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ELECTRICAL SUPPORT EQUIPMENT FOR THE
SATURN V LAUNCH VEHICLE SYSTEM

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ABSTRACT

Electrical support equipment for checkout and launch of the Saturn V vehicle is described. Functional descriptions of the digital computer and the electrical support equipment are presented. Projects that are being developed for future use are discussed briefly.
SUMMARY

Automatic checkout of the Saturn space vehicle is being developed because of fast and accurate performance offered by automated equipment. Launch Complex 39 electrical support equipment will include two general purpose digital computers to provide automatically controlled systems checkout for the Saturn V vehicle.

The electrical support equipment is designed in conformance with the National Aeronautics and Space Administration and Marshall Space Flight Center guidelines, with emphasis on standardizing the hardware.

An automation plan prepared by the Marshall Space Flight Center insures that comprehensive procedures are advanced and pursued for developing fully automated checkout and launch systems for larger space vehicles.

Functions and capabilities of the electrical support equipment are presented. Also, the logic and interlocks and safing circuits used in the Saturn V complex are discussed.

Future projects currently being developed include an electrical support equipment simulator, solid state switching devices, program boards wired by automatic machine methods, data evaluation, automatic drafting evaluation, electronic pressure sensors, and special packaging.
INTRODUCTION

History

The first Saturn test rocket weighed about 419,950 kg when fueled.

The need for a vehicle much larger than Saturn I was established when the late President Kennedy set, as a national goal, a manned lunar landing before 1970. After extensive studies, NASA announced on January 10, 1962, that MSFC had been assigned the task of developing the Saturn V, a vehicle which would be about 110 meters tall and would carry the Apollo payload.

The Saturn V will weigh more than two million kg at liftoff and will be capable of placing a payload of 108,862 kg in earth orbit or sending 40,815 kg to the moon.

Because of the size of the Saturn vehicle, additional facilities will be required for testing and launching. Among new projects being developed is the Merritt Island Launch Area (MILA), an area of over 3,240 million square meters adjoining the present facilities.

At the Merritt Island Launch Area, construction is in progress on the world's largest building, the vertical assembly building, where Saturn V rockets will be assembled upright on their transporters.
ELECTRICAL SUPPORT EQUIPMENT

Electrical Support Equipment Mission

The primary mission of the electrical support equipment (ESE) described herein is to provide specific checkout, control, and monitoring functions in testing and launching Saturn vehicles. A computer-oriented automatic checkout system provides the speed, accuracy, and versatility necessary for successful completion of this mission.

Electrical Support Equipment Design Philosophy

Space vehicle systems have become increasingly more complex as seen by comparing mission requirements of an early vehicle, such as the Redstone, with those of the Saturn vehicles. Checkout functions have become more numerous and more frequent, necessitating greater speed and accuracy. The number of information lines between vehicles and ground support equipment has increased from a few hundred to thousands, and distance from the launch pad to the control center has increased from 152 meters to a minimum of 4,828 meters for the Saturn V.

In the past, checkout and launch ESE was largely manually controlled. As the Saturn design developed, it became apparent that the ESE would be so complex that manually operated equipment would not be satisfactory. The magnitude and complexity of the Saturn V checkout and launch necessitate automation to perform the large number of tests or checks in a time period that does not consume too great a part of design life of the vehicle. Therefore, automated equipment, using general purpose digital computers, has been adapted to checkout and launch of the Saturn V.

Improvement of automated checkout has progressed rapidly since 1960 when MSFC undertook its development. Since the first Saturn was checked out, the use of computers to check various subsystems has increased. Each launch contributed much to improving computer-oriented automatic checkout.

A general purpose digital computer will control Saturn V vehicle subsystems during checkout and countdown. However, manual capabilities will be provided for emergency operations or procedures not covered by computer control.

Specifications and Standards

The ESE will be designed in conformance with NASA documents NPC 250-1, NPC 500-1, and NPC 500-6. In general, design support will provide for preparation of specifications and data requirement lists and insure the reliability of the systems from design to end use. The ESE Design Support Tree Chart (Fig.1) shows a general breakdown of the ESE design support mission.

Hardware Standardization

Approximately 1,334 panels are used on Saturn V ESE. Panels are kept simple wherever feasible, as are racks, distributors, modules, and subassemblies. Hardware that has been standardized for design simplicity includes terminals, connectors, panels, slides, chassis, printed circuit boards, plates, relays, diodes, resistors, meters, lights, and switches; all of which fit basic rack or console enclosures.
The standardization of ESE provides:

- Increased reliability
- Simplified construction
- Modular fabrication
- Use of proven components
- Maximum interchangeability
- Use of standard racks
- Minimum number of different components for logistic simplification
- Uniform and attractive appearance

Typical hardware used in the standardization of ESE is shown in Figures 2 and 3.

**ELECTRICAL SUPPORT EQUIPMENT LOCATION**

Integrated ESE for Saturn V is located at Launch Complex 39, Kennedy Space Center, Cocoa Beach, Florida, and at the Saturn V System Development Breadboard Facilities (SDBF), Marshall Space Flight Center, Huntsville, Alabama.

Launch Complex 39, as shown in Figure 4, is divided into the launch pad area, which includes the Launch Umbilical Tower (LUT), and the Launch Control Center (LCC).

The Saturn V SDBF is located in the bay area of the Quality and Reliability Assurance Laboratory, Building 4708. The SDBF consists of a complete set of ESE, simulators for the S-IC and S-II stages, a mockup of the S-IVB stage, an Instrument Unit, and associated mechanical hardware mockups or simulators.

The Saturn V SDBF is a proving ground to develop techniques for using digital computers to automatically check out and launch the Saturn V vehicle. Other SDBF objectives are:

- Design evaluation
- System compatibility
- Computer program verification
- Launch operations training

Since the integrated ESE at the SDBF reflects the overall checkout and launch concept, only the equipment at the SDBF will be discussed, except to point out that the distance between the LCC and LUT is taken into consideration in equipment design.

**Launch Umbilical Tower**

The LUT contains equipment to perform the Saturn V prelaunch tests and to serve as a cable distribution point. The LUT also contains the terminal countdown sequencer, which controls the last three minutes of countdown, and the ignition sequencer, which provides signals in the proper sequence to ignite the S-IC engines.

The digital data acquisition system (DDAS) located in the LUT provides data necessary for checkout and launch of the Saturn V vehicle; the DDAS transmitter in the LUT provides a data link between the LUT and LCC.
The Saturn V computer system consists of two operational computers operating in tandem through hardwire data links between the LUT and LCC.

Approximately 145 racks of electrical support equipment are located in the LUT area.

Launch Control Center

Electrical support equipment located in the LCC controls the checkout and launch of the Saturn V vehicle.

Checkout and launch equipment includes control and display panels that provide operational control of the system by meters, switches, lamps, potentiometers, digital readouts, and CRT displays. Data are transmitted to the displays by DDAS, by computer link, or by hardwire link.

Integration equipment, consisting of standard patch racks and relay control and logic, provides electrical distribution, interlocking circuitry, and the interfacing between functional systems.

Analog recorders record signals from DDAS through digital-to-analog converters, safing functions on hardwire link, and other analog functions present during checkout in the high bay area.

A digital event evaluator (DEE) located in the LUT with printers in the LCC detects any change in status that may occur by comparing the present state of each line with the stored result of the previous scan. Each change in status is processed and may be typed out or punched on paper tape.

A clock and timing system operates local displays of countdown time, maintains synchronization with the LUT clock and timing system, and provides time data to the computer.

The digital data acquisition system in the LCC provides a receiving station for each stage and the LUT monitoring transmitter and furnishes analog signals to displays and recorders. DDAS signals are available to the LCC computer.

Approximately 175 racks of electrical support equipment are located in the LCC area.

SATURN V ELECTRICAL SUPPORT EQUIPMENT MAJOR FUNCTIONS

Saturn V Automation Plan

MSFC has established an automation program that includes checkout at stage contractors' facilities, static test site, staging area, and launch site. Plans are to develop automatic checkout during the Saturn I and IB programs and to fully implement the system during the Saturn V program.

The primary mission of any space vehicle checkout system is to determine vehicle status, pinpoint troubles promptly after they occur, and verify the intent of the vehicle ESE design.
Computer-controlled automatic checkout systems offer the speed, accuracy, and versatility necessary for successful and timely completion. Resulting advantages of such a system include improvements in vehicle systems reliability and possible savings in time required for the many phases of the testing and launch preparations.

Saturn V vehicle electrical checkout is planned to be completely automated. The Saturn V SDBF is installed in the Quality and Reliability Assurance Laboratory so stage simulators and live stages or components can be located adjacent to the ESE. It is anticipated that when perfection of the equipment and the computer programs is accomplished, the checkout system could be mated to a live Saturn V vehicle and checkout performed.

Present plans are for total ESE with computer checkout programs to be developed at breadboard facilities so hardware and software produced for the launch complex and other checkout areas will represent complete and satisfactory systems. The machine portion of the man-machine team must be versatile and powerful and must increase the man's confidence in the status of the complex countdown and checkout procedure.

Specific ESE Design Requirements

During testing of a stage or subsystem, ample displays of systems under test must be provided to the station operator to keep him informed of the test status. Displays may be either analog or digital or both and will be operated by signals from the DDAS, computer, or hardwire connections to the stage. This requirement does not preclude the use of additional displays that are computer controlled.

Launch site ESE will be developed by MSFC and KSC using equipment developed for stage checkout. By assuming responsibility for all launch site ESE, MSFC eliminates the division of responsibility for launch site operations.

A key benefit of having only one organization accountable for launch site ESE is that design can be completed relatively late in the program and full advantage can be taken of concepts developed by different stage contractors, resulting in a minimum of modification and a more efficient design. A Saturn V vehicle flow diagram is shown in Figure 5.

Checkout System Fault Isolation Capabilities

The capability of performing checks that isolate faults or diagnose trouble when malfunctions are encountered can be a valuable function of a checkout system. In the Saturn system vehicle checkout ESE, the capabilities for fault location will be limited to isolation at the subsystem level. Signals through the umbilical connections will be limited to those necessary to ascertain proper functioning of subsystems. The following ground rules establish the MSFC philosophy of subsystem isolation and will be used as a guide by stage contractors.
Test cables and plugs for checkout of a stage in the manufacturing area or vertical assembly building are to be used to the fullest extent; but for the Saturn V design, there will be no such test cables on the umbilical tower or in the vehicle when it is on the launch pad.

Test or check points will be included in the vehicle and may be routed through the umbilicals, DDAS, or telemetry to provide data (supplemented where appropriate by command lines) on the status of the input and output of each subsystem. Fault isolation provisions should be included in early design so that each circuit may be analyzed for compatibility with MSFC fault isolation philosophy.

The Automation Board that prepared the Automation Plan functions as a center-wide engineering council for systems integration and automatic checkout operations. It is composed of key personnel from MSFC laboratories concerned with designing, checking, testing, and launching space vehicles. Also, the Kennedy Space Center and Manned Spacecraft Center are represented.

**ELECTRICAL SUPPORT EQUIPMENT FUNCTIONAL DESCRIPTION**

The functional interconnect diagram in Figure 6 shows the overall interface of Launch Complex 39 and the Saturn V vehicle. A functional description of the ESE is presented below:

**Controls and Displays.** Control and display stations are located in the LCC area for control of checkout, launch sequence, and ignition processes. The controls and displays available are lights, meters, switches, and an operational display system. A typical display station is shown in Figure 7.

The operational display system at Launch Complex 39 will consist of a general purpose digital computer and 14 display control consoles. A console will contain manual controls, keyboard, and a cathode ray tube (CRT).

**Control.** The LCC computer is the control source of commands for the test system; it directs the LUT computer as to what to do and when to do it. The LCC computer, in turn, is controlled by the test conductor and the subsystem engineers at display consoles.

Subsystem engineers can command the LCC computer to provide display stations with data such as test results, troubleshooting aids, or curve plotting of vehicle functions. Computer storage has a large quantity of reference data which may be supplied to the CRT displays on demand by subsystem engineers. Data may be updated and returned to storage, as necessary.

Non-critical manual operation via computer control will be afforded with a three-position lever lock switch. The switch positions will be labeled "on," "off," and "automatic." When in the "on" or "off" positions, the switch will signal the LCC computer to interrupt its program and to perform the required function within approximately one millisecond. The switch can also be used to control certain tests of operation while maintaining selected components in an abnormally "off" or "on" condition.

The normal method of transmitting discrete information to indication lamps on the ESE operator panels will be from the computer in the LCC. Emergency control will be available for safing purposes.

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Automatic Control Mode. In the automatic control mode, control of tests is exercised from the test conductor's console. Fully automatic operation employs previously prepared computer programs with a minimum of operator inputs. In the semiautomatic control mode, the test conductor will assume control of the computer program and will be able to select specific tests or groups of tests that are part of the stored program. By using control logic, tests for which no formal stored program exists can be run.

Manual Control Mode. When required for fault isolation, capability to perform specific operations will be transferred from the LCC to the LUT computer and the problem resolution will proceed as a single computer operation. The LUT computer complex will be available for analysis of test results.

Displays. Display stations must be capable of displaying relevant information from such sources as DDAS and computer memory by means of a CRT, meters, and lights.

The primary display in the display console is a CRT that is capable of operating in a random plot, tabular, or TV mode with both characters and vectors displayed.

Real time digital data, stored reference data (slides), or a closed circuit television channel can be used for display on the CRT. Digital data from the previous frame are always stored and may be recalled at any time.

Commands from the display control console will be via the display control computer to the launch computer. Each of the display control console complexes will be assigned a particular card code, and an operating system will contain tables listing the specific test program which can be requested by each display control console.

All tests will be conducted in accordance with established procedures and sequences and will deviate only in the event of malfunction and subsequent troubleshooting. The test conductor will have the responsibility of overall testing. He will establish test priorities, determine test sequences, and evaluate requests for individual system tests. Control equipment or test program modifications and loading of test programs will be under the direct supervision of the test conductor.

An editing capability is provided so the operator may correct or modify displayed digital data by erasing and typing.

A copy of a selected frame of digital data is obtained by converting the digital data to characters or vectors on the CRT display and then imaging the face of the CRT with a copy generator.

There will be two random access slide banks available. Each slide bank will be capable of handling 256 slides.

Closed circuit television transmission will be available by selecting a frame of digital data, converting the data to characters and vectors on a CRT display, and then scanning with a conventional TV camera.
Request for display outputs from the display control console are initiated through display executive programs.

All requests originating at the display control console for test programs and display presentation will go via the operational display computer.

Safety Logic and Interlocks

The elements of safety for personnel and equipment are of extreme importance in either a manned or unmanned vehicle. Close proximity of highly combustible and corrosive propellants necessitates positive control of all critical valves, relays, etc. Control can best be maintained by interlocks and hardlines providing positive feedback indications.

Operating conditions at the launch pad during countdown are extremely critical because the vehicle is fueled, pressure systems are pressurized, and destruct explosives are aboard. Two requirements are of the utmost importance at this time.

First is the positive control and indication to insure that the destruct system is completely armed and available for operation at liftoff. However, it should be noted that a failure to arm should result only in a launch abort. An inhibit relay in the "preparation complete chain" is used to insure that the vehicle is not launched. This chain is made from a list of items that are considered critical requirements and that will prevent countdown from continuing past T-150 seconds. Since launch is prohibited by these interlocks, it is considered safe to use a data link computer for issuing the arming command.

It is highly unlikely that more than one of the safety interlocks will fail and a destruct signal be inadvertently issued; however, if this condition should occur, the vehicle will be in an unsafe condition. To prevent this from occurring prior to the time the launch pad is cleared, a manual interlock in the form of a key or manual switch is provided in series with that computer channel.

The second most important requirement during countdown is the ability to return to a safe condition if a hold is required or an abort occurs; this control and indication must be as positive as possible and independent of all ac power sources. Therefore, direct hardline links are used for both commands and indications. These links bypass all automatic controls and data links. Functional components used in this system are the minimum number possible and consist of the most reliable switches, wires, and relays available. These safing circuits introduce no effective unreliability since they do not operate unless there is a failure in another system.

A final recourse is made available if any of these components fail. This is the hardline control capability for removing power from any specific power bus or all power busses of the vehicle.

An example of critical, but non-hazardous interlocking can be found in the warmup of the inertial platform used for flight control. Gas bearing gyros in this unit use only preheated gas. In this application, it is possible to utilize the computer to supply the proper sequencing of events; i.e., turn on heater, turn on gas, monitor gas temperature, and then arrive at a logical decision to continue the checkout or shut down, depending on the gas temperature.
Another example of safety interlocking is evident in the hydraulic system for flight control. This system usually has two temperature requirements for safe operation, and a requirement that actuator control voltage be previously applied. Therefore, the command circuit to turn on hydraulics is interlocked by relays that are driven by oil- and motor-temperature sensors and by an actuator-control-voltage sensor.

Component test operation is a further example of safety interlocking. Checking of pressure switches requires that sufficient GN₂ pressure be available to operate the supply valve that supplies pressure to pressure switches. Since no hazards of component degradation will occur if the valve supply pressure is absent, this interlock is performed by computer program.

As a summary, the safety interlock system philosophy can be put into two categories:

1. Catastrophic items that are hardline link interlocked with multiple relay interlocks.

2. Component safety items and minor hazards to personnel that are interlocked within the computer program.

Safing Controls

At any time during vehicle prelaunch preparations and prior to liftoff, an emergency condition may arise that requires the restoration of the vehicle to a safe condition, that is, safe for personnel to work with or around. The vehicle will be restored to a safe condition by relay logic operating independently of the computer.

Equipment that affects stage safing is not contained in explicit safing equipments per se, but is distributed throughout the ESE, mostly in the networks rack, propulsion rack, and pneumatic consoles. All of this equipment is supplied electrically by a ground bus paralleled by a battery system to safe the vehicle in the event of a power supply failure.

If a "safe" vehicle condition is one in which personnel can work, then some propellants must be unloaded. In any event, the procedure for stage safing is semiautomatic. Certain emergency cutoff signals automatically initiate the stage safing sequence. Such signals include bus voltage failures, stage pneumatic control spheres over pressure, engine rough combustion, thrust failure, fire detection alarms, and other similar conditions. Cutoff may also be initiated by the observer.

When cutoff occurs, engines shut down automatically through their cutoff sequences, stage busses are automatically transferred to external power, and external power is applied to selected stage control and monitor busses. Automatic vent-down of the propellant tanks may be accomplished if necessary. High pressure bottles on board are vented manually. Safe and arm devices, such as those in the command destruct system, are motorized to the safe condition and the status is read out on hardwire link.
The safing operation is controlled via hardwire link to provide the maximum in reliability. This hardwire link will be controlled from the control and display consoles and go directly to the vehicle with a minimum number of connectors.

**Digital Events Evaluator**

The digital events evaluator (DEE) detects by comparison and records changes in status such as opening and closing of valves, relays, and switches, which occur during the prelaunch and launch checkout of Saturn V vehicles. This provides a continuous recording of discrete activities and replaces previously used recording methods.

The DEE-6 model, which will be used in the LUT, provides discrete input monitoring for a maximum of 3,220 discretes and a detection resolution of two milliseconds. The DEE-6 output buffer storage has a data backlog capacity of 600 discretes, thus insuring that discrete information occurring at high rates in short time intervals will not be lost because of the relatively slow output rate of the printer in the LCC. A printout is initiated upon detection of a change in state between scanning periods of any input or upon demand. DEE functions are accomplished through stored programs.

Pen recorders in the LCC area record analog signals and other measurements.

**Electrical Power**

Electrical power from ground equipment is required for vehicle checkout to conserve onboard battery capacity and to provide power for operational functions which cannot be met by the vehicle power supplies.

The following types of electrical power supplies are required:

- **(S-IC) First Stage:**
  - One 200 A, 56 V dc
  - Two 250 A, 28 V dc
  - One 100 A, 28 V dc

- **(S-II) Second Stage:**
  - Three 250 A, 28 V dc
  - One 200 A, 28 V dc
  - One 500 A, 28 V dc
(S-IVB) Third Stage: One 100 A, 28 V dc
One 500 A, 28 V dc
One 250 A, 28 V dc
One 200 A, 56 V dc

Instrument Unit Two 250 A, 28 V dc

In addition to vehicle power supplies, auxiliary power requirements include:

Two 500 A, 28 V dc supplies for signal conditioning
Four 500 A, 28 V dc supplies for propellant loading
One 250 A, 28 V dc supply for clock and timing
One 60 kW, 28 V, 400 Hz motor generator set for platform motors, S-11 pumps, and other 400 Hz loads
Two 15 kW, 400 Hz solid state frequency changers for measuring power
Two 60 kW, 60 Hz MG sets for computer power
One 500 A, 28 V dc power supply for LCC switching and indications
One 100 A, 30 to 60 V dc supply for hardline safing power
Two 500 A, 28 V dc supplies for swing arm power
One 250 A, 28 V dc supply for LUT auxiliary functions and in-transit power
Eight 10 A, 28 V dc supplies for stage DDAS signal conditioners
Two 50 A, 28 V dc supplies for ground DDAS signal conditioners
Two 10 A, 28 V dc supplies for computer signal conditioners

The foregoing figures are representative only.

Each power supply is remotely controlled by a power panel or through the operational computer. Controlled functions are start-stop, voltage control, and output power on and off. Voltage, current, and frequency are monitored by meters and recorders.

Direct current power supplies are solid state devices with input contactors, transformers, rectifiers, regulating circuits, filtering devices, sensing circuits, and output contactors.
The power regulation varies with the purpose. Most of the 28 V dc power supplies are regulated as follows:

- Static line regulation ± 0.25%
- Dynamic regulation, ± 3 V
- Response time, 100 milliseconds for 98% recovery
- Ripple, 100 millivolts, peak-to-peak

Direct current power supplies are equipped with remote sensing, allowing a set voltage to be maintained at a remote bus.

The 60-kW, 208 V, 400 Hz power is produced by conventional synchronous motor generator sets. The 15-kW units are solid state devices.

Many of the vehicle loads are critical, and damage will result from interruption of power. Also, certain equipment must be operated during a power supply failure prior to shutting down for repairs. These requirements are met by placing batteries across all critical circuits. These batteries maintain voltage long enough to shut down the system.

Power distributors consist of circuit breakers, fuses, contactors, shunts for current measurements, current transformers for current measurements, and voltage sensing devices.

Power is fed from the distributors to the using equipment by means of a standardized system of cables and connectors.

Clock and Timing

A clock system provides timing signals and clock signals and clock displays for use of test operations and ground support equipment. The clock system is divided into two major categories; the real time clock and the count clock.

Real time clock systems provide time (time of day in hours, minutes, and seconds) to the launch computer for a time reference and will display this time at various locations within the test complex. This information is obtained by synchronizing an encoder with an Eastern Standard Time or Central Standard Time signal. This encoder establishes the reference time from which to count and, upon coincidence with the received time, starts the binary counter counting at a 1-kHz rate. The timing reference provided is accurate to within 10^-3 seconds.

Computer System

The Saturn V launch computer system consists of two operational computers. Computers located in the LUT and LCC operate in tandem through a data link to handle the Saturn V vehicle and ESE signals transmitted between the two areas. The Saturn V computer complex in the LUT and LCC will consist of approximately 6 consoles and 35 racks of equipment.

LUT computer input-output interfaces communicate with test equipment by digital, analog, and discrete signals. The computer is connected to equipment in the LCC through a computer interface data link. The LUT computer generates stimuli to aid in vehicle checkout, to measure analog voltages, to compare results with predicted values, and to alter testing sequence, when necessary.
The computer recognizes out-of-tolerance and alarm conditions and can activate displays or alarm indications. A phase-modulated carrier transmitted over two pairs of video cables provides the data link between the LUT and LCC computers. Inputs to the LUT computer from the Saturn V vehicle are by DDAS receiving stations in the LUT and by hardwire through the umbilical cable to the computer.

Central control for the test system is the LCC computer. It directs sequences of actions to the LUT computer and is controlled by operators at console keyboards and ESE panels. Eastern Standard Time and the clock and timing system are used as time reference by the computer. Monitoring, response evaluation, and data recording functions of the LCC computer are similar to those of the LUT computer.

The LCC provides the data display system with information on test results, troubleshooting aids, and time curve plotting of vehicle functions. A console operator has access to the reference stored in computer memory for CRT display. This data can be updated as required.

**Computer Complex Description.** The Saturn V launch computer system is divided into seven functional data control subsystems comprising components of both the central data processor and peripheral equipment. Each subsystem functions to control and monitor a unit of the Saturn V system.

The discrete signal subsystem operates with Saturn V units requiring signals at discrete time intervals for optional sequencing of specific events. Signals returned to central data from the equipment are monitored to insure correct operation and sequencing. The subsystem includes components that convert the digital control bits to discrete (-28 V dc) signals from transmission to the unit under test.

Analog signal subsystems operate similarly to the discrete signal subsystem, monitoring analog measuring devices of the Saturn V system for operation within tolerance. The input analog data from the unit under test are converted to digital signals for tolerance comparison by the central data processor; the resulting data may be recorded for analysis or storage.

The airborne computer, payload, and remote computer subsystem provide monitoring, checkout, and operating data transmission with the Saturn V airborne computer, payload, and remote computer. The real time and telemetry subsystems operate with the central data processor to provide input data control and storage of digital information required for performance analysis of Saturn V units at the completion of a system program.

**Discrete Signal Subsystem.** The discrete signal subsystem functions to select and sense 3,024 discrete input signals and generate 2,016 discrete output signals for communicating with units of the Saturn V system. The discrete output circuits, under program control, generate signals at discrete time intervals for operational sequencing of specific events in the Saturn system.

The discrete output function encompasses the input-output address register, discrete output steering drivers, discrete output registers, and relay drivers which generate 2,016 discrete output signals to communicate with units of the Saturn V system. The 2,016 discrete output signals are conditioned by relay drivers to operate external relays contained in the system units.
Discrete input functions encompass input-output address register, a discrete input address decoder, and 24 discrete input units which select and sense up to 42 of the 3,024 discrete inputs for monitoring the Saturn V system discrete functions.

**Analog Signal Subsystem.** The analog signal subsystem functions to control, select, and sense 600 analog input signals and to generate two analog outputs for communicating with units of the Saturn V system.

The analog output circuits encompass a digital/analog input register and two digital/analog converters. A special instruction transfers a 24-bit computer address word to the digital/analog input register. The digital/analog input register processes the 24-bit computer address word to provide an 11-bit digital word for each digital/analog converter.

The analog input circuits select two of the 600 analog input signals for each computer address word. The two signals are selected and sensed in a succession requiring two separate conversion cycles to fulfill one computer address. While the analog input circuits are capable of selecting 600 analog input signals, only one half of the first level drivers and switching units are implemented, allowing only 300 analog input signals to be sensed. Additional analog signals can be implemented by the addition of analog switches and drivers.

**Airborne Computer Subsystem.** The airborne computer subsystem provides for transmission of 27 bits of digital information between the central data processor and the airborne computer in the Saturn V vehicle.

**Payload Subsystem.** The payload subsystem provides for the transmission of 24-bit digital data between the central data processor and the payload equipment in the Saturn V system.

**Remote Computer Subsystem.** The remote computer subsystem provides transmission of 24 bits of digital information between the central data processor and the remote computer in the Saturn V system.

**Real Time Subsystem.** The real time subsystem provides the selection and gating of real time digital clock inputs required by the central data processor. Three time sources are continuously available to the subsystem; the countdown clock, an Eastern Standard Time clock and a special computer timer.

**Telemetry Subsystem.** Telemetry inputs are directed to the central data processor for storage. The telemetry equipment of the Saturn V system directs 48 bits of digital information to the telemetry subsystem for input gating. Since the input register of the telemetry subsystem has a 24-bit capacity, the 48-bit is multiplexed and sensed to determine the status of its telemetry equipment.

**Test Equipment**

Several sets of test equipment verify the vehicle electrical systems and the ESE. These test sets are used in various areas as required and do not necessarily form a part of the equipment used to launch the vehicle. This test equipment consists of the ground equipment test set (GETS), overall test set (OATS), and stage interface substitute (SIS).
The GETS, OATS, and SIS equipment will be located in the central section of
the high bay areas of the vertical assembly building (VAB). This test equipment
can be used manually in single-step testing, malfunction isolation, and repair.
During the normal testing, when sufficient design lead time exists, this equipment
will be computer controlled.

**Ground Equipment Test Set.** The GETS will be located at different levels of
the VAB, as near as possible to the umbilical connections for each stage to reduce
cable requirements.

The function of each GETS is to check the operation of the applicable ESE.
The GETS will provide a verification signal upon a correct command and will provide
an error indication upon the receipt of an incorrect signal.

The GETS receives its signal from the LUT computer through the umbilicals
or from the LCC computer through supplementary cables. It processes these signals
through the logic circuits or time delays and supplies responses to each computer.
It also provides monitoring points for analog records and for the LCC RCA-110A
computer discrete monitoring.

During the GETS use, the LUT computer will be disconnected from the DDAS
equipment and connected to the LCC computer. The LCC computer will supply timely
signals as required to simulate the outputs of the DDAS.

Ground equipment test sets for the IU, S-IVB, S-II, and the S-IC stages consist
of four racks each, located near the applicable umbilical connector inside the VAB.

**Overall Test Set.** The OATS will be located close to the GETS equipment at
the various levels in the VAB. This equipment will be used during vehicle test
to simulate those vehicle functions which occur normally only during actual
launch.

The OATS includes typical recorder hardware, distributors, control panels,
test cables, and "dummy" plug substitutes designed to simulate the functions of
the vehicle and its support mechanism which cannot feasibly be performed during
sequential testing of the vehicle and ESE. Propellant tank pressurization and
holddown arms release solenoids are examples of functions to be simulated.

**Stage Interface Substitute.** This equipment will be centrally located in the
VAB to reduce the amount of equipment required to simulate signals passing through
the individual stage interfaces.

The primary purpose of the SIS is to permit testing of the S-IC and IU stages
in the VAB high bay area when other stages of the vehicle are not available. The
SIS electrically simulates the interface connections for any stage that may not
be functional in order that electrical tests may be made of the remaining stages.
Without the SIS, testing of the vehicle would be contingent on all stages being
present and fully operational. With the SIS, however, testing may proceed on
any one or more stages that may be available. During testing, if a stage should
malfunction, the proper section of the SIS may be connected in lieu of the defunct
stage and testing of the other stages may proceed while repairs are made to the
malfunctioning stage.
The interface substitutes are remotely located and connected to the vehicle by cable runs that terminate in plugs mated directly to the stage interface connectors. This provides the proper cable connections for the SIS if a stage malfunction occurs.

All stages of the Saturn V vehicle including the payload and instrument unit will be equipped with a stage interface substitute.

**FUTURE PLANS**

The present mode of checkout of space vehicles with computer-controlled automatic checkout systems has many advantages over previously used checkout methods. There are, however, many areas where much improvement of system and hardware can be achieved.

Projects that are currently being developed or evaluated in an effort to improve the performance of the central checkout complex include the following:

**ESE Simulator**

A general purpose digital computer simulator is being developed. This simulator will be used to prove the validity of the launch vehicle ESE design, to discover where redundancy exists in the system, to perform the failure analysis, and to develop fault location routines.

**Solid State Switching**

Solid state switching devices are being developed to replace relays in control and logic circuitry. These will perform switching, give cleaner wave shapes, contain no moving parts, require less power, and be more reliable than relays for many applications.

**Program Boards Wired By Automatic Machine**

A means of wiring distributor patchboards by automatic program machine methods is being developed. This will reduce required man hours by an order of magnitude.

**Data Evaluation**

The expansion of the capability of the digital events evaluator to monitor analog data is being evaluated. This will reduce the load on the launch computer.

**Automatic Drafting**

An evaluation of automated graphic hardware is being completed as the first step in the development of an automated drafting system.
Electronic Pressure Sensors

A feasibility study of the electronic pressure sensing devices is being performed. This could reduce size and weight while increasing accuracy.

Packaging

Gasket materials are being evaluated that will reduce gas leaks and radio frequency interference when used with low-pressure cabinets.
Figure 2. Typical Relay Module Assembly
Figure 3. Typical Printed Circuit Board Module
Figure 4. Saturn V Launch Complex
DESIGN AND PROCUREMENT

ASSEMBLY

QUALIFICATION & TESTING

PRELANCE & LAUNCH

LAUNCH PADS & VERTICAL ASSY. BLDG.

TRANSPORTER LAUNCHER

LAUNCH CONTROL CENTER

Figure 5. Saturn V Vehicle Flow Diagram
Figure 6. Functional Interconnect Diagram
LAUNCH CONTROL CENTER

• Typical Display Station •