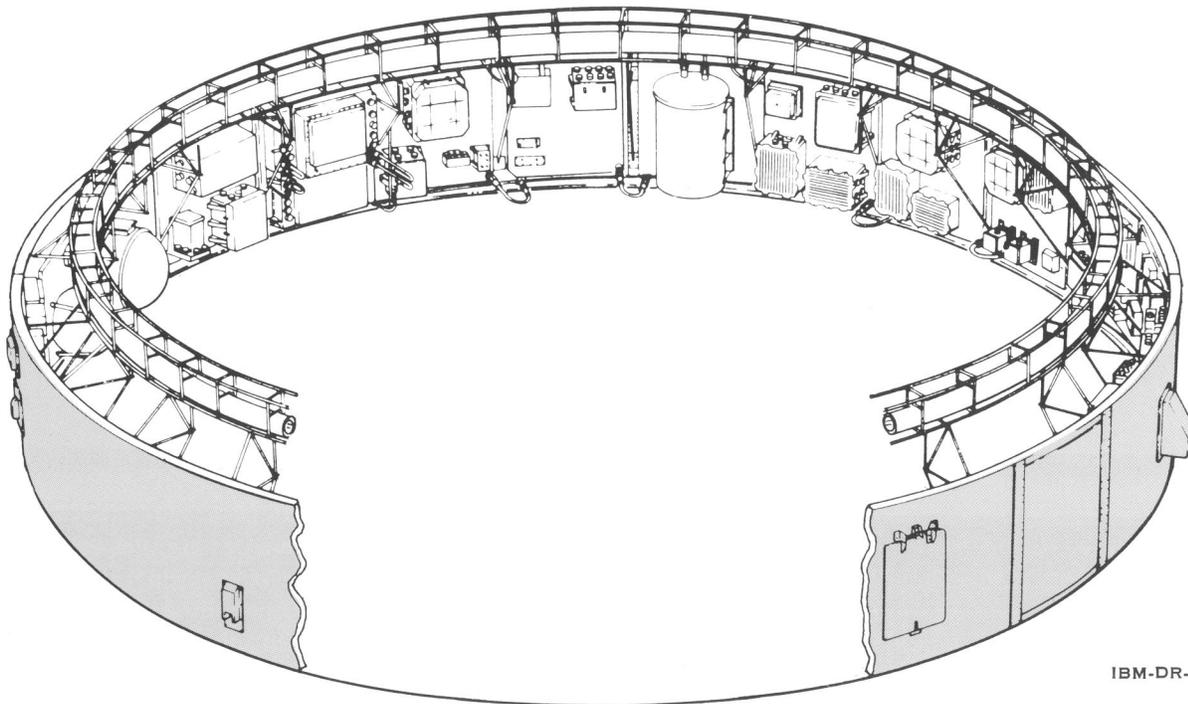


INSTRUMENT UNIT FACT SHEET



IBM-DR-9

DIAMETER: 260 in
HEIGHT: 36 in
WEIGHT: 4,100 lb (approx)

MAJOR SYSTEMS

ENVIRONMENTAL CONTROL SYSTEM: Provides cooling for electronic modules and components within the IU and forward compartments of S-IVB stage.

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

MEASURING AND TELEMETRY SYSTEM: Measures vehicle conditions and reactions during mission, and transmits this information to ground for subsequent analysis.

RADIO FREQUENCY AND TRACKING SYSTEM: Provides for ground station-to-vehicle communication.

ELECTRICAL SYSTEM: Provides basic operating power for all electronic and electrical equipment in the IU.

EMERGENCY DETECTION SYSTEM: Monitors vehicle performance, and may initiate automatic mission abort if an emergency arises.

INSTRUMENT UNIT

INSTRUMENT UNIT DESCRIPTION

The Instrument Unit (IU) for Saturn IB was designed by NASA at MSFC, and was developed from the Saturn I IU. Overall responsibility for the IU is being assigned to IBM 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 "software" necessary to support the IU. Software packages include computer programs necessary to simulate mission conditions and predict vehicle performance, operate automated checkout equipment, guide the vehicle in flight, and post-flight reduction and analysis of vehicle environment and performance data.

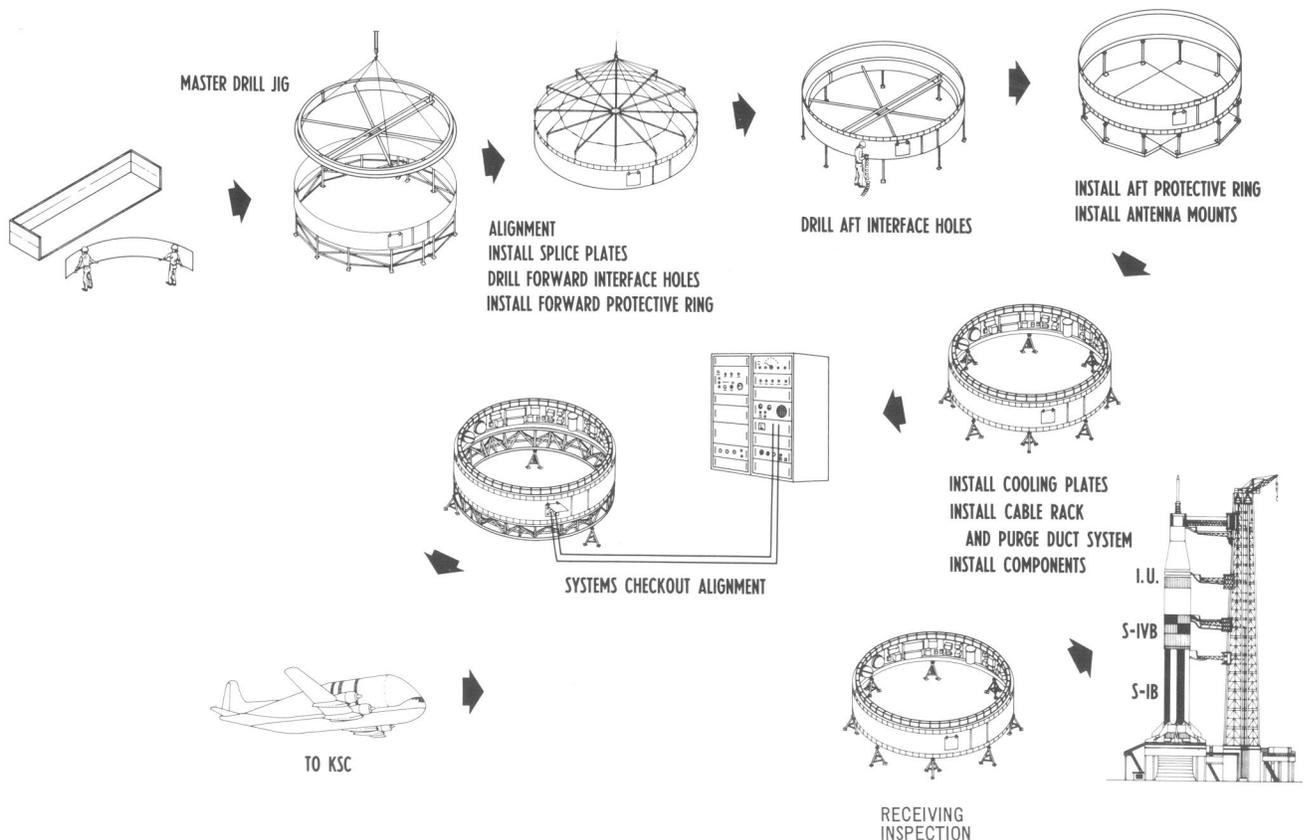
The IU is the nerve center of the Saturn IB. It contains electronic and electrical equipment necessary for guidance, tracking, and origination and communication of vehicle environmental and performance data. The IU also contains environmental control equipment for heat dissipation, and batteries and power supplies which furnish basic operating power for electronic equipment.

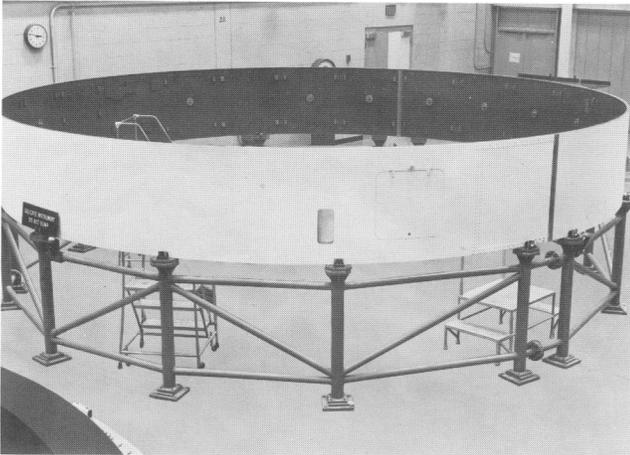
The stage structure is 260 inches in diameter and 36 inches high, and becomes a load-bearing part of the vehicle. It supports the components within the IU, and the weight of the spacecraft.

INSTRUMENTATION UNIT FABRICATION AND ASSEMBLY

The structure is manufactured in three 120 degree segments, each consisting of thin-wall aluminum alloy face sheets bonded over a core of aluminum honeycomb. An aluminum alloy channel ring, bonded to the top and bottom edge of each segment, provides mating surfaces between the IU, the S-IVB stage, and the payload adapter. Brackets mounted on the inner skin of each segment provide attachment points for the cold plates of the environmental control system, or for components not suitable for cold plate installation.

Segments are precisely aligned and joined by means of splice plates bolted to the inner and outer surface of each joint. This spliced-joint design provides a structure of great strength that may be easily disassembled for packaging and shipping. A spring-loaded umbilical door in the structure provides for electrical connections





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.

between equipment within the IU and ground test areas. A larger access door, bolted in place, permits personnel to enter the IU after it is mated to the launch vehicle.

Manufacture of an IU begins with the arrival of three curved structural segments three feet high by 14 feet long at IBM's Huntsville, Alabama, facility. Each segment weighs only 140 pounds.

Extremely accurate theodolites similar to a surveyor's transit are used to precisely align the segments in a circle prior to splicing. Metal splicing plates are attached at each of the three joints, 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. Protective rings are bolted to these edges to stiffen the structure. Following completion of splices, holes are cut through the structure for vehicle antennas.

When fabrication of the structure is completed, IU module and component assembly operations are started. Temperature transducers are fastened to the inner skin; thermal conditioning panels (cold plates) are then mounted, and a cable tray is installed around the top of the structure. Components are mounted on the thermal conditioning panels, and thermal conditioning system pumps, storage tanks (called accumulators), heat exchangers, and plumbing are installed. A nitrogen supply system is installed for gas bearings of the inertial platform and pressurization of the environmental control system. 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.

INSTRUMENTATION UNIT SYSTEMS

Environmental Control System

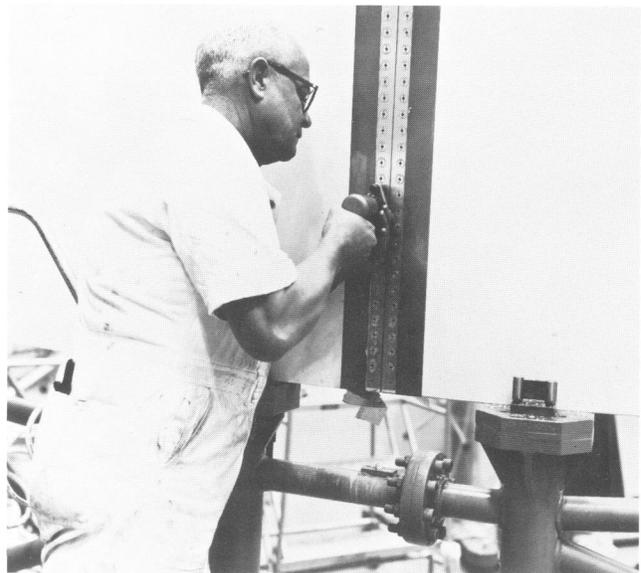
The environmental control system provides for cooling electronic modules and components within the IU and the forward compartment of the S-IVB stage through 32 thermal conditioning panels, or cold plates, secured to the inner skin of the IU and S-IVB skirt.

Coolant from a reservoir within the IU is circulated through the cold plates to provide heat transfer from electronic components mounted on the plates. The coolant is a solution of 60 per cent methanol and 40 per cent water.

Prior to liftoff, heat is removed from the coolant by a preflight heat exchanger serviced by ground support equipment. After launch vehicle attains altitude, heat dissipation is accomplished by a sublimator-heat exchanger.

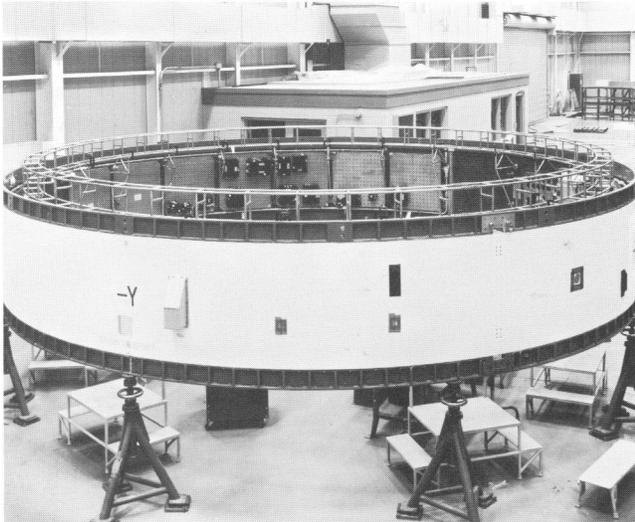
In the sublimation process, water is passed through porous plates and the sublimator side of the heat exchanger, which are exposed to the low temperature and pressure of outer space and freezes, blocking the pores of the plate. Heat from the coolant is transferred through the plate to be absorbed by the ice, which sublimates to water vapor.

The system is self-regulating in that the rate of heat dissipation varies directly with the amount of heat input, speeding up or slowing down as more or less 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 cooling again.



IBM DR 16

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

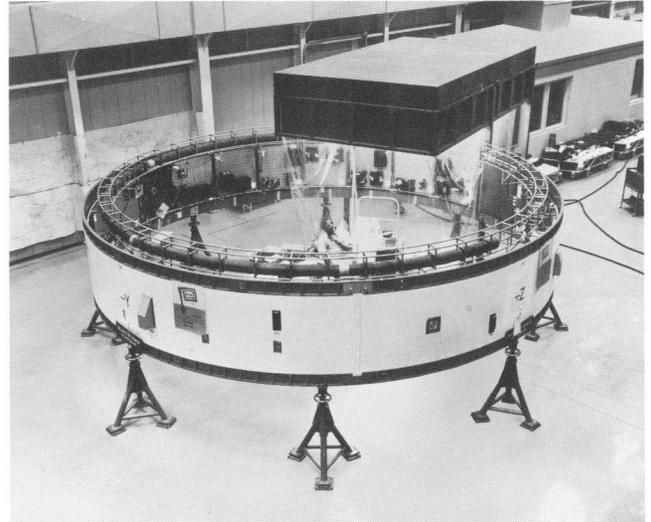


IBM DR 19

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. Forward and aft protective rings will remain in place until the unit is mounted on the launch vehicle. Objects protruding from the outer skin are flight antennas.

A supply of nitrogen gas is provided to maintain artificial pressure in the reservoirs for both the coolant solution and sublimator water during periods of weightless flight. Nitrogen from this supply is also provided to the gas bearing of the ST-124-M inertial platform.

A pump circulates the coolant, and the necessary valves and piping to control its flow complete the environmental control equipment.



IBM DR 23

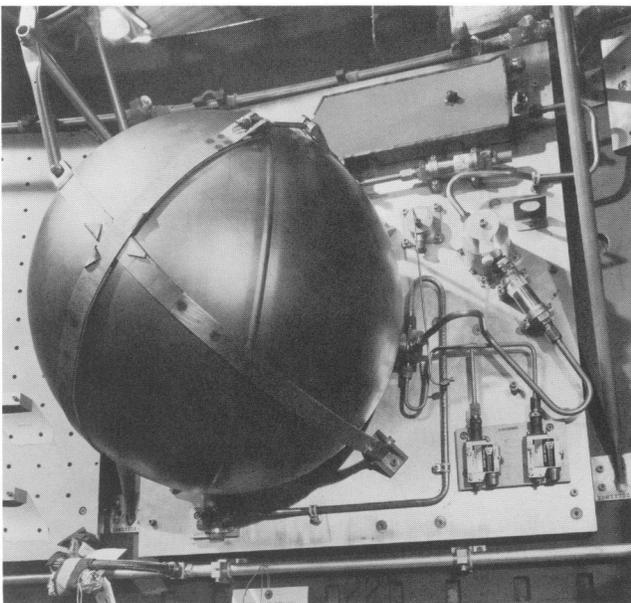
Instrument Unit — A mobile clean room protects against contamination during assembly of environmental control system components. Gaseous nitrogen will be circulated from a ground supply through the duct partially assembled in the cable tray to purge the IU following vehicle fueling.

Guidance and Control System

The guidance and control system navigates by determining vehicle position and velocity from measurements made on board, guides by computing maneuvers necessary to achieve the desired end conditions of trajectory and controls by executing maneuvers to control the proper hardware. These functions are performed in a manner to accomplish mission success with a minimum of propellant consumption. In addition, the system avoids excessive structural loads caused by aerodynamic flow and wind during ascent through the dense portion of the atmosphere, and during vacuum flight controls maneuvers to assure that structural bending and propellant sloshing are not dangerously excited by maneuvers.

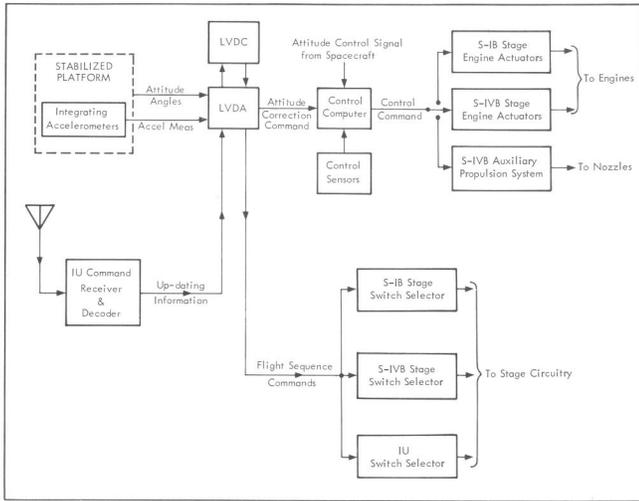
Three major components or subsystems comprise the system: an inertial platform (ST-124-M); a high speed digital computer, and an analog control computer.

Prior to launch, parameters that define a particular launch window are fed into the launch vehicle digital computer (LVDC) and the ST-124-M platform is erected to a true vertical and aligned to launch azimuth. Just prior to liftoff the platform is released and becomes space fixed oriented. Vehicle acceleration is sensed and measured to be integrated with time since launch. These integrated inputs are used to determine vehicle position to its starting point and intended destination, burn time for engines, and direction of thrust required to arrive at the proper altitude and velocity at the required point in space.



IBM DR 21

GN₂ 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 8

Block Diagram of Guidance and Control System

GUIDANCE AND CONTROL FUNCTIONS

The flight control computer generates the proper control commands for the engine actuators and the S-IVB auxiliary propulsion system. This is accomplished by processing and combining signals from the LVDC, control sensors, and spacecraft.

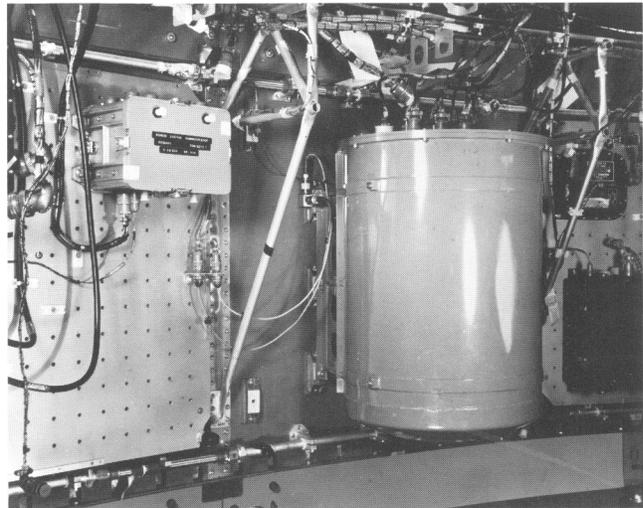
During first stage powered flight, the vehicle lifts off vertically from the launch pad and maintains its liftoff orientation long enough to clear the ground equipment. It then performs a roll maneuver to align the vehicle with flight azimuth direction. This maneuver gives the vehicle control axes the correct alignment to the flight plane thus simplifying the computations in the attitude control loop. On the launch pad, the vehicle always has a roll orientation fixed to the launching site.

During first-stage propulsion, a time tilt program, stored in the LVDC, is applied simultaneously with the described roll maneuver. The pitch angle of the vehicle is commanded according to the tilt program which is a function of time only 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., 5 seconds before

liftoff). Cutoff of the first stage engines occurs when the fuel level in the tanks reaches a predetermined level. Thereafter, the first stage is separated from the launch vehicle.

After ignition of the S-IVB stage, adaptive guidance (i.e., the iterative guidance mode) is used during all propellant flight phases of the mission. The iterative guidance mode computes the pitch and yaw angle of the required direction to guide the vehicle on a minimum propellant trajectory into the predetermined orbit.

During orbital coast flight, the navigation program continually computes the vehicle position and velocity from the equations of motion based on insertion conditions. Attitude of the vehicle roll axis in orbit is maintained at 90 degrees with respect to the local vertical. The local vertical is determined from navigational computation.



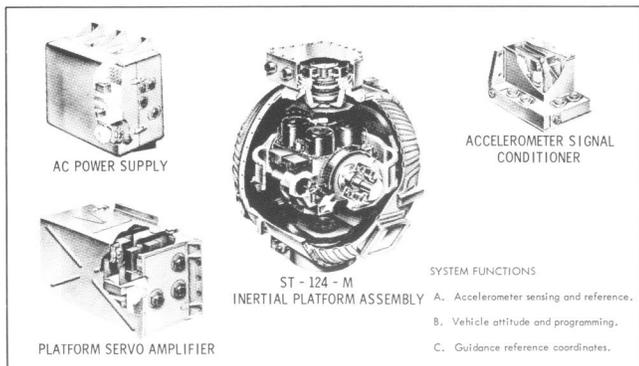
IBM DR 17

Instrument Unit 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. Use of nonflight hardware such as this during initial assembly minimizes handling of critical flight components.

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

TRIPLE RELIABILITY

To ensure the accuracy and reliability of information supplied by the guidance and control system, critical circuits in the LVDC are provided in triplicate. Known as triple modular redundancy (TMR), this system corrects for failure or inaccuracy of a particular circuit by providing three identical circuits. Each circuit produces an output which is then voted upon. In case of a discrepancy in these outputs, the majority rules, and a random failure or error can be ignored. In addition, the computer memory



IBM DR 4

ST-124-M Inertial Platform System

is duplexed and if an error is found in one portion of the memory, the required output is obtained from the other memory and correct information read back into both memories, thus correcting the error.

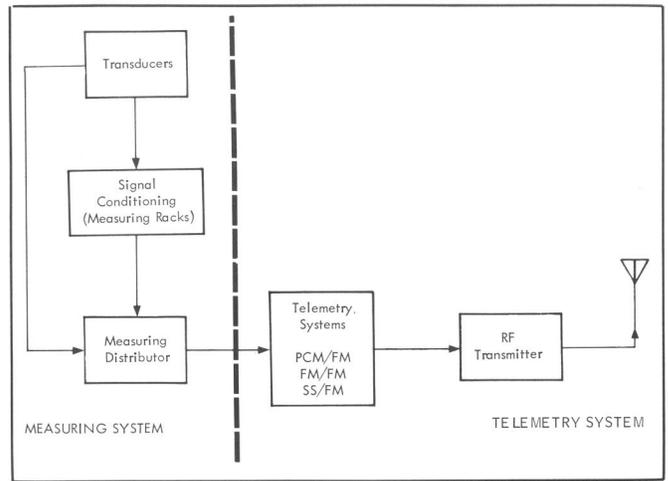
The ST-124-M inertial platform provides signals representing vehicle attitude. Since a small error in these signals could produce an intolerable error in ultimate vehicle position, friction in these components must be held to an absolute minimum. To this end, their bearings are floated in a thin film of dry nitrogen supplied at a controlled pressure and flow rate from reservoirs within the IU.

PRELAUNCH FUNCTIONS

In addition to guidance computations, other functions are performed by the launch vehicle digital computer and the launch vehicle data adapter (LVDA). During prelaunch, the units conduct test programs; during launch phase they direct engine ignition and cutoff, stage separations, and conduct reasonableness tests of vehicle performance. During earth orbit, the computers direct attitude control, conduct tests, isolate malfunctions, and control transmission of data.

Measuring and Telemetry System

A basic requirement for vehicle performance evaluation and for planning of future missions is a knowledge of conditions encountered during each mission, and vehicle reaction to those conditions. This requirement is satisfied by the IU's measuring and telemetry system. Measuring sensors, or transducers, are located throughout the vehicle to monitor environment and systems' performance.



Measuring and Telemetry System

IBM DR 1

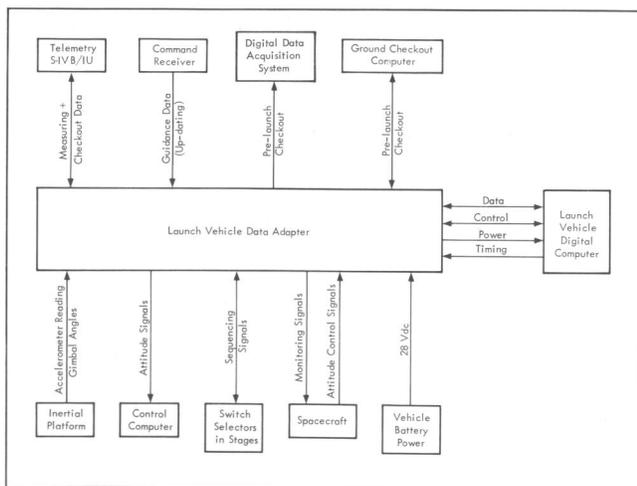
Measurements are made of physical quantities such as mechanical movements, atmospheric pressures, sound levels, temperatures, and vibrations, and are transformed into electrical signals. Measurements are also made of existing electrical signals, such as voltage, currents, and frequencies which are used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

Approximately 200 measurements are made within the IU. A wide variety of sensors are employed to obtain different types 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 within a uniform range of 0-5 volts dc.

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 efficient telemetry equipment; a routing performed by the measuring racks within the IU.

To provide for maximum utilization of transmission equipment, multiplexing is employed on all telemetry channels. Information originated by various measuring devices is repeatedly sampled by multiplexers, or commutators, and successive



IBM DR 6

Block Diagram of Guidance and Control System—The guidance and control system's LVDA and LVDC receive information from all parts of the vehicle and issue commands based on the evaluation of incoming data in accordance with previously stored instructions.

samples from different sources are transmitted to earth.

Information transmitted over any channel represents a series of measurements made at different points within the vehicle, and this time sharing permits a large amount of data to be handled with a minimum of communication equipment.

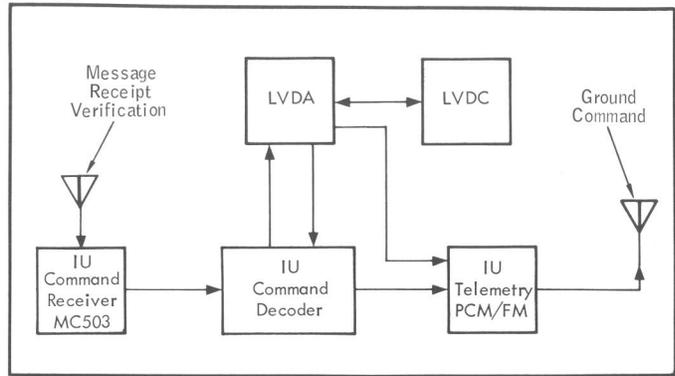
To further increase the amount of data which can be effectively handled, the LVDC is employed to sequence transmission of certain measurements. For instance, once the vehicle has left earth atmosphere, sound levels requiring air for propagation no longer exist, and the LVDC can signal a measuring distributor to switch from an unused or relatively unimportant measurement to those that are more critical for that flight phase. During retrorocket firing, when flame attenuation distorts or destroys telemetry transmissions, signals are automatically recorded by an onboard tape recorder, and retransmitted later.

To effectively monitor vehicle performance it is necessary to determine precise position of the vehicle at any instant and to track its flight path. The RF system of the IU provides this capability, as well as providing communication with the vehicle's guidance and control equipment during flight.

Several tracking systems are used to determine vehicle trajectory during powered ascent and orbital flight. Consolidation of data supplied by different systems provides best possible trajectory information and increases reliability of data.

Tracking System

Tracking equipment located within the IU consists of vehicle antennas and transponders, which



Saturn IB Instrument Unit Command System

IBM DR 7

serve to increase range and accuracy of ground-based tracking systems.

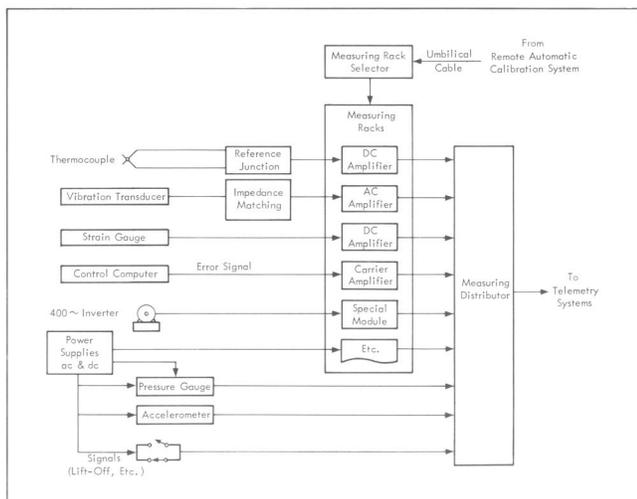
A pulse or series of pulses of RF energy transmitted by ground stations in the general direction of vehicle in flight serves to interrogate the airborne transponder. Responding to this query from the ground, the transponder produces a pluse or series of pulses in turn. Triangulation between precisely located ground stations determines point of origin of these reply pulses and fixes location of the vehicle.

Two tracking systems are employed in conjunction with the Saturn IB IU: AZUSA and C-band radar. 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.

To provide for updating of information in the guidance system, based on real-time evaluation of data obtained from the tracking system or other significant inputs, a radio command link with the vehicle in flight is provided. It is imperative that data transmitted by the ground station is received and interpreted correctly. Any error in updating information could conceivably create a more serious problem than the original information being corrected.

Extensive verification is employed on the ground to ensure that the transmitted message is correct. Similar verification is provided within the IU to ensure that the message received agrees with the message transmitted. The incoming message is accepted only after this verification process is completed.

An incoming message is routed from the system antenna to the command receiver, where it is amplified and demodulated. The message is sent from the receiver to the command decoder for decoding into original pattern of digital bits. First check of message validity occurs here: if



Typical Saturn Measuring System

IBM DR 2

a deviation in bits or a missing bit is detected, the entire message will be rejected. If the command is accepted, it is subjected to a further verification.

First, the vehicle address supplied as part of each command is checked. This address is necessary to differentiate between commands intended for the IU and those intended for use within the vehicle spacecraft—both use similar command links.

If the address is valid, establishing that this message is intended for the IU, the message is then checked to determine intended routing of the command within the guidance system. If no discrepancy is noted, the command is furnished to the LVDA, where it is held for action by the LVDC.

At the same time that the message is released to the LVDA, the command decoder relays a pulse through a telemetry link with the ground station to indicate that a message has been received and processed. A similar pulse is generated by the LVDA to confirm its receipt of the completed message.

Data intended for updating information in the LVDC is stored in the LVDC and read out to telemetry as an additional safeguard against introduction of erroneous information. These bits are sent to the Manned Space Flight Control Center, where they are compared with the message originally transmitted by the ground station. If all bits are verified, an execute command is transmitted. The LVDC will act upon the update data message only upon receipt of this command.

Seven types of messages can be processed: updating LVDC; commands to perform updating; commands to perform tests, special subroutines or special modes of operation; a command to dump or clear certain sectors of the computer memory; and 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.

Electrical System

The IU electrical system provides power to operate equipment of other systems. In addition, the electrical system contains the emergency detection system (EDS) distributor for detecting abnormal conditions affecting safety of the mission. If severe abnormal conditions are encoun-

tered, an automatic abort will be initiated. When less severe abnormality occurs, the electrical system will provide an indication which may be used as a basis for an abort, if deemed necessary.

Similar to other systems of Saturn IB, operation of the electrical system can be divided into two phases: prelaunch and flight. Electrical power during prelaunch is furnished from ground sources through the IU umbilical connection.

At approximately 25 seconds prior to liftoff, a signal originated in the launch control center transfers power to four 28 vdc batteries mounted within the IU. Each battery has a capacity of 300 ampere hours and is capable of operating to an altitude of 15,000 nautical miles above earth. Loads are distributed over the four batteries to equalize drain on each battery and to provide a redundant power source in the event of battery failure.

Two special power supplies are provided: a 5-volt master measuring voltage supply converts 28 vdc main supply to a highly-regulated 5 vdc to be used as a reference and supply voltage for the components of the measuring system; and a 56-volt power supply provides for operation of the guidance and control system's ST-124-M inertial platform.

To provide maximum power utilization with a minimum penalty in battery weight, selective power application is employed throughout vehicle flight. The guidance system's LVDC and LVDA control switching operations, to turnoff unused or unimportant circuits in favor of more important applications as the mission progresses.

Emergency Detection System

The emergency detection equipment monitors thrust for both stages of the vehicle, guidance computer status, angular attack rates, attitude error, and angle of attack. This information is sent to the IU electrical system where it is processed by the emergency detection system (EDS) distributor.

The EDS distributor serves as an interconnecting and switching point, and contains the logic circuits which must decide the nature of an emergency. Serious difficulty allowing no time for human intervention will initiate an automatic mission abort; less urgent problems will result in a visual display in the spacecraft, allowing the astronaut to decide whether an abort is necessary.