentation coverage for testing the spacecraft in earth orbit.

Four land stations (Cape Kennedy, Grand Bahama, Antigua, and Bermuda) and one instrumentation ship are required to provide continuous USB coverage from launch through insertion. Seven land stations [Canary Islands (planned), Guaymas, Texas, Ascension Island, Carnarvon, Guam, and Hawaii] and two additional instrumentation ships are required to complete the USB system coverage requirements. In addition to these stations, the Apollo networks will also include two reentry ships and eight instrumented aircraft.

The USB system will be installed in the network during the next year. It will be checked out on the SA-202 through SA-206 and on SA-501 and SA-502 missions and will be used to provide primary mission support data beginning with SA-207 and SA-503.

N67 18994

APOLLO REMOTE SITE DATA PROCESSOR SYSTEM

William E. Willis, Jr.

Mr. Willis is computer system engineer in the Manned Flight Systems Engineering Section (MFOD). He is responsible for computer systems design, engineering and specifications. Formerly, he headed the CADFISS (Computation and Data Flow Integrated Subsystems Tests) effort at Goddard and was instrumental in introducing computers and their use into the manned space tracking network. Mr. Willis has been working at Goddard since November 1959.

The data processing system presently being installed on the Manned Space Flight Tracking Network is one of the most complex of its kind ever attempted within the manned space flight effort.

The data processing system selected for the Apollo remote sites is being manufactured and assembled by the UNIVAC Military System, Division of the Sperry Rand Corporation, located in St. Paul, Minnesota. The computer is identified as the UNIVAC 642 B Modified and has been designed to meet military specification. There will be two identical computing subsystems installed on each of the sites of the Apollo Tracking Network. These subsystems are identical in every respect with the exception of the mission requirements which will be assigned to each subsystem. One computer subsystem will be used for the processing of telemetry data and will also provide a command processing back-up capability. The second computer subsystem will be used for the processing of command data and will also provide a telemetry processing back-up capability. The purpose of the back-up capability is to provide continuous operation for the remote site computing requirements should either computer malfunction during a critical period of the mission.

DIGITAL COMMAND COMPUTER

The purpose of the Apollo Command Computer is to provide a means for communicating with and controlling the spacecraft equipment from the ground.

Commands and command loads will be transmitted from the mission control center (MCC-H) over high speed data lines (2.4kbs) to the command computer located on any one or all of the remote sites. The computer will perform error checking functions on the received data as the data is stored in the command computer memory. It will also be outputted from the computer to the digital magnetic tape recording unit for storage and possible future use. Retransmission from the mission control center (MCC-H) of all or any part of the message can be accomplished to update the command requirements stored in the computer memory should a change be required. Indications of a command load or a special command having been received by the computer on the remote sites will be provided to the computer operators and the flight controllers by way of a hard copy print-out.

Every effort is made to insure that the commands generated at the mission control center are transmitted correct to the remote site and from the remote site to the orbiting spacecraft.

Two command validation loops are available from the remote site computer to the orbiting spacecraft. One loop will sample the command throughout the monitor receiver for comparison in the computer. The other validation loop consists of message acceptance pulse data or any other special parameter from the spacecraft telemetry bit stream through the PCM system to the computer.

Diagnostic program routines may be utilized in real time by the computer to check the status of the command transmitting systems and the ground validation loops during times of no command transmissions. This feature will greatly increase the level of confidence in the peripheral systems in that the malfunctions will be detected very rapidly.

TELEMETRY COMPUTING SYSTEM

The telemetry computing system will initially interface with three (3) Pulse-Code-Modulation (PCM) decommutation ground stations. Data inputted to the computer will be derived from the PCM telemetry serial bit stream after being processed through the PCM system. All data transfers between the PCM ground stations and the computer will be parallel, word size will be determined by mission configuration, spacecraft telemetry systems or computer program. Each PCM data will be inputted to a separate input channel of the computer and all inputs may occur at different rates. All data inputted to the computer from the PCM stations will be buffered and formatted for various types of requests issued to the computer, i.e.,

a. Summary message generation and transmission to the mission control center, Houston, Texas.

b. Display request to the memory character generator memory for further display on the twelve (12) cathode ray tube displays located on the flight controller consoles.

c. Command history and command transmission to the spacecraft.

d. Command transmission and verification should a failure occur in the command computer.

Each remote site computing system will comprise the following listed equipments:

a. 2 each 642 B Modified Computers, each having 16 input and 16 output channels and a 2 micro second read/write cycle.

b. 2 each 1232 Input/Output Consoles which are used to communicate with the computer by a Keyboard, reader, or a paper tape punch.

c. 2 each 1259 Teletype Systems, to receive or transmit low speed teletype data (100/60 wpm).

d. 4 each 2010 Data Transmission Units, to receive or transmit high speed data (2.4kbs).

e. 2 each 1299 Distribution Switch Panel, to switch data from one computer to the other depending on mission requirements.

f. 2 each 1540 Digital Magnetic Tape Recorder/Reproducer Units, with bit packing densities of 200, 556 or 800 frames per inch. Each unit will be duplexed to both computers.

g. 1 each Model 1000 Interface Systems Adapter, which contains five multiplexed inputs to one computer channel. This will provide the flight controllers with the capability of communicating with the computer.

Contained in the same cabinet will be the time buffer which is used to input GMT into both the computers at a rate of once per second. This time data will be used for computer documentation. All messages received or transmitted by the computer must be time tagged for later reference.

h. 1 each Console Computer Interface Adapter (CCIA). This unit will provide the means of communications between the seven flight control consoles and the telemetry and command computers. The CCIA consists of two identical sections which are independent in all respects excluding their source of power. One section will service four consoles and the second section will service three consoles.

To complete the system the computers are also interfaced with the unified S-Band up-data buffer for transmission of commands and the PCM simulator for closed loop tests.

3 APOLLO DISPLAY SYSTEM 6

6 Keith D. Fellerman 96

Mr. Fellerman is the Technical Officer for the Apollo Display System. Prior to joining Goddard in April 1964, he worked on radar and data processing for the Westinghouse Electric Company. He was an Electronics Officer in the U.S. Air Force for four years after graduating from the U.S. Naval Academy in June 1952.

The Apollo Display System now being installed at the Flight Controller stations of the Manned Space Flight Tracking Network is a step forward in the science of displaying data.

The Display System for Apollo is being designed and fabricated by Raytheon Company at their Wayland and North Dighton, Massachusetts plants. The system has been designated Digital Display System AM102.

The Display System serves as an interface between flight controllers and the high speed data processing equipment such as the telemetry and command computers and the Pulse Code Modulated (PCM) Data Handling Equipment.

There are seven operator consoles (six on a land station) and four cabinets of electronics equipment called the Memory and Character Generator in each system. Each of the consoles has one or two cathode ray tube displays which can display alpha-numeric characters in two sizes and vectors. The Flight Controller may control the display format presented on his cathode ray tube (CRT) by use of the display request keyboard. The keyboard may request as many as 50 different display formats. In addition, each display request keyboard is provided with two overlays, doubling the number of switch functions provided. The identity for the overlay to the computer is provided by four coding switches. Overlays may be transferred from console to console.

The displays may be updated with new data twice a second. The system is capable of more than this but to prevent flashing the rate is held down.

The 642 B computer loads the memory in the Memory Character Generator (MCG) on 30 parallel lines. The words are transferred from the computer until a complete message is loaded.

The memory in each of the Memory Character Generators has a capacity of 4096 18 bit words. This is divided into two 4096 9 bit word halves which serve two Character and Vector Generators. The memory halves are divided once more by use of a command word from the computer. Each display has a section of memory assigned to it since one Character Vector Generator serves two displays and there are two Character Vector Generators (CVG) per MCG channel. The two displays served by each Character Vector Generator are in different consoles so that failure of a CVG would not cause a total console failure in any of the five consoles having two displays.

The Character Vector Generator decodes the digital words into the analog voltages to form letters, numerals and vectors. The position information for the electron beam is transferred through the CVG as a 9 bit word.

The displays are unique in that there is the ability to write on any part of the CRT with direct access to the particular X and Y coordinates that the character or vector are to appear at, rather than a sweeping of the entire tube. The CR tube viewing surface is a 10 inch by 10 inch square. On this square, there is room for 18 lines of large characters of approximately 0.28 inches high and 36 lines of small characters of 0.14 inches in height. In each line, there may be a maximum number of 36 large or 72 small characters. The size of vectors line segments may be varied between 0.02 inches and 0.5 inches.

The characters are drawn on the face of the CRT by the electrostatic deflection slates using the analog voltages from the CVG. The beam is positioned to the proper area in which a character will be written by the electromagnetic deflection amplifier and this character is written by electrostatic deflection. This amplifier also draws the vectors. The use of both electromagnetic and electrostatic deflection is a unique method developed for this system.

In addition to the cathode ray tube displays the consoles have event displays which are lamps driven by either the PCM stations and the computers via the CCIA.

The consoles have on them a Computer Address Matrix keyboard which is used to control the high speed printer associated with each display and to transmit summary messages to the Manned Spacecraft Center in Houston. On all but one of the consoles there are command keyboards which are used to send commands to the spacecrafts.

There is an intercom panel for each Flight Controller position. This intercom gives the Flight Controller complete communication with the other locations on a station and to the spacecraft and other stations.

The consoles in a system are:

The Command Communicator at which the Chief Flight Controller is stationed.

The Lunar Excursion Module (LEM)/SIVB System Console.

The Lunar Excursion Module (LEM) System Console.

Two Command Systems Monitor (CSM) Consoles.

The Aeromedical Console, which two doctors staff, monitors the biomedical data of the Astronauts by use of a cardioscope and one CRT display.

The Flight Dynamics Officer's Console is located on board the three tracking ships used for Apollo only. This console is used primarily to monitor and control orbital insertion.

There will also be a Maintenance and Operations (M&O) Console which is used to monitor the station systems. This console has no CRT displays. On non-flight control sites the M&O console will be the location of the Station Controller during missions.

PRECEDING PAGE BLANK NOT FILMED.

N67 18996

CCIA-DATA CALL-UP SYSTEM FOR APOLLO

Charles E. Trevathan

Mr. Trevathan is the System Design Group Leader of the Manned Flight Systems Engineering Section (MFOD). Formerly with the Westinghouse Electric Company, he was a senior engineer responsible for design and development of digital communications and computing equipment. He joined Goddard in May 1965.

Tracking sites at Guaymas, Mexico; Carnarvon, Australia; Ascension Island and Canary Island along with three Instrumentation Ships will form a unique group of facilities in the Manned Space Flight Network (MSFN).

Support of Apollo Missions by all MSFN sites must continue even when adverse conditions in communications with Mission Control Center at Houston (MCC-H) exist. Lack of ultra-reliable communications between MCC-H and these seven stations requires that they be equipped to accomodate teams of Apollo Flight Controllers. These teams will have the tasks of evaluating telemetry data received from three space vehicles, making relevant decisions, and initiating the transmission of appropriate commands to the spacecrafts. As described in previous Data Topics articles, nineteen MSFN sites are implemented with a Command (CMD) Computer and a Telemetry (TLM) Computer which operate in conjunction with three Pulse Code Modulation (PCM) Decommutation Stations and the Unified S-Band System. However, to provide the Flight Control capability the seven facilities mentioned here contain a large quantity of additional display type hardware. Each station is equipped with up to seven flight control consoles, seven high speed printers, four analog strip recorders (8 channels each), and six digital clocks for display of spacecraft time. Located on each console are spacecraft event indicators and command and data request keyboards containing push button indicator switches which afford Flight Controllers the means of initiating commands and requesting display of various data. These display subsystems and push button switches on the keyboards are interconnected with the TLM and CMD Computers by means of a Console Computer Interface Adapter (CCIA).

Contained in the CCIA subsystem are two Univac 1218 Computers and a Multiplexer (MUX), which is composed of two identical sections. Each MUX section contains a switch position scanner, a data distributor, hundreds of indicator and clock element drivers, and sixteen digital to analog converters. Also included in the MUX cabinet is the buffer and translating circuitry required by seven high speed printers. All logical functions of the CCIA are accomplished by the sequential operation of a program stored in the 1218 computers. Each of thc two computers is connected to one section of the MUX and this combination services one half of the consoles, recorders, and clocks. Communications between the CCIA and the CMD and TLM computers is established by a straight forward intercomputer mode of operation controlled and timed by the 1218 operational program. Other logical tasks of the 1218 are to accept continuous data from the MUX identifying the state of several hundred push button switches, detect a change in any switch state, and determine the legality of switch operation. If the actuation is legitimate a 30 bit code identifying console, keyboard, and switch type is transferred to either the CMD or TLM computer as appropriate. The 1218 program also operates to accept telemetry data and command status from the TLM and CMD computers, perform some processing and distribute the data through the MUX to the various display devices. The processing mentioned includes such operations as converting binary coded decimal time codes to straight decimal and addressing or labeling all through-put data to facilitate easy distribution by the Multiplexer.

Suggested by the use of two 1218 computers and two identical MUX sections is a redundant system organization. This dual configuration yields a Console Computer Interface Adapter that can tolerate any "worst case" failure and continue mission support with at least half the Flight Controllers display hardware and keyboards operational. In the event of such failure, the overall system functional capability would not be seriously impaired since keyboard overlays and switch selection would signal the computer program to redefine console identity and therefore continue with the high priority operations. By versatility gained with usage of computers in the CCIA, malfunction of either the CMD or TLM computer systems can also be tolerated. All four computers are programmed to automatically redefine the data flow configuration as appropriate in event of failure. Consequently, multiple failures in the overall system could be experienced and yet mission support would be maintained with only a degradation in capability.

APOLLO PCM DECOMMUTATION SYSTEM

William A. Dentel

Mr. Dentel is the Technical Officer for the Apollo PCM Decommutation System. Prior to joining Goddard in March 1964, he was project engineer on a dual channel telemetry receiver at Vitro Electronics.

The Pulse Code Modulation (PCM) system being installed at this time throughout the Manned Space Flight Network is one of the latest types to be developed in the PCM field which in itself has been growing and advancing due to the industries' response to the users' requirements.

The PCM decommutation system for the Apollo Tracking site was designed and is being built by Dynatronics, Inc., at Orlando, Florida. The system is designed to fulfill requirements and specifications which were written at Goddard. Three identical PCM decommutation systems are being installed at each new Apollo tracking site.

The PCM system is an important link in the information transfer chain from our astronauts in the spacecraft and the Flight control team on the ground. The system serves as the interface between the RF receiving system and the Display System as well as the Data Processing Systems.

The purpose of the PCM Decommutation system is to, first, reconstruct the incoming serial data, second, get into synchronization with the spacecraft's commutation equipment and third, to distribute selected data or measurements to the proper output for further processing or display.

The system employs a core memory of 4096 x 36 bit words which is capable of storing the decommutation and data routing information for ten different PCM formats, any one of which can be selected by a front panel control or at a remote location.

The incoming serial data is processed in one of the system's two signal conditioners whose function is to obtain bit synchronization, make a bit by bit decision on the incoming data in the presence of signal perturbations such as noise and jitter and then reconstruct the data in the form required by the decommutator. The decommutator receives this reconstructed data and begins a searching process to obtain synchronization with the incoming data. Synchronization is obtained by the decommutator's "looking" for a repetitive and fixed bit configuration or pattern. The correct pattern is stored in the PCM system's memory and is continually compared with the incoming data until a matching pattern is found in the incoming spacecraft data at which time the decommutator changes to another mode of operation in which it checks that this is the correct pattern and is repetitive. When the check made has been completed and the pattern has been confirmed then the system goes to the lock mode at which time the PCM decommutation system on the ground is in synchronization with the spacecraft commutator. At this time, the incoming data is further processed by converting the serial data or "bit stream" into parallel data or "words". A word in the Apollo PCM format contains eight bits and the serial data is converted to "words" eight bits long.

Data is further processed for various output devices. Two computer buffers in the PCM station provide parallel data for the DCS and telemetry 642 B computers. The two buffers are independent and any data in the PCM bit stream may be routed into either or both buffers for transfer to the computers. The data is further processed by the computers for display on the consoles and transmission to MCC-H. Each PCM system is wired for 127 digital to analog converters to provide analog information to the various systems on site. Each PCM station also contains 127 binary stores for the display of single bit information. This data is available in the form of relay closures to drive light displays on the display consoles. The PCM system is designed so that any bit in the PCM bit stream may be routed to any one of the 127 binary stores.

The memory of the PCM system, which controls the input format and the distribution and routing of data, may be loaded manually from the panel by a paper tape reader included in the system or from the 642 B computer. The memory has a "cycle stealing" capability which permits the memory program to be up-dated in real time. This feature will provide the capability of closed loop data selection routing by the 642 B computer.

The PCM system has the capability to perform (without the use of additional equipment) diagonistic self test routines for the purpose of maintaining the equipment. This self test capability has also proven to be of great value as a means of checking the interfaces between the PCM system and the Display consoles without the necessity of utilizing other equipments.

Each site is also receiving a stored program simulator which has the capability of completely exercising the PCM system.

APOLLO DIGITAL COMMAND SYSTEM

Carl B. Knox

Mr. Knox is with the Systems Section of the Manned Flight Engineering Branch. He received his BS in Electrical Engineering at the University of Denver in 1953 and joined NASA in 1963. Previous to his Goddard employment, Mr. Knox worked for seven years at the Naval Security Engineering Facility in digital data transmission systems.

The ground stations in the Manned Space Flight Network (MSFN) will have the capability of sending commands to orbiting spacecraft from computerized command systems.

The purpose of the Apollo Digital Command System (DCS) is to provide a means for communicating with and controlling the spacecraft's equipment from the ground. Some commands are identified before the launch, others are developed by the computing complex at the Mission Control Center in Houston (MCC-H) during the mission.

The commands identified before the launch are the type that are to be executed at selected intervals during the mission. One of these commands may be sent several times from one or more ground stations. For example, a command requesting a tape playback of spacecraft recorded data may be sent by all stations once or twice during a mission.

Other commands developed during the mission by the MCC computers would ordinarily be sent only once by one station. However, if the transmission were not successfully accomplished by the selected station, it would be retransmitted by another station later during the mission. An example would be the correct time for the spacecraft computer. The time of the spacecraft computer is telemetered to the ground stations. If this parameter does not agree with the indicated ground time a command will be sent to the spacecraft computer that will update the timing system with the correct time.

Commands are generated at the MCC in Houston then transmitted to the MSFN stations around the world for retransmission to the spacecraft. The ground communication circuits and the RF communication circuits will have periods of low signal and high noise conditions that may result in the misinterpretation of some data bits in the command words.

All transmissions, ground to ground and ground to spacecraft, employ coding techniques to maintain a probability of 1×10^{-9} that the spacecraft will not accept a wrong command.

The MCC computer transmission to the MSFN remote site computers will employ a data format that includes data bits and error detection bits. There will be a sufficient number of error detection bits in each frame of data to provide the protection noted above, 1×10^{-9}.

When the data is transmitted to the spacecraft via the RF link, a different technique is employed that has been used successfully in the Gemini program. First, each data bit is encoded into five sub-bits. If any five sub-bit pattern is not decoded properly by the spacecraft, the entire message is rejected. Secondly, the first three bits of each word are employed as a vehicle address and the second three bits (number 4, 5, and 6) are used as a system address (to identify a particular spacecraft system, i.e. timing, computer, event control, etc.) A different sub-bit code is used for the vehicle address bits than that used for the remaining bits to enhance the probability of rejecting a non-valid command word.

There will be two general operational modes of the command system depending on the site configuration.

Mode 1: Used at sites with flight controllers. The command is generated at Houston, transmitted to the site via high speed data modems where it is received, validated, and stored by the command data processor (Univac 642B). At the selected time, a flight controller at the remote site selects the command for transmission and the command is sent to the spacecraft.

Mode 2: Used at sites without flight controllers or consoles. The command is generated at Houston, transmitted to the site, validated and stored by the command data processor as described in Mode 1. At the selected time, a flight controller at Houston sends an execute command to the remote site and the command is then sent to the spacecraft.

The commands will be sent to the spacecraft via one of two links, the Unified S-Band (USB) equipment at 2106.4 or 2108.8 MC, or the UHF equipment at 408 to 450 MC. The UHF equipment will be used for the prime link in the early phases of the program during the evaluation of the USB equipment. The USB equipment will be the only mode of transmission during the lunar phases of the program.

The command information to and from the command data processor is composed of a series of ONES and ZEROES at D. C. voltage levels. This information is transformed by the up data buffer to an audio PSK signal that modulates the RF carrier for transmission to the spacecraft. The PSK signal is composed of a 1 KC sync signal and a 2 KC data signal that are added linearly and referred to as a 3 KC composite signal. Sub data bits (the result of sub-bit encoding, 5 for 1) are transmitted to the spacecraft at a 1 KBS rate. A ONE permits the 2 KC signal to cross the zero axis in the positive direction in phase with the 1 KC sync signal. A ZERO causes the 2 KC signal to be shifted 180° so that it crosses the zero axis in the negative direction as the 1 KC sync signal goes positive. In the spacecraft, the composite signal is separated into its two component signals. The 1 KC signal is then used to control a phase lock demodulator circuit that extracts the binary data from the 2 KC data signal.

A constant check on the effectiveness of the ground equipment is maintained by sampling the RF signal with verification receivers located near the transmitters. The output of the verification receivers is returned to the command data processor via the up data buffer. Valid command reception by the spacecraft is verified by the telemetry downlink which is also returned to the command data processor via the PCM decommutator equipment. In the event of ground equipment failure or spacecraft rejection of a valid command, the status information is presented to the local operators on a high speed printer. A command summary message is also transmitted to the MCC in Houston. This message itemizes the time of each command transmission, describes the command, and indicates the spacecraft response to the command.

One goal of the design and implementation of the Apollo Digital Command System was to provide for all known requirements of the Apollo program, plus the flexibility to satisfy any future requirements. Utilizing a general purpose computer as the main component in the command system will provide this flexibility with all the reliability obtainable by other special purpose devices of comparable complexity. The present system should prove adequate for the Apollo program and many future programs that require MSFN support.

PRECEDING PAGE BLANK NOT FILMED.

N67 18999

3 APOLLO REMOTE SITE COMPUTER PROGRAMMING 6

Paul J. Pashby 7

Mr. Pashby is the Head of the Network Computer Section of the Data Operations Branch. Mr. Pashby received his BS in Mathematics at Boston College in 1955 and joined NASA in 1960. He was responsible for the implementation of the Coordinate Conversion Computer System at Goddard, used for Gemini mission simulation. Mr. Pashby was employed at the Naval Ordnance Laboratory as a Programmer for five years prior to his joining NASA.

Much has been written about the hardware to be used for Apollo mission support on the Manned Space Flight Network (MSFN). This article concerns itself with the software necessary to integrate hardware subsystems into a unique tool for mission control.

The primary functions of computers on the MSFN in the past has been to display data for flight control purposes at the remote site, and transmit data to a central point, Mission Control Center in Houston. These functions have been perpetuated for Project Apollo, and an additional basic function has also been assigned to the digital computer on the Network. This added function is the control of the Digital Command Process. In Project Gemini, digital commanding was carried out by a "black box;" this function will now be implemented by a computer.

To accomplish these two basic tasks each site has been equipped with two UNIVAC M 642-B computers. Depending upon the type of peripheral equipment associated with the computers at the sites, a number of different computer programs will be required. Two basic types of remote sites will be configured for Apollo mission support: one will possess full local control capability (flight control consoles, display system, etc.) and the other will be used in a slaved or "remoted" fashion from Mission Control Center in Houston. Although many programs will be written, a description of the highest level program for both "Telemetry/Display" and "Command" will provide the complete picture.

TELEMETRY/DISPLAY

In general, the Telemetry/Display program will extract certain sets of parameters from raw telemetry input, perform some processing upon them, and present the group of parameters to a Flight Controller. The input to the program consists of up to three separate "vehicle-oriented" telemetry streams; a total of 174.4 kilobits per second. It is the selection of parameters from these input streams in real-time and the presentation of them in a suitable format that occupies the Telemetry/Display program. On an Apollo Flight Control Site there are a number of consoles having manual entry devices which may be used to signal the computer by means of an interrupt. Typically, the Telemetry/Display program will respond to the depression of pushbutton in the following way:

1. The interrupt status word will be analyzed to determine the meaning of the request.

2. The proper parameters associated with the request will be selected from the input streams.

3. The raw telemetry "bit count" will be converted to meaningful engineering units.

4. The present value of the parameters will be compared with preset limits.

5. The names of the parameter requested together with their present values, plus a visual indication of "out of limits" conditions will be displayed on a Cathode Ray Tube.

In addition to performing the monitoring function of telemetry parameters explained above, the next most basic function of the Telemetry/Display program, is the transmission of data on 2.4 Kilobits/Second (KBS) data lines to Houston. As stated above this input to the program may range up to 174.4 KBS. Since there are only 2.4 KBS available on the output side of the program it is obvious that some judicious editing must be done by the computer before data transmission may take place. One of the ground rules for data selection is that not all data are required for flight control simultaneously; that is, data requirements are dependent upon the phase of the mission. Therefore, the Telemetry/Display program will contain eight different formats which are selectable in real-time. Thus, as the mission phase changes and data requirements are modified, the telemetry program will be able to meet these changes in a flexible manner.

The Telemetry/Display program will also possess the same "Low Speed Summary" capability that exists in the Gemini telemetry programs. It will be possible to load last-minute engineering unit changes, calibration curve changes, and limits, into the program from the high speed input (2.4KBS) data lines. This feature will ease the logistical problem normally associated with last minute changes to an operational program.

Other methods of presenting data to flight control personnel will be implemented by the Telemetry/Display program. Four chart recorders each displaying 8 channels of analog information will be driven by the program. Each recorder will possess a six-position switch called "format control switch." When the position of the switch changes, the program will respond by selection of a different set of parameters to be transmitted to that particular recorder. Six digital clocks will be driven by the Telemetry/Display program. The six time words will be extracted from downlinked Telemetry data and transmitted to the clocks via the Console/Computer Interface Adapter.

COMMAND PROGRAM

The Command Program will be able to operate in two basic modes. When a command or load is selected at the remote site for uplinking, the site is operating in Mode 1. If the command process had been initiated from Houston, the site is said to be operating in Mode 2. Whether a site is operating in Mode 1 or Mode 2, the internal logic of the program remains identical for all classes. Prior to a mission, the Command Program will be assembled to contain the necessary Real Time Commands (RTC) and space will be provided in the program for Vehicle Computer Loads. This means that specific "loads" of computer data will be accepted by the Command Program in real time. Once a request for the uplink of a Real Time Command or Load has been initiated, the Command Program will react in the following way:

1. The Command data is formatted into the proper sub-bit encoding per the vehicle being commanded.

2. A data path through the requested uplink system is established by the Command Program.

3. The Command data is then transmitted to the Updata Buffer following the ground rules required by the hardware.

4. During the period of transmission of data through the uplink system, the verification receivers decode the computer output and transmit the information back to the Command Program. The program can compare

what it transmitted to what it received; and in the event of an error, can establish a new data path by switching alternate modules of equipment on line. This procedure is known as ground-loop verification.

5. When the program senses that the last piece of data has been transmitted, i.e., a complete command has been sent, it will go into a spacecraft validation loop. This simply means that the Command Program will attempt to verify that the spacecraft has accepted or rejected the transmitted command. The program does this by referring to the downlinked telemetry data which contains the acceptance or rejection information.

6. Finally, the Command Program performs the necessary bookkeeping function to inform flight control personnel about the status of the commanded vehicle.

The above steps constitute the essentials of the Command Program from the standpoint of internal data flow. If the site had been operating in "Mode 1," the request to uplink a command would have come from a local Flight Control Console (The Command Keyboard). Thus, it's evident that the Command Program will require the same type of keyboard interrupt processing as the Telemetry/ Display program. If the site had been operating in "Mode 2," it would mean that the request to uplink the "Load" or RTC had come directly from Houston via high speed data lines.

During the actual commanding process, the Command Program will record the highlights and milestones of the procedure; and the Flight Controller will be able to request a complete history of the commanding activity to be printed at his console. This history would contain information such as the name of each RTC transmitted, the number of uplink attempts, and a report if errors had been encountered. The program will also keep Maintenance and Operation (M&O) personnel informed of the status of the commanding process by means of printouts on high speed printers and illuminated indicators. For example, if in step 4 of the command uplink procedure, the program had detected a malfunction in ground equipment, it would inform site M&O personnel for corrective action.

It is impossible in the space allowed to explain every facet of all remote site programs. But I believe enough has been said to show that when flexible Software is merged with powerful Hardware, the result is a new level of sophisticated mission support on the MSFN.

N67 19000

MANNED SPACE FLIGHT NETWORK TESTING FOR APOLLO

Carl O. Roberts, Jr.

Mr. Roberts is Head of the Manned Flight Systems Engineering Section (MFOD). He is responsible for systems design, engineering, equipment specifications, and network qualification of the Manned Space Flight Network for Gemini, Apollo, and other manned programs. Formerly he headed up the Bendix Radio Engineering Support Group at Goddard.

The major data systems installed in the Manned Space Flight Network for Apollo support have been described in the previous articles. The test plan for the check-out and qualification of these sophisticated systems are described in this article.

The Apollo engineering test program is divided into five major categories:

- Factory Unit Test
- On-Site Unit Test
- Special Test
- Systems Integration Test
- Dynamic Integration Test

The purpose of this group of tests is to satisfactorily demonstrate that the Apollo systems have been properly designed and interfaced to support the Apollo missions. The tests are designed to progress from the lowest building block to the demonstration of the over-all site performance.

Factory Unit Tests—Upon completion of the manufacturing process on each system, acceptance tests are performed at the manufacturer's plant prior to shipment of the units to the remote sites. The factory unit tests are designed to demonstrate each system's capability of meeting the requirements of the engineering specification. These tests are prepared by the manufacturer and submitted to NASA for approval. Each equipment which is shipped from the manufacturer's plant must pass the test satisfactorily.

On Site Unit Tests—After installation of the various systems on site, unit tests are performed to insure that the equipment has been correctly installed and aligned. In most instances these tests are abbreviated versions of the factory unit tests. The purpose of these tests is to demonstrate the equipment's ability to perform to specification after shipment to the remote site.

Systems Integration Tests—When on-site unit tests have been completed on the various systems, integration tests are necessary to insure that they have been properly interfaced. The site integration tests are designed to check each of the interfaces between the various systems. The systems integration tests are divided into the following categories:

- Computer Display System
- PCM System
- Command System
- Telemetry RF
- Recorders
- Timing
- Voice
- Acquisition
- Site Intercommunications
- Up-Link Tests
- Down-Link Tests

The system integration tests have been designed to demonstrate the equipment's capability to meet engineering specifications rather than mission requirements. The various systems have been designed to exceed mission requirements, therefore, it is desirable to determine the overall capability of the site not only to support present missions but also to support requirements levied by future missions. Tests which are performed as part of the unit test are not repeated during this phase. The objectives of these tests are to demonstrate the capability of the various systems operating together. The equipment is tested under actual interface condition with artificial interface connections held to an absolute minimum. To insure that a minimum amount of time is required to perform the site integration tests, procedures have been designed to make maximum utilization of the on-site computers as test tools for checking the various systems. The majority of the interface tests have been automated to permit a larger number of tests to be performed with a minimum amount of effort by on-site personnel. The computers are utilized in the test to act as a stimulus for the various systems as well as analyzing the test results in real time.

Dynamic Site Integration Tests—The dynamic site integration tests will utilize an instrumented aircraft to simulate the Apollo spacecraft. The object of this test is to insure that dynamic incompatibilities do not exist between the various systems. The dynamic tests are divided into the following categories:

- Tracking Systems
- Voice Communications
- Down-Link Data
- Up-Link Data

During the performance of these tests the antennas track the instrumented aircraft to determine acquisition, tracking, and slaving capabilities. Up-link and down-link data tests insure that no RFI problems are encountered.

Special Tests—Several special tests have been prepared to further check the network. At present these fall into two categories:

- Site Acceptability Evaluation Program
- Site Operational Program Test

Site Acceptability Evaluation Program—The purpose of the Site Acceptability Evaluation Program (SAEP) test is to exercise the data processing system to insure that it will operate satisfactorily with all interface equipments operating at their maximum required rate. The test will check the computer and peripheral equipment operating at the maximum input and output data transfer rates and check queing functions between the computer and peripheral equipments.

Site Operational Program Test—Since the operational programs for the 642 B computers will not be available during site evaluation tests, a procedure is being prepared to repeat certain tests of the various systems after the operational program is available. During this test the operational program will be loaded into the 642 B and simulated data will be provided by pre-recorded tapes. This test will not simulate an actual mission but rather will provide a means for checking the computer and peripheral equipments to determine their satisfactory performance when operating with the operational program.

By the performance of these tests, MFOD will establish a high level of confidence that the Manned Space Flight Network is capable of supporting the Apollo missions. The successful completion of these tests will conclude one phase of the Apollo design and implementation efforts which GSFC has expended over the past three years in the development of the Apollo network. It represents the efforts of the many personnel assigned to the Apollo program at GSFC to complete another vital link in the landing of a man on the moon and his safe return.