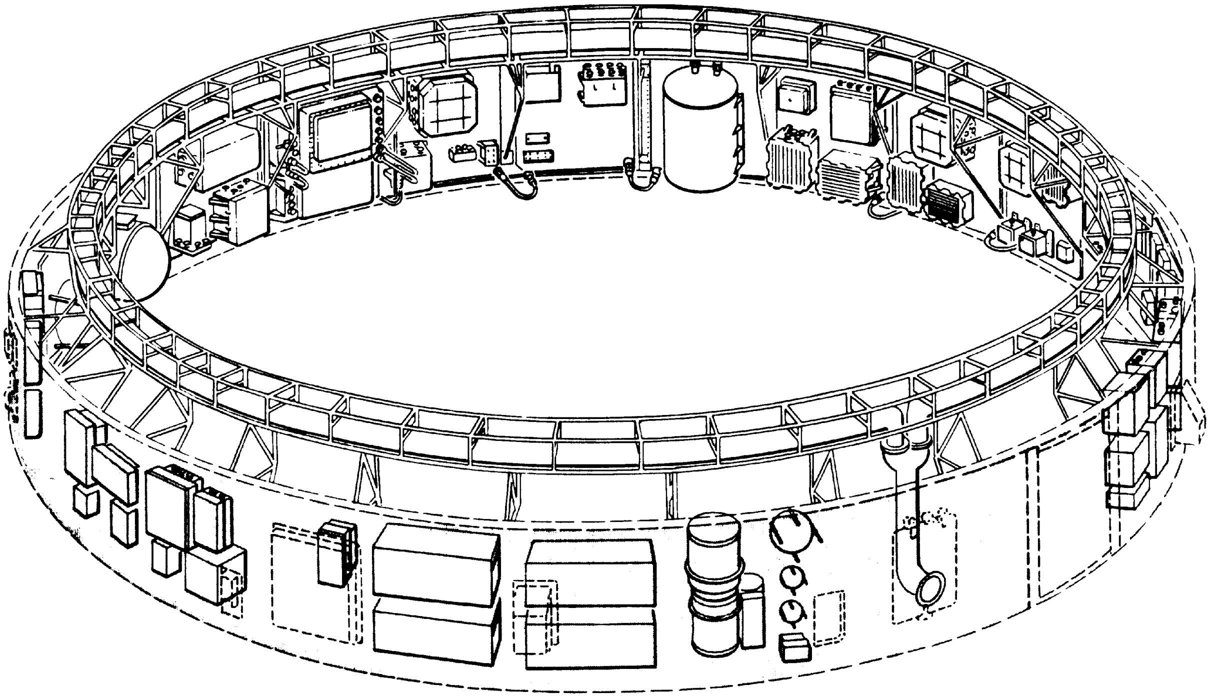
SATURN V NEWS REFERENCE

INSTRUMENT UNIT FACT SHEET



IBM-DR-27

DIAMETER: 260 in.
HEIGHT: 36 in.
WEIGHT: 4,500 lb. (approx.)

MAJOR SYSTEMS

ENVIRONMENTAL CONTROL SYSTEM: Provides cooling for electronic modules and components within the IU and forward compartments of third stage

GUIDANCE AND CONTROL SYSTEM: Determines course of Saturn V through space and adapts that course to fulfill mission requirements

INSTRUMENTATION SYSTEM: Measures vehicle conditions and reactions during mission and transmits this information to ground for subsequent analysis, as well as providing for ground station-to-vehicle communication

ELECTRICAL SYSTEM: Provides basic operating power for all electronic and electrical equipment in the IU; also monitors vehicle performance and may initiate automatic mission abort if an emergency arises

STRUCTURAL SYSTEM: Serves as a load bearing part of the launch vehicle, supporting both the components within the IU and the spacecraft; composed of three 120-degree segments of thin-wall aluminum alloy face sheets bonded over a core of aluminum honeycomb about an inch thick

INSTRUMENT UNIT

INSTRUMENT UNIT DESCRIPTION

The instrument unit (IU) for Saturn V was designed by NASA at MSFC and was developed from the Saturn I IU. Overall responsibility for the IU has been assigned to IBM's Federal Systems Division for fabrication and assembly of the unit, system testing, and integration and checkout of the unit with the launch vehicle. IBM also assembles and delivers computer programming necessary to support the IU. These programs are used:

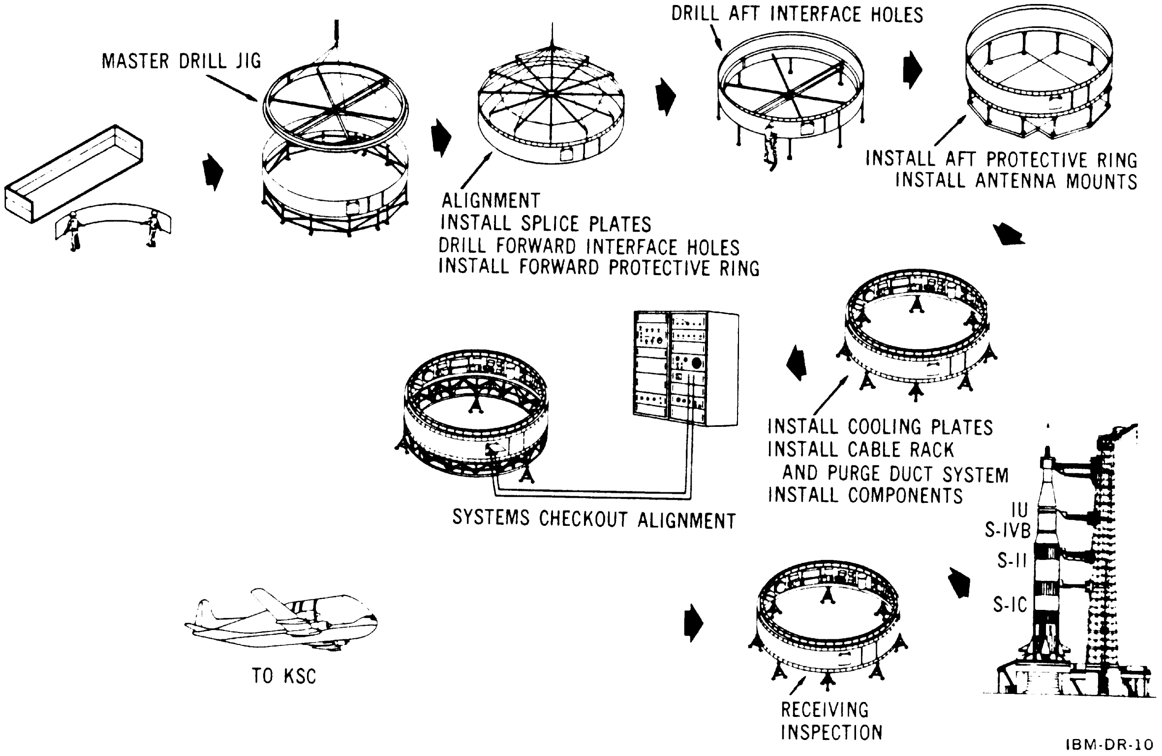
1. In IBM's automated systems checkout computer complex in Huntsville. This system verifies IU system integrity prior to release of the IU to NASA.
2. In IBM's simulation laboratory in Huntsville to verify the flight readiness of the IU's launch vehicle digital computer program, as well as the passive filters contained in the IU's analog flight control computer.
3. To operate the automated launch computer complex at John F. Kennedy Space Center. This computer complex is used to automatically checkout the flight readiness of the vehicle prior to liftoff.
4. To operate the IU's launch vehicle digital computer in flight, as well as programming that will be used by NASA, for postflight analysis of vehicle environment and performance data.

The IU is Saturn V's nerve center. It contains the electronic and electrical equipment needed for guidance, tracking, and origination and communication of vehicle environmental and performance data. The IU also contains environmental control equipment for temperature control, batteries, and power supplies to furnish operating power for electronic equipment.

The stage structure is 260 inches in diameter and 36 inches high and becomes a load-bearing part of the vehicle. It supports the components within the IU and the weight of the spacecraft.

INSTRUMENT UNIT FABRICATION

The structure is manufactured in three, 120-degree segments, each consisting of thin-wall alumi-

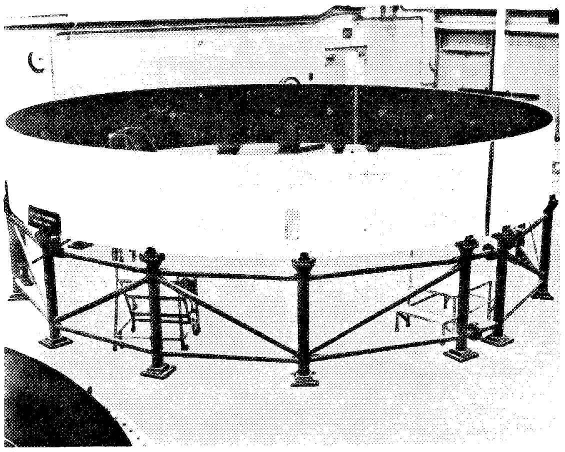


IU Production Sequence

num honeycomb. An aluminum alloy channel ring, bonded to the top and bottom edge of each segment, provides mating surfaces between the IU, the third stage, and the payload adapter. Mounted, inner skin brackets provide attachment points for the environmental control system's cold plates or for cold plate installation.

Segments are aligned and joined by splice plates bolted both inside and outside the joints. A spring-loaded umbilical door provides access to electrical connections between IU equipment and ground test areas. A larger access door, bolted in place, permits personnel to enter the IU after vehicle mating.

Assembly of an IU begins when the three curved structural segments, three feet high by 14 feet long, arrive at IBM's Huntsville, Ala., facility. Each segment weighs only 140 pounds.



IBM-DR-22

Structure Segments—Prior to splicing, mounting brackets for thermal conditioning panels can be seen on interior surface of segments. The exterior of the spring-loaded umbilical door and the access door are visible at right center.

Extremely accurate theodolites, similar to a surveyor's transit, are used to align the segments in a circle prior to splicing. Metal splicing plates join the three segments, and the holes which permit the IU to be joined to mating surfaces of the launch vehicle are drilled at top and bottom edges of the structure for ease in handling. Protective rings are bolted to these edges to stiffen the structure. Vehicle antenna holes are cut after splices are bolted.

After structure fabrication is completed, module and component assembly operations begin. Temperature transducers are fastened to the inner skin, environmental control system (ECS) cold plates are mounted, and a cable tray is bolted to the top of the structure. Components are mounted on the cold plates and ECS system pumps, storage tanks (called accumulators), heat exchangers, and plumbing are installed. Two nitrogen supply systems are installed: one for gas bearings of the inertial platform and the other for pressurization of the ECS. Finally, ducts, tubing, and electrical cables complete the assembly and the IU now weighing in excess of 4,000 pounds is ready for a long series of tests.

INSTRUMENT UNIT SYSTEMS

Environmental Control System

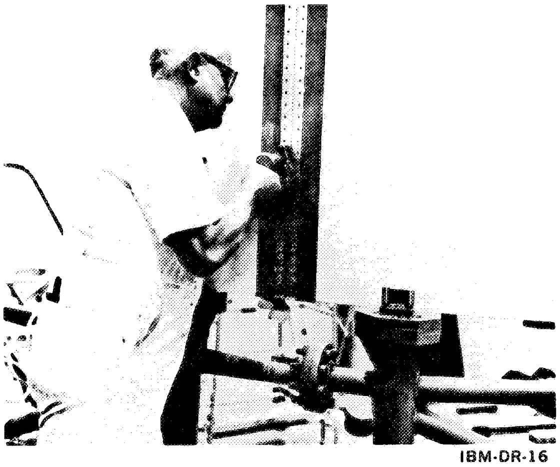
The ECS cools the electronic equipment in the IU and the forward third stage skirt. Sixteen cold plates are installed in each stage.

An antifreeze-like coolant, 60 per cent methanol and 40 per cent water, from a reservoir within the IU is circulated through the cold plates. Heat generated by the mounted components is transferred to the coolant by means of conduction.

Prior to liftoff a preflight heat exchanger serviced by ground support equipment transfers heat from the coolant. Approximately 163 seconds after liftoff, ECS's sublimator-heat exchanger takes over the job of temperature control.

Some of the more complex components like the guidance computer, flight control computer, and the ST-124-M platform, have coolant fluid circulated through them to provide more efficient heat removal.

In the vacuum of space the warmed coolant, after leaving the cold plates, is routed through a device called a sublimator. Water, from an IU reservoir,

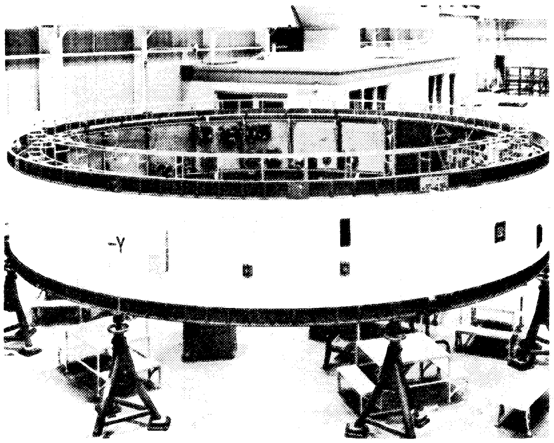


IBM-DR-16

Splice Joint Operations—Final grinding of a splice joint ensures a smooth surface prior to splice plate assembly.

goes to the sublimator and is exposed through a porous plate to the low temperature and pressure of outer space where it freezes, blocking the pores in the plate. The heat from the coolant, transferred to the plate, is absorbed by the ice converting it directly into water vapor (a process called sublimation).

The system is self-regulating. The rate of heat dissipation varies with the amount of heat input, speeding up or slowing down as heat is generated. If the coolant temperature falls below a pre-set level, an electronically controlled valve causes the coolant mixture to bypass the sublimator until the temperature rises sufficiently to require further cooling.



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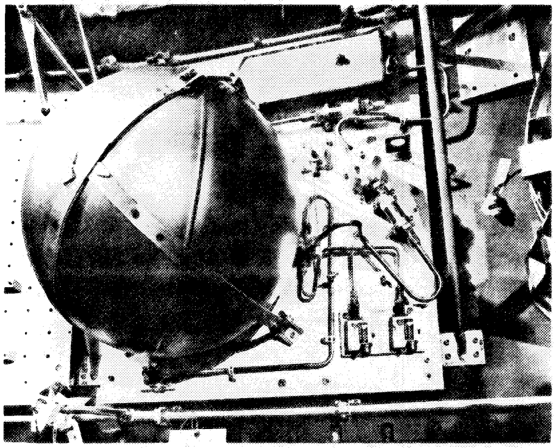
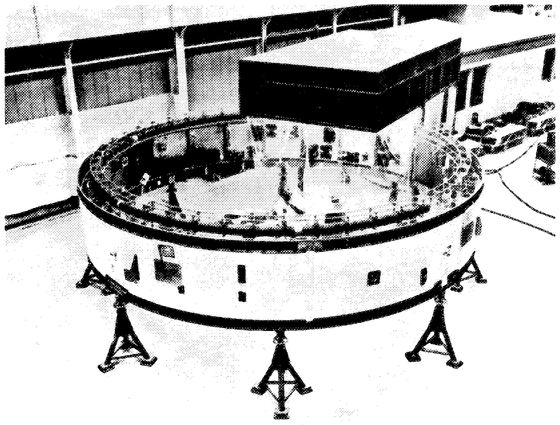
Instrument Unit Assembly in IBM Manufacturing Area—Splicing operations and assembly of the tubular cable tray are complete, the cold plates have been installed, and installation of components is underway.



IBM-DR-21

GN_2 Storage Sphere—In place next to the ST-124-M inertial platform, the sphere holds 2 cubic feet of gas used for gas bearings of the platform. Also visible are a pressure regulator, heat exchanger for warming gas, and pressure indicators.



IBM-DR-23

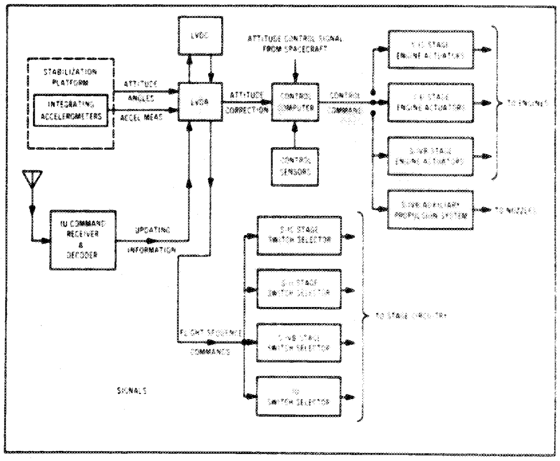
Environment Control—A mobile clean room protects against contamination during assembly of environmental control system components. Gaseous nitrogen will be circulated from a ground supply through the duct partially assembled in the cable tray to purge the IU following vehicle fueling.

Nitrogen gas provides artificial pressure for both coolant solution and sublimator water reservoirs during orbit.

A coolant circulating pump along with the necessary valves and piping to control flow complete the environmental control equipment.

Guidance and Control

The IU's guidance and flight control systems nav-

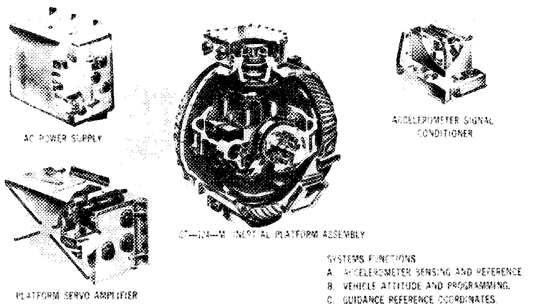


IBM-DR-8

Block Diagram of Guidance and Control System igate (determine vehicle position and velocity), guide (determine attitude correction signals), and control (determine and issue control commands to the engine actuators) the Saturn V vehicle.

Completely self-contained, these systems measure acceleration and vehicle attitude, determine velocity and position and their effect on the mission, calculate attitude correction signals, and determine and issue control commands to the engine actuators. All this is done to place the vehicle in a desired attitude to reach the required velocity and altitude for mission completion.

Major components are an inertial platform, the launch vehicle digital computer (LVDC), the launch vehicle data adapter (LVDA), an analog flight control computer, and control and rate gyros.



IBM-DR-4

ST-124-M Inertial Platform System

Prior to liftoff, launch parameters go to the LVDC.

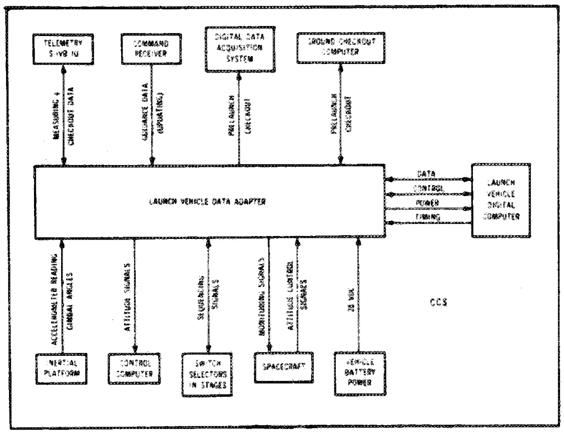
About five seconds before liftoff, the inertial guidance platform and the LVDC are released from ground control. As the vehicle ascends, the guidance platform senses and measures vehicle acceleration and attitude and sends these measurements to the LVDC via the LVDA.

The LVDC integrates these measurements with the time since launch to determine vehicle position relative to starting point and destination. It then computes the desired vehicle attitude, using data stored in its memory, and the difference between the desired attitude and the actual becomes the generated attitude correction signal.

This signal is sent to the analog flight control computer, where it is combined with information from rate gyros. Using this data, the flight control computer determines and issues the command to gimbal the engines and change the thrust direction.

Each mission has at least three phases: atmospheric-powered flight, boost period after initial entry into space, and the coasting period.

Atmospheric boost causes the greatest vehicle load because of atmospheric pressure. During this time the guidance system is primarily checking vehicle integrity and is programmed to minimize this pressure.



IBM-DR-6

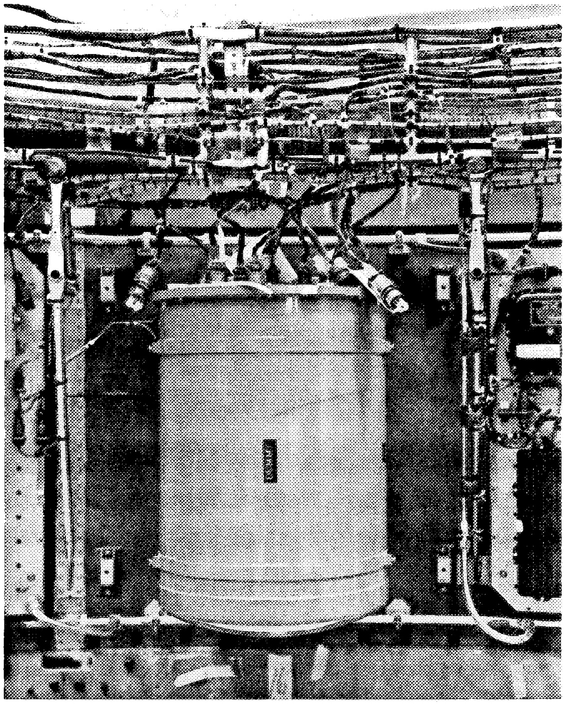
Guidance and Control—The LVDC and LVDA portion of the guidance system is shown in this block diagram. The LVDC receives information from all parts of the vehicle via the LVDA, and in turn issues commands.

The vehicle maintains liftoff orientation long enough to clear the launch equipment, and then it performs a roll maneuver to get to the flight azimuth direction.

The time tilt program is applied after the roll maneuver. The pitch angle is regulated by the tilt program, and is independent of navigation measurements. However, navigation measurements and computations are performed throughout the flight, beginning at the time the platform is released (i.e., five seconds before liftoff). First stage engine cutoff and stage separation are commanded when the IU receives a signal that the tank's fuel level has reached a predetermined point. During second stage powered flight the LVDC guides the vehicle via the best path to reach the mission objectives.

During orbit, navigation and guidance information in the LVDC can be updated by data transmission from ground stations through the IU radio command system.

Approximately once every two seconds, the LVDC, using iterative or "closed loop" guidance, figures vehicle position and vehicle conditions required at the end of powered flight (velocity, altitude, etc.) and generates the attitude correction signals to gimbal the engines so that the vehicle reaches its predetermined parking orbit.



IBM-DR-17

IU Interior During Assembly—The large, cylindrical component simulates size and shape of the flight control computer and is used to check cable lengths and mounting arrangement.

Second stage engine cutoff comes when the IU is signaled that stage propellant has reached a predetermined level, and then the stage is separated. By this time, the vehicle has already reached its approximate orbital altitude, and the third stage burn merely gives it enough push to reach a circular parking orbit.

TRIPLE RELIABILITY

To ensure the accuracy and reliability of guidance information, critical LVDC circuits are provided in triplicate. Known as triple modular redundancy (TMR), the system corrects for failure or inaccuracy by providing three identical circuits. Each circuit produces an output which is voted upon. In case of a discrepancy, the majority rules, and a random failure or error can be ignored. In addition, the LVDC has a duplexed memory, and if an error is found in one portion of the memory, the required output is obtained from the other and correct information read back into both memories, thus correcting the error.

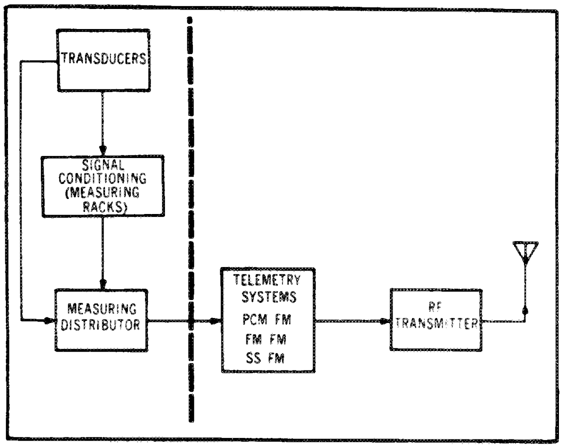
The ST-124-M inertial platform provides signals representing vehicle attitude. Since a signal error could produce vast changes in ultimate position, component friction must be minimized. Therefore, the platform bearings are floated in a thin film of dry nitrogen supplied at a controlled pressure and flowrate from reservoirs within the IU.

PRELAUNCH FUNCTIONS

In addition to guidance computations, other functions are performed by the LVDC and the LVDA. During prelaunch, the units conduct test programs. After liftoff they direct engine ignition and cutoff, direct stage separations, and conduct reasonableness tests of vehicle performance. During earth orbit, the computer directs attitude control, conducts tests, isolates malfunctions, and controls transmission of data, plus the sequencing of all events.

Instrumentation

A basic requirement for vehicle performance analysis and for planning future missions is knowing what happened during all phases of flight and just how the vehicle reacted. The IU's measuring and telemetry equipment reports these facts. Measuring sensors or transducers are located throughout the vehicle monitoring environment and systems' performance.



IBM-DR-1

Measuring and Telemetry

Measurements are made of mechanical movements, atmospheric pressures, sound levels, temperatures, and vibrations and are transformed into electrical signals. Measurements also are made of electrical signals, such as voltage, currents, and frequencies which are used to determine sequence of stage separation, engine cutoff, and other flight events and to determine performance of onboard equipment.

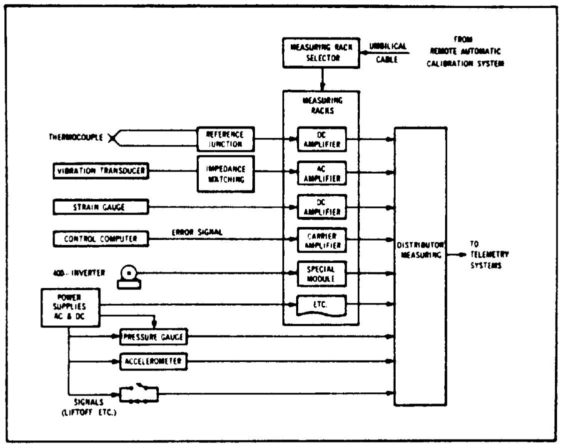
In all, the IU makes several hundred measurements. A wide variety of sensors are used to obtain all kinds of information required: acoustic transducers monitor sound levels; resistor or thermistor transducers monitor temperature environments; bourdon-tube or bellows transducers measure pressures; force-balance, or piezoelectric accelerometers measure force levels at critical points; flow meters determine rates of fluid flow.

Various measuring devices produce a variety of outputs, and before these outputs can be effectively utilized, they must be standardized to some extent. Signal conditioning modules are employed to adapt transducer outputs to a uniform range of 0-5 VDC.

Different types of data require different modes of transmission, and the telemetry portion of the system provides three such modes: SS/FM, FM/FM, and PCM/FM. Each type of information is routed to the most suitable telemetry equipment; a routing is performed by the measuring racks within the IU.

To get the most out of the transmission equipment, multiplexing is employed on some telemetry channels. Information originated by various measuring devices is repeatedly sampled by multiplexers, or commutators, and successive samples from different sources are transmitted to earth.

Information sent over any channel represents a series of measurements made at different vehicle points. This time-sharing permits large chunks of data to be handled with a minimum amount of equipment. The LVDC also helps in data transmission. For instance, when the vehicle is between ground receiving stations, the LVDC stores important PCM data for later transmission. Once the vehicle leaves the earth's atmosphere, sound levels requiring air for continuance no longer exist. The LVDC signals a measuring distributor to switch from unimportant measurements to those more critical to the mission. And during stage separation retrorocket firing, when flame attenuation distorts or destroys telemetry transmissions, signals are automatically recorded by an onboard tape recorder, and transmitted later.



IBM-DR-2

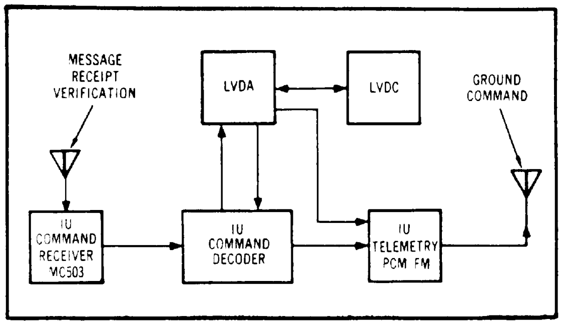
Typical Saturn Measuring System

In order to monitor vehicle performance, ground controllers must know the vehicle's precise position at all times. The RF section of the instrumentation system provides this capability, as well as linking the IU's guidance and control equipment during flight.

TRACKING SYSTEM

Several tracking systems are used to follow vehicle trajectory during ascent and orbit. Consolidation of this data not only increases data reliability, but gives the best trajectory information.

Vehicle antennas and transponders, which increase ground-base tracking systems' range and accuracy, make up the IU's tracking equipment.



IBM-DR-7

Saturn V Instrument Unit Command System

A pulse or series of pulses of RF energy sent by ground stations to the vehicle's general direction will interrogate the airborne transponder. In response, the transponder produces a pulse or series of pulses. Triangulation between precisely located ground stations determines point of origin of these reply pulses and fixes location of the vehicle.

Three tracking systems are employed in conjunction with the Saturn V IU: AZUSA, C-band radar, and the S-band portion of the command and communication system (CCS). Two C-band transponders are employed to provide tracking capabilities for this system independent of vehicle attitude. A single transponder is employed with the AZUSA system.

Real-time navigation, needed to update the guidance system, is received in the IU by a radio command link. But before it is sent, and before it is accepted in the IU, both ground equipment and IU instruments scrutinize update information for accuracy. The slightest error in transmission could conceivably produce a greater problem than if the original data had been left alone.

The message goes from antenna to command receiver for amplification and demodulation. Then it is routed to the decoder for breakout into the original pattern of digital bits.

The first validity check is here. If there is an error in a bit, or a bit is missing, the entire message is rejected. Accepted commands get further checking in the command decoder and in the LVDC.

First the vehicle address is checked in the command decoder. This is important because commands for both IU instruments and the spacecraft use similar command links. If the spacecraft address is recognized, the IU ignores the message.

Passing this test, the message is sent to the LVDC. Upon receipt, the LVDC tests the message to determine if it is proper. If it is, then the command decoder releases a pulse via the telemetry link to the ground station verifying message acceptance. If the message fails the test, the LVDC rejects it and telemeters an error message.

Depending on the mission, several types of messages can be processed. For example: commands to perform updating, commands to perform tests, commands to perform special subroutines or special modes of operation, a command to dump or clear certain sectors of the computer memory, or a command to relay a particular address in the computer memory to the ground. Provisions have been made to expand the number of types of messages if experience indicates this is necessary.

SWITCH SELECTOR

All stages, and the IU, are equipped with a switch selector. This unit has electronic and electromechanical components which decode LVDC/LVDA sequence commands and switches them to the proper circuits en each stage. This system has several advantages: reduction of stage interface lines, increased flexibility with respect to timing and sequencing, and conserving the discrete output circuitry in the LVDC/LVDA. Sequencing commands can come as fast as every 100 milliseconds.

Stage power isolation is maintained in the switch selector by using relays as the input circuit. The relays are driven by IU power, while the decoding circuitry and driver output are powered from the parent stage. Input and output are coupled through relay contacts. These contacts drive a diode matrix used in decoding the 8-bit input code to select the output driver, producing the switch selector output.

There also is a check and proceed system built into the switch selector. After the switch selector relays have been "picked," the complement of the received message is fed back to the LVDA/LVDC where it is checked. If the feedback is good, a read command is issued. If there is disagreement, a new message is sent which accomplishes the same function. (Note: For redundancy, two messages' codes are assigned for each switch selector output).

Electrical System

The electrical system powers the IU's equipment. As with most of the IU's systems, the electrical system is divided into two sectors: prelaunch and flight. Ground sources provide power through the umbilical lines before launch. At approximately 25 seconds prior to liftoff, power is transferred to the four 28 VDC IU batteries. Each battery has a 350 ampere hour capacity, and loads are equally distributed to drain.

Two special power supplies are provided: a 5-volt master measuring voltage supply converts 28 VDC main supply to a highly regulated 5 VDC for reference and supply voltage to the measuring components, and a 56-volt power supply for operation of the guidance system's ST-124-M inertial platform and the platform's AC power supply.

In order to get the most out of the battery stored power during flight, the LVDC and LVDA turn off unused or unimportant circuits in favor of more important applications as the mission progresses.

EMERGENCY DETECTION EQUIPMENT

The Saturn V is equipped with a myriad of equipment designed to detect malfunctions. Some of this equipment checks engine thrust, and monitors guidance computer status, attitude rates, angle of attack, and abort request.

This emergency detection information is flashed to the IU where it is routed to the emergency detection distributor (EDS) in the electrical system. The EDS distributor is an interconnector and switching point and has the logic circuits which determine the emergency. In case of a malfunction, the equipment will turn on a light in front of the astronauts. If the spacecraft abort selector switch is in the automatic abort position, the abort will take place without further crew participation; the action cannot be vetoed by the astronauts. However, if the selector switch is in the manual position, the crew, consulting with NASA flight controllers, decides when to abort a mission.