



APOLLO SUPPORT DEPARTMENT • GENERAL ELECTRIC COMPANY • DAYTONA BEACH, FLORIDA



# ACE-S/C

- AN ADVANCED, COMPUTER CONTROLLED CHECKOUT SYSTEM PRESENTLY USED FOR TESTING THE APOLLO SPACECRAFT AND LUNAR EXCURSION MODULE.
- A LARGE-SCALE DATA PROCESSING SYSTEM PROVIDING REAL-TIME ANALYSIS AND DISPLAY OF TEST PARAMETERS.
- A TRULY GENERAL-PURPOSE SYSTEM CAPABLE OF MEETING OTHER DIVERSE CHECKOUT REQUIREMENTS.

THE ACE-S/C GROUND STATIONS WERE ORIGINALLY PRODUCED FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/MANNED SPACECRAFT CENTER BY THE GENERAL ELECTRIC COMPANY

## INTRODUCTION

With the development of each new manned spacecraft program came a growing awareness of the ever-increasing complexity of tasks relating to the integrated acceptance testing and preflight checkout of complex spacecraft systems and subsystems.

Large numbers of both separate and interacting measurements and diagnostic tests must be performed on each spacecraft system before it may be accepted for mating with other systems into a completed spacecraft. Numerous additional measurements and tests must then be performed upon the assembled spacecraft to assure the integrity of the system and verify a capability to perform the intended mission. The problems relating to the checkout of a spacecraft intended for a manned flight mission are further compounded by the necessity to achieve maximum system reliability and thereby minimize the risk to human life.

The magnitude of later-generation spacecraft checkout requirements precludes utilization of conventional testing methods. For example, testing of the Apollo Spacecraft by manual operation of individual test equipments and devices would be time-consuming, costly, and would not provide the capability of interrelating various test results. Manual analysis of the many thousands of individual test results and measurements would not only be time-consuming, but could also reduce the reliability of the test effort as a result of possible human error.

The Acceptance Checkout Equipment-Spacecraft (ACE-S/C) system was developed to minimize these problems in the checkout of the complex spacecraft systems.

Although first developed for Apollo Spacecraft testing, the ACE-S/C equipment, as a result of its inherent flexibility, is applicable to a wide range of ground and in-flight aerospace testing. No other checkout system available today offers as great a degree of capability and versatility as the ACE-S/C equipment.

In the discussion that follows, the equipment is described primarily as it is presently used for testing of the Apollo Spacecraft.



Figure 1. ACE-S/C Simplified Data Flow Diagram

## EQUIPMENT DESCRIPTION

The ACE-S/C equipment may be thought of as two functional systems: Command and Display (see Figure 1).

The Command System consists basically of test consoles, a Command Computer, and transmitting equipment. With the Command System, test operators may conduct a wide variety of tests from controls on their consoles. The test commands are received and interpreted by a computer, which, in turn, sends appropriate instructions to the equipment under test. The Command System thus initiates testing.

Test results are monitored by the Display System. The Display System consists of data acquisition and recording equipment, another computer, and display devices located on the test consoles. Signal flow through the Display System begins with the transmission of test data to the data acquisition and recording equipment. A part of the data then is routed to the Display Computer, where it is processed for presentation on alphanumeric cathode ray tube (CRT) displays. The second part of the data is sent directly to the system consoles for presentation on other recording and display devices.

In a typical ACE-S/C installation, the majority of equipment is located in two rooms, a Control Room and a Computer Room. (See Figures 2 and 3.) The Control Room contains the various consoles from which the test engineers initiate spacecraft testing and monitor the test results. The associated computers, data acquisition equipment, and recording equipment are located in the Computer Room.

#### COMMAND EQUIPMENT DESCRIPTION (See Figure 4, Page 21)

The testing of each functional spacecraft system is controlled from Selection-To-Activate-Random-Testing (START) modules located on an associated ACE-S/C system control console. The following functional systems are tested:

- Environmental Control System
- Fuel Cell and Cryogenics System
- Power and Sequential System
- Guidance and Navigation System
- Stabilization and Control System
- Service Propulsion and Reaction Control System
- Instrumentation System
- Communications System

The START modules are plug-in units and are located in varying numbers on the system control consoles. There are three distinct types of START modules: R START modules providing for manual control of discrete events; C START modules providing for manual



Figure 2. Typical ACE-S/C Control Room



Figure 3. Typical ACE-S/C Computer Room



selection of computer subroutines and the parameters required by the subroutines; and a single K START module (not a plug-in unit) providing for manual and automatic insertion of information into the spacecraft Apollo Guidance Computer (AGC).

Each system control console operates simultaneously with, and independently of, the other system consoles. Each has a variety of test command capabilities necessary for complete checkout of a particular spacecraft system. In order that the Command Computer may systematically process each of the many parallel inputs from these consoles, a unit called the Communications Unit Executor (CUE), operating essentially as a commutator. interrogates each START module on all of the system control consoles in sequence. These interrogations occur at a high scanning rate. Therefore, to the individual console operators, there is no perceptible delay in their individual test procedures. When an interrogation determines that a command input exists at a particular START module. the scanning process ceases momentarily while the CUE transfers the digital command to the Command Computer.

The computer interprets and acts upon the command. A specific command may instruct the computer to modify memory or require some action to occur in the spacecraft. In the latter case, the computer formulates a digital command message for transmission to the spacecraft. The digital command message, which is generated by the computer in a parallel format, is converted into a serial format by a Data Transmission and Verification Converter (DTVC) and transmitted to the spacecraft over a hardline link.

At the spacecraft location, each message is received and stored in registers in a Receiver-Decoder Unit. The messages are then decoded and applied to analog and relay command modules where the proper stimulus is generated and transmitted to the spacecraft.

Verification of the command message is achieved by redundant transmission of the command words from the DTVC to the Receiver-Decoder. A bit-by-bit comparison is made of the redundant words. In addition, checks are made of each message to determine whether it contains a valid address. A verification reply message, containing the results of the foregoing checks, is transmitted from the Receiver-Decoder back to the DTVC. The delivery of a command message to the Command Computer and the verification of proper transmission from the computer to the spacecraft are indicated to the control console operator by appropriate lamps on the START modules.



#### **R START Module Functions**

The R START (relay selection START) module contains four pushbutton function switches, an execute (XEQ) pushbutton, and appropriate lights to indicate the status of the switches and of the module. The function switches provide the means to select the specific discrete events desired, and the XEQ switch initiates the sequence resulting in their occurrence. Each module controls the occurrence of four discrete events (e.g., individual relay action at the spacecraft) by providing a logical 1 or 0 from each function switch. The presence or absence of a 1 is established by the on or off condition of the function switch. The R START can also be used to call up certain computer subroutines.

#### **C START** Module Functions

The C START (computer communication START) module includes ten 12-position switches that select a specific command function. Each individual switch position provides a 4-bit digital word in binary-coded-decimal form for transmission to the computer. Thus, the output of the C START is a 40-bit command message and an 8-bit address that instructs the computer to perform specific operations (and also may provide parameters for these operations) and instructs the computer in the disposition of the results. The C START panel also includes status indication of the switches, an XEQ pushbutton to initiate the transmission, and appropriate lights to indicate the module status.

#### K START Module Functions

The K START (keyboard START) module may be operated either manually (using a keyboard) or automatically (using a perforated tape reader). The keyboard contains 18 pushbutton switches. Depressing any one of these switches initiates the transmission of a binary word to the AGC. The module panel also includes tape reader control switches. These switches provide for automatic sequencing of binary words from the tape or manual sequencing including both forward and reverse steps. A visual tape character readout display is provided. Appropriate display lights on the panel indicate the status of the module and of various events within the AGC.

#### **Communications Unit Executor Functions**

The primary function of CUE is to control the twoway communication path between the test operators and



the Command Computer. To accomplish this control function, CUE sequentially interrogates all START modules in a repetitive fashion.

The depression of an XEQ pushbutton (R START or C START) or a K START keyboard pushbutton results in halting of CUE interrogation when it reaches that point in its scanning cycle. CUE accepts the command data and an address from the START module, compares this address with the scanner address, and transmits the data and the address to the computer. (The address assigned at this point is used for identification purposes between the START modules and the computer only.)

Data transmission to the computer is accomplished in one of two ways. If the data is from an R START, the data and the address will be transferred as a single 12-bit word in parallel format. If the data is from a C START or K START, the data and the address will be transferred as four consecutive 12-bit words in parallel format.

When instructed by the computer, the CUE transmits verification replies to appropriate lights on the START modules.

#### **Command Computer Functions**

The Command Computer receives the addressed data words from the CUE and performs the required processing under program control. Data from an R START or K START is encoded into a 24-bit message which includes the required address for processing at the spacecraft location. Usually, C START data instructs the computer to perform preprogrammed subroutines, the results of which may or may not be transferred out of the computer.

The output of the computer consists of 24-bit messages that are applied to a DTVC. Each 24-bit message is a separate command intended for equipment in the Digital Test Command System (DTCS) at the spacecraft test area. The computer selects one of three available DTVC's to transmit the message, depending on whether the message is intended for airborne, carry-on, or service equipment. Each 24-bit message is transmitted twice for verification and for increased reliability purposes.

When the Command Computer receives verification of proper message delivery from the DTCS via the DTVC, the CUE is instructed to indicate verification on the appropriate START module panel. Should the reply



indicate malfunction, the computer retransmits the message a predetermined number of times – each time waiting for verification of proper message delivery. Should the final reply still indicate failure, the computer branches into a malfunction isolation subroutine. In this case the computer will SEAL the START module from which the command has originated. This prohibits entering additional data in the START module until the SEAL is removed by the computer.

#### Data Transmission and Verification Converter Functions

The DTVC is a two-way communicator and a parallel-to-serial and serial-to-parallel converter. All computer input/output communications are in parallel format, but all transmissions over the hardlines to and from the Receiver-Decoder at the spacecraft test area are in serial format.

The Command Computer input to the DTVC is a 24-bit message. This message, during normal operation, is transmitted twice to the DTVC. The DTVC reformats these two messages and transmits them to the Receiver-Decoder in the DTCS at the spacecraft test area. The first transmission of the message is stored by the Receiver-

Decoder. The second transmission is compared with the first by the Receiver-Decoder. If the two transmitted messages compare, the Receiver-Decoder will execute the stored message.

The data interface between the Command Computer and DTVC prevents the transfer of more than one 12-bit parallel word at a time. This forces the computer to break each 24-bit message into two 12-bit words that are transferred successively. The DTVC can process only one 12-bit word at a time. Therefore, it reformats and transmits the first 12-bit word before it accepts the second 12-bit word. After the second 12-bit word is transmitted, the DTVC receives a reply from the Receiver-Decoder that verifies or indicates the status of the transmitted 24-bit message. If the message was properly received, the computer again transfers the same 24-bit message to the DTVC for retransmission. If the second message compares with the first message received by the Receiver-Decoder, the first message will be executed as a command. After the second message has been transmitted, the DTVC receives a second reply from the Receiver-Decoder. This reply verifies correct transmission of the message and is used by the computer to indicate verification on the START module that generated the command.



The Command Computer performs a redundance check by transmitting the same 24-bit message twice. The DTVC also performs a redundance check. This is accomplished by transmitting each 12-bit word twice. Each time that the DTVC receives a 12-bit parallel word from the computer, it generates a 24-bit serial word that is transmitted to the Receiver-Decoder. The first 12 bits of the serial 24-bit word are identical to the second 12 bits in the word. After 48 bits (one 24-bit message) have been transmitted to the Receiver-Decoder, the DTVC receives a reply from the Receiver-Decoder. This reply verifies redundant reception of the message during normal operation. If a malfunction has occurred and the message was not received again, it will be indicated in the reply.

## DIGITAL TEST COMMAND SYSTEM DESCRIPTION (See Figure 4.)

The signals generated by the ACE-S/C ground station Command Equipment are transmitted via hardlines to the spacecraft test site where they are processed and distributed by the DTCS. The DTCS is modular in construction; each of the modules may contain 16 relays or one digital-to-analog converter. Four modules, in various combinations of relay or analog, are mounted on a baseplate along with a fifth module designated the baseplate logic module. This packaging of five baseplatemounted modules is collectively referred to as a baseplate.

Baseplates are connected together in groups of eight or less. As many as four groups of baseplates are coupled to a DTCS Receiver-Decoder.

The Receiver-Decoder receives the first 24-bit word from the DTVC and assembles the first 12 bits into a 24-position register. It then compares the remaining portion bit by bit to check redundance. The second 24-bit word of the command message is received, and the first 12 bits are assembled into the remaining spaces in the register. A bit-by-bit redundance check is then performed on the last 12 bits. If either redundance check fails, the register is cleared, and a reply, coded to indicate transmission error, is transmitted back over the hardline to the DTVC.

After redundance checking of the first 24-bit message is successful, the second 24-bit message is received and checked in the same way. If this redundance check is successful, the two 24-bit messages are compared. If the comparison is successful, the first 24-bit message is transferred to an execute buffer memory where decoding takes place.

Decoding is accomplished at several levels. At each level, a number of discrete bits are examined to de-



termine which of several alternate routes the remaining message bits are to follow. Decoding begins with the more significant address bits. In each case, the decoded bits are dropped, and only the remaining bits of the word are transmitted to the next lower level.

The Receiver-Decoder performs the first step of address decoding and accordingly selects one of several groups of modular assemblies known as baseplates, or the Guidance and Navigation (G and N) module. If the G and N module is selected, the remaining message bits are sent to this module which transfers the proper data into the spacecraft Apollo Guidance Computer. If one of the baseplate groups is selected, the remaining message bits are sent to all baseplates in this group for further decoding.

A given baseplate group may contain as many as eight baseplates. However, only one of these can accept the message as addressed. The selected baseplate decodes the message further and selects one of the modules installed on the baseplate. The selected module accepts the remaining bits for further decoding.

There are two types of modules mounted on the baseplates: a digital-to-analog (D/A) converter module and a relay module. Each baseplate can contain up to four modules with any combination of the two types, or all four of a single type.

If a D/A converter module is selected, it will decode the remaining bits and provide the indicated spacecraft stimulus as a positive or negative voltage level.

If a relay module is selected, it will decode the message further to select one of four subgroups of relavs controlled by the module. Four data bits will be transferred to a buffer memory of the subgroup which exercises control over four relays. A second message transmitted from the Command Computer and containing an execute command code provides four duplicate data bits which are compared with those from the first transmission. When the comparison is exact, the first four data bits are shifted from the buffer memory to an execute memory which causes the four relays to react to the data bits: a 1 causing latch and a 0 causing unlatch. When the comparison is not exact, the data bits are not shifted to the execute memory, a coded verification reply is sent to the DTVC to indicate the comparison failure. and the Receiver-Decoder is set to receive.

At each level of decoding, from the Receiver-Decoder to the relay subgroup, the validity of the address is determined. In every case, there are fewer valid addresses than the total which the number of bits would permit. If the decoded portion of the address is found invalid, decoding ceases, and a coded verification reply is sent to the DTVC to indicate the level of decoding at which the error was detected.



#### SIGNAL CONDITIONER AND COMMUTATOR EQUIPMENT DESCRIPTION (See Figure 4.)

Test data to be processed by the Data Recording and Display Equipment is obtained from sensors in the spacecraft (permanently installed), from the carry-on equipment (which is removed prior to flight), and from the Ground Service Equipment. Data obtained from the permanently installed spacecraft sensors is identical to that which is transmitted by the flight telemetry system and is called airborne (A/B) data.

Signal conditioners, designed to sample, timereference, and condition signals to a 0- to 5-volt level (analog signals) or a 0- or 6-volt logic level (digital signals), are connected to the sensor outputs. The conditioned signals are then pulse code modulated (PCM). At present, the PCM system operates at bit rates of 51.2 kilobits per second and 204.8 kilobits per second. The decommutator, however, allows bit rates of up to 1 megabit per second.

The flight telemetry system contains the commutation, encoding, and digital multiplexing equipment necessary to convert the A/B sensor outputs into a serial PCM output at 51.2 kilobits per second. This output is called A/B PCM. The carry-on equipment performs these same functions for the carry-on sensors. The resulting carry-on PCM serial output is also at 51.2 kilobits per second.

The outputs of the Ground Service Equipment sensors are applied to a unit known as the Service Equipment Adapter. This adapter performs the commutation, encoding, and digital multiplexing required to convert the outputs to a third serial output, the service equipment PCM, at a rate of 51.2 kilobits per second.

These three PCM outputs (A/B, carry-on, and service equipment) are fed to an interleaver that combines the three PCM inputs into a single, interleaved (I/L), serial PCM output and transmits this to the ground station over a hardline at a rate of 204.8 kilobits per second. The A/B PCM, in addition to being interleaved with other data, is also transmitted intact (at its original rate of 51.2 kilobits per second) to the ground station over another hardline.

The majority of data is converted to serial PCM format; however, certain data (e.g., the outputs of vibration sensors) which is required in raw form, is frequency modulated (FM) and transmitted to the ground station over a separate hardline.



#### DATA RECORDING AND DISPLAY EQUIPMENT DESCRIPTION (See Figure 4.)

The Recording and Display Equipment provides for receiving, recording, and displaying the spacecraft performance parameters and other data necessary for complete checkout of the spacecraft. This system is made up of the Data Acquisition and Decommutation Equipment, Alphanumeric Display Equipment, and Analog and Event Recording and Display Equipment.

The Digital Acquisition and Decommutation Equipment (DADE) synchronizes on the incoming serial PCM bit stream, decommutates the data, provides an address for each event and analog data word, and presents these words for parallel transmission. The FM data is recorded directly on wideband magnetic tape and, after discrimination, on an oscillographic recorder. The analog and event words, derived from the PCM data, follow three paths when they leave the DADE.

One path goes to the Display Computer where selected portions of the data are processed. This processing includes comparison of analog data with predetermined limits, and the conversion of this data into engineering units. A binary word representing the value of the data in engineering units is transferred into a memory in a Symbol Generator and Storage (SGS) Unit. The SGS uses these words to generate alphanumeric character display signals (analog) for application to control console CRT displays. These alphanumeric characters appear in page form on the console displays. The particular page of data to be displayed at any console is selectable by the console operator. When a parameter has been determined by the computer to be out of limits, the characters representing the parameter will blink.

The second data path transfers the digital data to the Decommutator Distribution/Event Storage and Distribution Unit (DD/ESDU). This unit accepts the data words and, in the case of event data, stores each bit (representing an event) in an appropriate location in storage registers. The outputs of the storage registers, connected to indicator lamps and event recorders on the control consoles, cause the event lamps and recorders to indicate when an event has taken place. The analog data words are fed via the decommutator distribution circuits of this unit to all of the control consoles in parallel. When a console recognizes its particular address in these data words, it transfers the data portion of the word to a D/A converter in the console. The output of the D/A converter drives meters or analog recorders located on the console.



The third path transfers digital and analog data to the Event Distribution, Recording, and Patching Unit, and then to roll-chart recorders in the Computer Room. The digital data is processed in a manner similar to the processing in the DD/ESDU.

#### Data Acquisition and Decommutation Equipment Functions

The DADE provides for acquiring, recording, synchronizing, decommutating, and distributing the data received from the spacecraft vicinity. The three data lines (A/B, I/L, and FM) are routed to this equipment through a terminal patch facility. The DADE equipment group is made up of the Video Distribution and Tape Transport Control Unit and the decommutators.

#### Video Distribution and Tape Transport Control Unit Functions

The three incoming data lines are initially terminated at the Video Distribution and Tape Transport Control Unit which provides patching and switching to route the data to the desired decommutator (PCM), discriminator (FM), and magnetic recorder-reproducer (PCM and FM). The data is routed as follows:

- All data is routed to wideband magnetic tape recorders.
- The FM data may be routed to discriminators and then to a roll-chart recorder.
- The A/B PCM data is routed to one of two decommutator units.
- The interleaved stream of A/B, carry-on, and service equipment data is routed to the other decommutator unit.

#### Decommutator Functions

The Decommutator Unit provides the processing necessary to convert the incoming eight-bit serial data words into parallel format and assigns addresses to them for distribution within the ground station. Bit synchronization is achieved at the decommutator input; each pulse is reshaped to assure good bit definition prior to further processing. The serial data bits are read into a shift register and as the data is shifted through the register, frame synchronization is established. This defines the location and identity of each word within the time frame. The data words are then presented at the decommutator output in parallel format. Simultaneously, in accordance



with decommutator programming, the appropriate address for each data word, and a read pulse, are presented at the decommutator output. The decommutator output is routed to the Alphanumeric Display System via the Decommutator / Computer Interface Unit and Display Computer, and to the Event and Analog Data Display System.

#### **FM** Equipment Functions

The FM equipment provides the discriminators necessary to demodulate the incoming FM data. Following decommutation the data is applied via a patchboard to an oscillograph recorder, and via the Video Distribution and Tape Transport Control Unit to magnetic tape recorders.

The ACE-S/C equipment can accept PAM or PDM telemetry data by the addition of the appropriate subcarrier discriminators, and PAM or PDM decommutators to the FM equipment group. The output of the PAM/PDM decommutator can be applied directly to analog recorders and other display devices, or by the use of analog-todigital converters and an interface unit, the output can be processed by the Display Computer.

#### **Alphanumeric Display Equipment Functions**

The Alphanumeric Display Equipment provides the primary means of monitoring test results in real time.

All data words from the decommutators (addresses are not included) are supplied to the Display Computer, where mathematical operations are performed on certain data. The results of these operations are displayed on CRT monitors by an SGS unit.

#### **Data Processing Functions**

Data from the decommutators is routed to the Display Computer through the computer I/O module. This data is stored in two locations in the memory. While a block of data is being stored in one location, the computer processes data in the other location. The primary operations that the computer must perform in processing the downlink data include the following:

- Assemble the data into proper word length and format.
- Compare any given word or words to determine whether the data falls within predetermined limits, and flag out-of-limit conditions.
- Compute the average of a block of words and retain this average for output display.
- Convert data into engineering units (e.g., degreesper-second rise), using both linear and quadratic functions, and curve techniques.
- Place data in proper format for alphanumeric CRT display.



Operating under program control, the computer provides a series of 12-bit coded words that includes parameter value and address and associated instructions. These 12-bit words are transmitted in parallel format to the DTVC.

#### Data Transmission Functions (These functions are included only at certain sites.)

The DTVC converts each 12-bit word to serial format and transmits it redundantly as a 24-bit serial message to a Digital Communication and Control Unit (DCCU). The DCCU assembles the first 12 bits into a register and then compares the second 12 bits with the first 12 bits to check redundance. If the redundance check is successful, the DCCU transmits the 12-bit word in parallel format to an SGS Unit. The DCCU has the capability of preventing transmission to the SGS if the redundance check fails.

#### Symbol Generation and Storage Functions

The SGS Unit receives the coded words from the DCCU. The 12-bit words are decoded, and the data is stripped out and stored in memory locations according to received instructions and addresses. The content of this memory is updated once per second, and the memory is

scanned at least 30 times per second to rewrite all alphanumeric displays.

The character repertoire of the SGS allows display of all alphanumeric characters together with a set of special symbols. Also incorporated is the capability to cause characters to blink on the CRT screen when so instructed by the computer. This blinking indicates an outof-tolerance condition.

Memory allocations in the SGS are sufficient to provide for display of 20 pages of data, a page consisting of 24 lines of 40 characters each plus two 32-character lines, one at the top and one at the bottom of the page. Upon demand, the SGS will provide the proper signals to cause the contents of any top half-page and any bottom half-page to appear on the screen of the requesting CRT. Any given half-page can be selected by as many as 20 CRT's simultaneously.

#### CRT Modules

The CRT's utilized for the Alphanumeric Display System are 10-inch, electrostatically-deflected devices. The modules include controls for selecting any top half-



page and any bottom half-page of the 20 pages of data stored in the SGS for simultaneous display. In addition, the CRT module includes controls for focusing, brightness, horizontal and vertical gain and centering, and an on/off switch.

Any given half-page display contains 12 lines of identified data in decimal numbers and engineering units. In addition, a single top (or bottom) line provides page identification.

#### Analog and Event Display Equipment Functions

All data words from the decommutator are applied to the decommutator distribution section of the DD/ESDU. This portion of the unit acts as a distribution amplifier, providing one 21-line output to the event storage and distribution section (for events) and one 21-line output to each console (for analog words).

#### **Event Data Display Functions**

Event data words are selected from intermixed analog and event data words received from the decommutator distribution circuits in the event storage and distribution section of the DD/ESDU. This selection (by address recognition) and the storage location of each event bit are predetermined by the selection and arrangement of plugin logic modules within the event storage and distribution circuits.

The ESDU will select and store 150 event words, each of which consists of eight discrete event functions (a total of 1200 events). The event words are gated into registers within the ESDU. The output of each bit position in a register represents the status of a specific event (whether it has or has not occurred).

The outputs of the storage registers are routed to a patch facility in the DD/ESDU. The patching at this point determines the distribution of each event function to the various consoles and permits routing any specific event function to multiple locations. The outputs of the ESDU are fed to event recorders and/or lamp drivers (in the consoles) which cause event lamps to light.

Event modules are located on the various system control consoles. The front panel of an event module contains 24 lamps arranged in three vertical rows of eight lamps each. Each lamp is equipped with a colored lens engraved to identify the event function. These lenses are



replaceable if it is necessary to change the display. A lamp test switch on the module tests the function of all lamps simultaneously.

Event recorders are utilized to provide permanent records of events where the time and/or duration of events are desired. Two types of event recorders are used: a 32-channel recorder providing a continuouswrite, deflection-type presentation; and a 100-channel recorder providing a write/no-write indication of event status. Both recorders have paper speed controls and each includes time-recording channels.

#### Analog Data Display Functions

The intermixed analog and event data words from the decommutator distribution circuits of the DD/ESDU are routed to all system control consoles. Each control console has address selection circuits that select the analog data words to be displayed at that particular console. The division between decommutator output and the selection of addresses that will be accepted is predetermined by the selection and arrangement of plug-in logic modules in each control console. These address logic circuits decode the address portion of analog data words to gate the data portion of the word into a storage register. The storage register is connected to a D/A converter that operates a meter and/or a pen on an analog recorder. In some consoles, the data to be displayed on a particular indicator can be selected from as many as four different addresses. This address selection is controllable by means of a selector switch on the console front panel.

## SUPPORT SYSTEMS DESCRIPTION (See Figure 4.)

There are several systems that form an integral portion of the ACE-S/C ground station, but cannot be categorized as portions of the Command, or Data Recording and Display Equipment.

These include:

- Timing Equipment
- System Switching Equipment
- Status Display Equipment
- Voice Communications Equipment
- Closed-Circuit Television System



#### **Timing Equipment Functions**

The Timing Group provides real-time signals for the two computers, the roll-chart recorders, and the raw data magnetic tape recorders. The time signals also drive wall- and console-mounted time displays. In addition, the Timing Group supplies countdown-time signals to the computer, wall clock displays, console displays, and to the magnetic tape recorders.

#### System Switching Equipment Functions

The System Switching Equipment provides fast, accurate, reliable switchover of major equipment groups between multiple ground stations at an ACE-S/C installation. Any Control Room may be switched to any Computer Room, and any Computer Room may be switched to any test area. This allows the use of one ACE-S/C ground station as backup for another, greatly increasing reliability through redundance.

#### Status Display Equipment Functions

The Status Display System consists of go/hold switches located on the command and display consoles

for reporting the test operation status to the Test Conductor. The controls are connected to a display panel on the Test Conductor Console that displays indications of test go/hold conditions.

#### **Voice Communications Equipment Functions**

The primary voice communications equipment in the ground stations is a multichannel intercommunication system. A public address system and a commercial telephone system are also available. The multichannel intercommunication system provides for two-way voice communication among ground station operators and between operators and personnel at the test bays. The number of channels available at any given intercommunication station and the specific stations with which the system can communicate are assigned on the basis of test requirements. The test conductor station has the capability to communicate with all others.

The public address system is employed to communicate with personnel whose location or mobility prevents the use of the intercommunication system.

The commercial telephone system is used for nonroutine communications and can be used as backup for



the other systems. In a critical test procedure, contact between two or more control points can be established prior to the test and maintained throughout the test.

#### **Closed-Circuit Television Functions**

Effective integration of certain checkout procedures and, in some cases, safety considerations require that operators within the ground station have the capability to monitor visually the operations and tests being performed at the test bays. This capability is provided by a closed-circuit television (CCTV) system. The CCTV system employs nine portable vidicon cameras. Eight are distributed among the four test bays in accordance with specific test requirements, and one is placed in the fuel tank trailer area.

All cameras are remotely controlled from CCTV control racks within the ground station. The CCTV control racks contain two 17-inch monitors, two waveform monitors, and the controls necessary to permit remote positioning and focusing of the cameras.

The CCTV system provides eighteen 21-inch monitors, nine in each of the two Control Rooms. The monitors are mounted on the ceiling or walls and are located to permit viewing by the system control console operators.



Figure 4. ACE-S/C Detailed Block Diagram



## ACE-S/C SYSTEM UTILIZATION

#### ACE-S/C APPLICATIONS

ACE-S/C systems are presently being installed at four locations. At the facilities of North American Aviation, Downey, California, the ACE-S/C systems will be used for subsystem and integrated system testing of the Apollo Command Module and Service Module during the various stages of assembly and checkout. The Grumman Aircraft Engineering Corporation (GAEC), Bethpage, New York, will use the system for similar testing of the Lunar Excursion Module. At the Manned Spacecraft Center, Houston, Texas, the testing of the spacecraft, both manned and unmanned, in simulated space and lunar environments will be accomplished. At the Merritt Island Launch Area, the complete range of subsystem and integrated system testing will take place. This test cycle spans from receipt of the spacecraft modules, through spacecraft and launch vehicle mating. and the final prelaunch checkout. (See Figure 5.)

It is evident that a wide variety of tests are performed and that these tests are accomplished in a number of different areas. The magnitude of spacecraft checkout requirements is emphasized in Figure 6 which illustrates a test cycle for the spacecraft environmental control system. The ACE-S/C system is capable of meeting these diverse requirements because of its great flexibility and its ability to control a wide variety of test commands and monitor a vast number of test results.

#### NOTE

Detailed checkout activities are in the planning stage. All plans are continually reviewed and modified in accordance with engineering requirements, equipment modifications, etc. Figures 5 and 6 are provided as an aid to understanding the general flow of the spacecraft through the MILA checkout cycle. They do not reflect program planning and should not be so interpreted.

#### PREOPERATIONAL PLANNING

In planning a test operation, the user selects the ACE-S/C Control Room(s) to be used, the specific equipment applicable to the particular test operation, and outlines the test sequence. From this general test operation outline, the operational checkout procedures and computer programming requirements are generated.

#### **Operational Checkout Procedures**

The measurements to be made, test limits and parameters, specific display devices and records, and



Figure 5. Spacecraft Test Cycle at MILA



Figure 6. Spacecraft Environmental Control System (ECS) Checkout Cycle at MILA



the test sequence are delineated in the operational checkout procedures document. The information contained in this document is in the form of step-by-step operating procedures and defines (1) the START modules to be used to enter a test command, (2) the specific test commands to be generated, (3) the display devices used to monitor each test result, and (4) measurement parameters.

#### **Test Operation Programming Requirements**

To generate the required Command and Display Computer programs and the appropriate decommutator programs, computer programmers must be provided with detailed information concerning the specific command functions assigned to various control consoles, measurement limits, display devices to be used for the various measurements, etc. This information is provided to the programmers in the test operation programming requirements document. This document is in the form of punched cards and defines the configuration of the ACE-S/C equipment, and the content of the computer and decommutator programs.

#### **Computer Programming**

Upon receipt of the programming requirements, the programmers generate an assembly program. This

assembly program is used to assemble the test operation program by calling up existing routines and subprograms from a master file or program library tape. This method of program assembly presupposes the existence of the required routines or subprograms. These routines and subprograms are generated as the need arises and are filed in the master file or library tape.

#### **Program Library**

A central program library of official ACE-S/C computer programs, subprograms, and subroutines is maintained. All programs to be used at an ACE-S/C facility are originated, validated, and distributed by the central program library. The program library contains a master card file for each program. This file is reproduced into master program magnetic tapes. From these tapes, a working library tape is prepared.

#### Library Tapes

The library tape contains all programs, subprograms, and subroutines in common use at a specific ACE-S/C facility. Provisions are made to replace, insert, or delete routines from the library tapes during



all phases of operation, including test preparation, checkout, and spacecraft test operations.

#### STATION CONFIGURATION AND CHECKOUT

Prior to any test operation, the ACE-S/C equipment must be prepared for operation and tested to ensure that it is properly configured and operational. Configuring the station requires that the General Electric site support personnel be provided with detailed information concerning the equipment to be used during the test and the specific display and recording devices to be used to monitor each measurement and event. This station configuration information is compiled by the headquarters support personnel at Daytona Beach through use of data processing techniques. The station configuration documents consist of a patch instruction list and a patch configuration list.

#### Patch Instruction List

Each of the Control Room consoles to be used during a test operation must be patched to route the analog and event data to the display and recording devices dictated by the test operations and programming requirements documents. In addition to the consoles in the Control Room, the Decommutator Distribution/Event Storage and Distribution Unit, and certain units of Computer Room equipment must be patched. Instructions for patching this equipment are generated automatically through use of a computer.

Computer programmers at the headquarters activity process the programming requirements cards in a general-purpose computer. The computer produces the patch instruction listing that contains the display routing addresses and the exit and entry hubs to be patched on each equipment patchboard. The listing is printed in a numeric order that allows the patchboards to be wired beginning at the center of the board and working outward to the edges, thus making for an efficiently patched board.

#### Patch Configuration List

To meet the mean-time-to-repair requirement, maintenance personnel must be provided with accurate, detailed, and current documentation of the analog and event data paths through the system. Again, this is accomplished through use of data processing techniques. The



programming requirements cards, used to generate the aforementioned patch instruction list, are used in a similar manner to produce the patch configuration list. This list contains the equipment reference designations for all of the significant test points the maintenance personnel need to trace the path of any analog or event signal through the equipment. Use of this form of documentation enables rapid isolation of malfunctions.

#### **Preoperational Testing**

In addition to patching the equipment for a specific test operation, magnetic tape and chart paper must be loaded on the various recorders, the recorders and FM discriminators must be calibrated, etc. Once all equipment is properly configured and calibrated, the system is tested to ensure that the equipment functions properly for the test to be accomplished.

Special test tapes are used to simulate test data to the display portion of the system. The tapes are loaded on one of the magnetic tape transports and data is patched to the input of the decommutators. The decommutators function just as they would during actual system operation. Display results are monitored on the display equipment and compared to known performance standards. Prior to loading the command test operation program, a special checkout program is loaded into the Command Computer, and the data entry equipment is tested. Test operation commands are entered into each START module, and the resultant data transmission is printed out by the Command Computer typewriter. The operational command program is then loaded, and the command portion of the system is ready for operation.

#### SPACECRAFT TEST ACTIVITIES

During a typical spacecraft test, the Test Conductor Console is manned by the Chief Test Conductor, the Spacecraft Test Conductor, the Test Project Engineer, and the ACE-S/C Control Room Engineer. The control consoles for each spacecraft system are manned by the lead engineer for that system at the low console and an engineer for the system at the high console.

Just prior to the start of the test, all test engineers log the console elapsed-time meter readings, perform a pretest preparation checklist (turn-on, initial control settings, etc.) and report their condition of readiness to the Spacecraft Test Conductor.



The Spacecraft Test Conductor notes the readiness reports, and orders the start of the test, recording the start time. The test operation then proceeds in accordance with sequential instructions listed in the operational checkout procedure (OCP) for that test. Most of the test stimuli are initiated by the test engineers at the high consoles, who perform their tasks under the instructions of the lead engineers responsible for each spacecraft system test. The over-all test effort is coordinated by the Spacecraft Test Conductor. The necessary control and coordination are accomplished by means of the intercommunication and go/hold status control equipment.

#### **POST-TEST ACTIVITIES**

At the conclusion of a test, all roll-chart recorders are recalibrated to determine whether the validity of the recorded data is affected by long-term drift. The equipment is then shut down in accordance with step-by-step deactivation procedures in the OCP. Each console operator records the reading of the console elapsed-time meter in the console equipment log. The Spacecraft Test Conductor records the completion time of the test and other pertinent data such as total run time, total hold time, etc.

## EQUIPMENT OPERATION

As stated previously, spacecraft testing is initiated and monitored from test consoles in the Control Room. The following paragraphs briefly describe the use and operation of the primary control and display devices utilized by the console operators and the test conductor during test operations.

#### **R START MODULE OPERATION**

The R START module is one of the subassemblies used to control operations in the test bays. Entering a test operation command into the R START module causes the Command Computer to transmit a command (or series of commands) to the spacecraft test area.

Some test operation commands entered at the R START modules cause the computer to issue a single command, calling for one action such as a relay closure. Other test operation commands cause the computer to issue a series of commands, calling for several actions at the test area. The computer issues the series of commands through use of a subroutine. The processing of an R START command that calls for such a subroutine may take some time. For example, a command might call for a series of three actions in the test bay occurring at 30-second intervals. During the required 90-second processing interval, the computer places the R START module (that initiated the subroutine) in an inactive state referred to as the SEAL condition. This precludes entry of further commands until the processing of the original command is completed.

Each R START panel (Figure 7) contains four R START modules. The controls located on the R START modules, and their functions, are described in the following paragraphs.

#### **Function Switches**

Each R START module contains four function switches. These are bi-stable pushbutton switch indicators. Each switch is divided into upper and lower halves, the lower half lights red to indicate entry of a binary 1, the upper half lights white to indicate transmission (and verification) of a binary 1. Depressing any function switch that is on will turn the light off. Depressing any function switch that is off will turn the light on.

#### **XEQ/SEAL** Switch

The XEQ/SEAL switch is a split-legend, momentary-contact, pushbutton switch indicator. The



Figure 7. R START Panel

upper half (XEQ) lights green to indicate that an R START command is being processed by the Command Computer. The lower half (SEAL) lights red to indicate that the R START module is in a SEAL condition. When the SEAL portion of the XEQ/SEAL switch is lighted, no new command function code can be executed.

#### PRESS-TO-TEST Switch

All lamps in the function switches and in the XEQ/ SEAL switch are lighted for confidence test purposes by depressing the PRESS-TO-TEST switch.

#### **POWER ON Indicator**

The POWER ON indicator lamp will light when the J-Box associated with the R START is turned on.

#### **C START MODULE OPERATION**

The C START module contains ten 12-position rotary switches, ten projection-type indicators that indicate the status of the module, and an XEQ/SEAL pushbutton switch. This module is used by the operator to call up a



Figure 8. C START Panel

test control subroutine and to enter test operation parameters into that subroutine. These parameters can cause the subroutine to:

- Enter time controlling the start and stop of an analog function.
- Enter time interval controlling the time between discrete steps of an analog function.
- Vary the frequency and amplitude of an analog function.
- Enter time controlling the start and stop of a sequence of switching events.
- Enter time interval controlling the time between each event of a sequence of switching events.
- Institute a prestored sequence of switching events or analog functions.

For example, assume that a subroutine contains a sequence of instructions to be performed on capsule internal pressure. Further assume that the subroutine contains all the instructions and data necessary to perform this sequence with the exception of the upper and lower pressure limits of the capsule. These limits could be entered into the C START module and combined with the instructions and data in the subroutine to produce a complete sequence of test operations in the test bay.

During normal operation, command data is entered in the C START module (Figure 8) by properly positioning the ten rotary switches. As each switch is positioned, the projection indicator above the switch indicates the character selected by the switch. (The characters include the digits zero through nine, a plus sign, and a minus



sign.) The projection indicators are then compared with the switch settings for correct command entry. After the command has been entered and visually verified, the XEQ/SEAL switch is depressed, causing the upper half of the XEQ/SEAL switch to light. This may or may not be visible to the operator since the switch remains lighted only as long as the command is on the lines. If the SEAL (lower half) portion of the XEQ/SEAL switch does not light, it indicates that the command has been accepted and processed by the computer. A SEAL condition is required, if a portion of the computer program will take some time to process. When the command has been processed, the computer will send a remove-SEAL signal to the module which will extinguish the SEAL portion of the XEQ/SEAL switch.

The verification indicators (located directly over the XEQ/SEAL switch) indicate verification commands as they are entered and processed by the computer. The specific pattern (or combination) of indicators which light to denote a verification is a function of the computer program.

#### **K START MODULE OPERATION**

The K START control panel provides the means to enter and transmit digital commands to the spacecraft onboard Apollo Guidance and Navigation Computer via the ACE-S/C Command Computer. The programming and/or input stimulus to the spacecraft onboard Apollo Guidance and Navigation Computer may be modified by the operator through the use of the K START control. The operator may enter commands into the K START manually by the K START keyboard, or automatically by a perforated paper-tape reader. The functions of controls and indicators necessary for the operation of the K START are identified in Figure 9 and are described in the following paragraphs.

#### **Event Indicators**

The left-hand portion of the K START control panel contains three columns of eight indicators each, providing a capacity for displaying up to 24 events. These event indicator lamps indicate the occurrence of selected events to the operator.

#### **Data Display Indicators**

The eight data display indicators provide a visual display of the last command word entered into the K START either from the keyboard or from the perforated paper-tape reader.



Figure 9. K START Control Panel Front View

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#### NON-VERify Indicator Switch

The NON-VER indicator lights whenever an error occurs during a digital command transmission. Momentarily depressing the indicator switch turns the indicator off and allows the operator to enter another command.

#### Execute/SEAL Indicator

The upper half of the split-legend indicator (XEQ) will be lighted whenever the K START is receiving command data from either the keyboard or perforated papertape reader pending readout by the CUE. The SEAL command received by the K START causes the lower half of the indicator to light indicating the SEAL condition. The K START is unable to transmit any data or execute signals to the CUE while in the SEAL condition.

#### **VER**ify Indicator

The VER indicator is lighted whenever a command data entry is successfully received, processed, and transmitted by the ACE-S/C Command Computer to the space-craft Apollo Guidance and Navigation Computer.

#### **TAPE/KEY** Indicator Switch

The TAPE/KEY indicator allows the operator to select either the perforated paper-tape reader or the keyboard as a source of command data to the K START.

#### LOAD/INHibit Indicator Switch

The operator can enable or disable the K START transmit function by the use of the LOAD/INH indicator switch.

#### Forward/Reverse Indicator Switch

The FWD/REV indicator switch allows the operator to control the perforated paper-tape movement.

#### INDex/CONTinuous Indicator Switch

The IND/CONT indicator switch allows the operator to select one of two paper-tape reader operating modes. When the upper half of this split-legend switch is lighted (IND Mode), the paper-tape reader will move the tape one character position in the direction specified by the FWD/



REV indicator switch, for each depression of the RUN indicator switch. When the lower half of this switch is lighted (CONT Mode), the paper-tape reader will advance the tape one character at a time continuously until a programmed stop instruction is read, or the RUN indicator switch is again depressed.

#### **RUN Indicator Switch**

The RUN indicator switch allows the operator to start the paper-tape reader drive as specified by other K START controls.

#### Keyboard

The K START keyboard provides the operator with the means to manually enter command data codes into the K START for transmission to the CUE. Depressing any of the keyboard pushbuttons causes the proper binary code associated with that particular pushbutton to be placed on the K START output lines.

#### **Tape Reader Operation**

The tape reader is a self-contained, bidirectional, asynchronous assembly for reading an eight-channel perforated paper or metal tape. Activation of the tape reader and direction of tape movement is controlled by pushbutton switches located on the K START module. The tape reader allows the operator to enter rapidly and automatically a large quantity of test commands into the K START for subsequent transmission to the onboard Apollo Guidance and Navigation Computer.

#### EVENT MODULE OPERATION

The event modules provide a means to indicate to the control console operators the occurrence of discrete events within the spacecraft. These modules (Figure 10) contain three rows of eight indicators each, providing a capacity for displaying up to 24 events. The indicator lamps light when the particular events associated with those lamps have occurred. The LIGHT TEST switch is provided to verify that all indicator lamps are operating properly.

#### METER MODULE OPERATION

Meter modules (Figure 11) are utilized to display current analog data transmitted from the spacecraft to the control console operators. Each meter module contains four edgewise 0- to 1-milliampere meters, each

#### EVENT INDICATORS



Figure 10. Event Module Panel

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Figure 11. Meter Module Panel

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Figure 12. CRT Module



capable of displaying a different analog signal. Insert tags are provided above each meter to indicate the measurement identity. These tags are readily removed and replaced without removing a meter from the module. Each meter also contains a meter scale insert that can be easily removed for the insertion of different meter scale inserts as required. Certain meter modules are interchangeable with the event modules to accommodate varying test requirements.

#### **CRT MODULE OPERATION**

CRT modules (Figure 12) are located on consoles in the Control Room and Computer Room. They are used to display analog and event data from the spacecraft that has been processed by the Display Computer. The CRT module basically consists of a CRT screen that displays 26 lines of alphabetic, decimal numeric, and special symbols, PAGE CALLUP thumbwheel switches, and various controls for adjusting the display on the CRT screen. These controls are located behind an access door on the front panel.

The CRT screen displays information in 26-line page formats, so arranged that the top half or bottom half of any of 20 such pages can be selected by the operator. The top and bottom lines, which can display 32 alphanumeric characters each, are used for page identification. The top line on the display identifies the top half-page selected, while the bottom line identifies the bottom halfpage selected. The remaining 24 lines on the screen can display 40 alphanumeric characters each. Figure 13 illustrates an actual page of data on a CRT.

The PAGE CALLUP thumbwheel switches allow a Control Room operator to select the upper and lower halfpage displays appropriate to his particular test operation. If a test parameter is determined to be out of limits, the Display Computer will cause that particular line of data to blink. This alerts the operator of an existing problem.

#### ANALOG AND EVENT RECORDERS

Three types of recorders are contained in the Control Room consoles. The Analog Recorders (Figure 14) are eight-channel, moving paper, ink-trace devices incorporating a vertical oscillograph. The 32-channel Event Recorders are also ink-trace devices that record on/off event status. Each event is shown in time relation to the others, providing an immediate picture of the situation monitored. The 100-channel Event Recorder indicates on/off status by an electric-writing metal stylus that remains in contact with electro-sensitive paper.

COMMAND MOD-RCS	PG.	D2 TANK A	TANK
CR0001 HE PRESS CR0003 HE TEMP CR0007 FVEL QUA CR0013 0XIDIZER CR0502 HE REG 0	NTITY QUANT UT	5.4 -24.4 44.9 87.4 198	5.3 PSIA -23.6 DEGF 44.6 LBS 88.3 LBS 204 PSIA
SR5001 HE PRESS SR5005 HE PRESS SR5013 FUEL QUA SR5025 0XIDIZER SR5065 ENGINE P	-RCS NTITY QUANT ACKAGE	5. 20 -31. 0 506. 3 67.	5.7 PSIA -30.4 DEGF 49.9 LBS 87.2 LBS 64.2 DEGF
TD0185 TWR PYRO CD0200 LES LOGI CD0205 ADAPTER TD0005 LES PYRO CD0212 ELS ARM CD0214 ELS SAFE	BUS C BUS PYRO BUS	A 6 37 220 8	-24.5 VDC 24.2 VDC 23.6 VDC 25.0 VDC 31.4 VDC 31.7 VDC 24.7 VDC

Figure 13. Actual CRT Display

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Figure 15. Status Display Panel

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The recorders are turned on, checked, and adjusted by maintenance personnel (prior to spacecraft test operations), and left in a standby condition. Test operation, therefore, involves only depressing the desired SPEED switch to start the recorder, and depressing the STOP switch to stop the recorder. Operation of the remaining controls is normally a function of the maintenance personnel.

#### **STATUS DISPLAY PANELS**

Two Status Display Panels are located on the Test Conductor's Console. Each panel (Figure 15) contains indicators for displaying 55 events associated with RF systems, POWER systems, ARMING, MISSION MILE-STONES, ACE-S/C, and other parameters as required. There are 8 lamp-type indicators for RF systems, 10 for POWER systems, 11 for ARMING, 20 for MISSION MILE-STONES, and 6 for ACE-S/C. Each lamp unit contains two lamps and an associated PRESS-TO-TEST switch. In addition to these 55 events, the Status Display Panel contains ten back-lighted indicators that are divided into two segments. The lower segment is designated GO and is colored green, while the upper segment is designated HOLD and is colored red. These indicators display the status of the various control consoles. When the operator at a particular control console depresses the GO or HOLD switch on the status control panel for that console, the green or red indicator on the Status Display Panel corresponding to that unit will light. The Status Display Panel thus allows the Test Conductor to monitor the status of all Control Room consoles.

#### WALL CLOCK DISPLAYS

Three wall clocks (Figure 16) are located in the Control Room and two are located in the Computer Room. Each Wall Clock Display consists of two sets of inline decimal display indicators – one set for real-time display (actual or range time) and one set for countdown-time display. All operators are made aware of the test operation time status with these devices.

The real-time portion of the Wall Clock Display shows the current time of day or range time – never playback real time. This display contains nine decimal inline indicators, three to indicate days, two to indicate hours, two to indicate minutes, and two to indicate seconds. Each indicator is made up of seven separate back-lighted segments that are turned on in various combinations to form the desired decimal characters.





The countdown time portion of the Wall Clock Display shows current countdown time, never playback countdown time. The countdown wall clock contains eight inline decimal indicators, one to indicate "+, " "-, " or H (HOLD), three to indicate hours, two to indicate minutes, and two to indicate seconds.

## CAPABILITIES OF ACE-S/C

- Completely Tests Integrated Systems and Independent Subsystems
- Provides Any Desired Degree of Test Automation
- Processes Large Quantities of Data for Real-Time Display
- Adapts to Any System or Test Mode by Means of Software Changes
- Is Capable of Inflight Checkout Via Radio Telemetry Link

## IN OPERATION

- Provides Remote Stimuli Control for Systems Test
- Transmits and Receives Data in Digital Form
- Records Data Inputs for Later Analysis
- Analyzes Test Results in Real—Time
- Displays Information in Optimum Decision Format

### **ADDITIONAL ADVANTAGES**

- Provides for Astronaut Participation and Launch Control
- Tests Across System Interfaces
- Uses Flight Telemetry Equipment
- Minimizes Cabling by Serial Transmission of Commands and Data
- Has Built-In Self-Check Capability

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