NASA

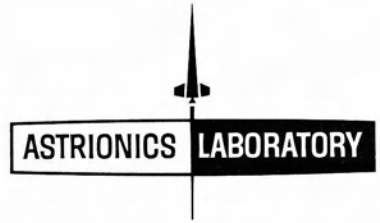
SATURN 1B / V

instrument unit...

M S F C

GEORGE C. MARSHALL SPACE FLIGHT CENTER / HUNTSVILLE, ALABAMA

ASTRIONICS LABORATORY

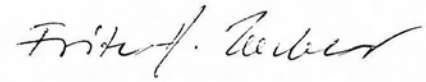


introduction...

This brochure provides some basic, general information about the **Instrument Unit,** a very important part of the Saturn IB and Saturn V launch vehicles. These launch vehicles are being developed primarily for the Apollo program for manned lunar exploration but will also be used for future space missions.

The **Instrument Unit** development is based on rather novel design concepts. For example, there is only one type of **Instrument Unit** with almost identical instruments serving two different launch vehicles—the Saturn IB and the Saturn V. The different components of the Instrument Unit are being developed as "building blocks" to allow the Instrument Unit to meet various missions by allocation of the required building blocks. However, many mission variations can be achieved by changing the program for the digital computer.

The **IU** may appear as a rather small part of a very large launch vehicle, but this small size is by no means a scale for its importance. In fact, it is considered the "brain" or "nerve center" of the vehicle and contains most of the instruments and systems for navigation, guidance, control (auto pilot), range safety, telemetry, tracking, and others.



FRITZ H. WEBER
Chief / Project Engineer
Instrument Unit

SATURN 1B/V IU ASTRIONICS SYSTEM

...major systems

1 STRUCTURAL

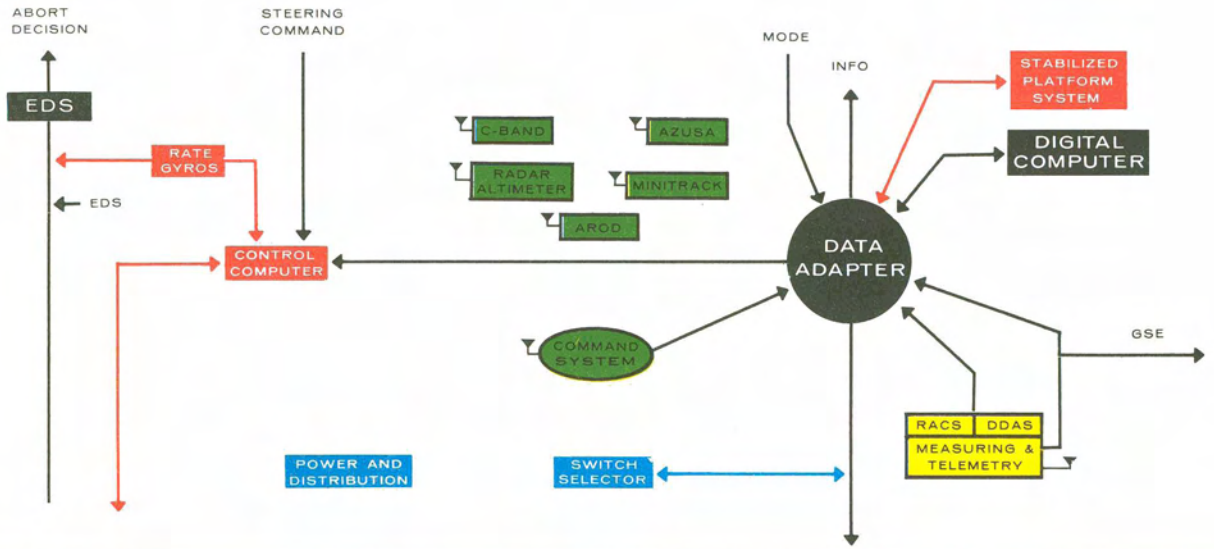
2 ENVIRONMENTAL CONTROL

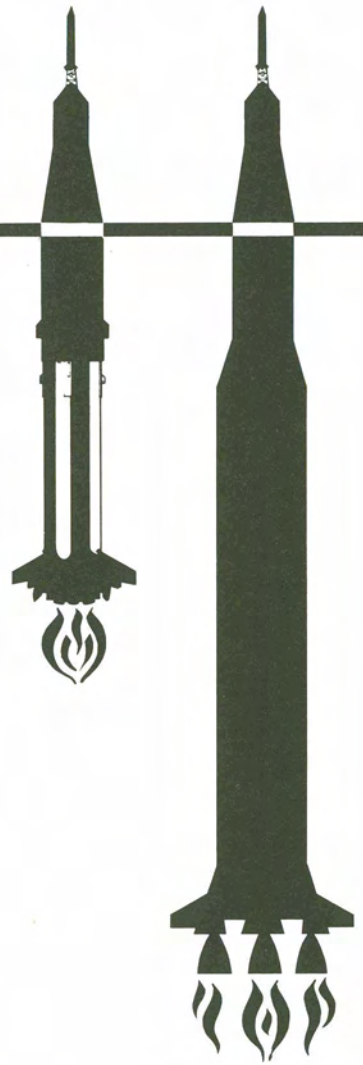
3 GUIDANCE AND CONTROL

4 MEASURING AND TELEMETRY

5 RADIO FREQUENCY

6 ELECTRICAL

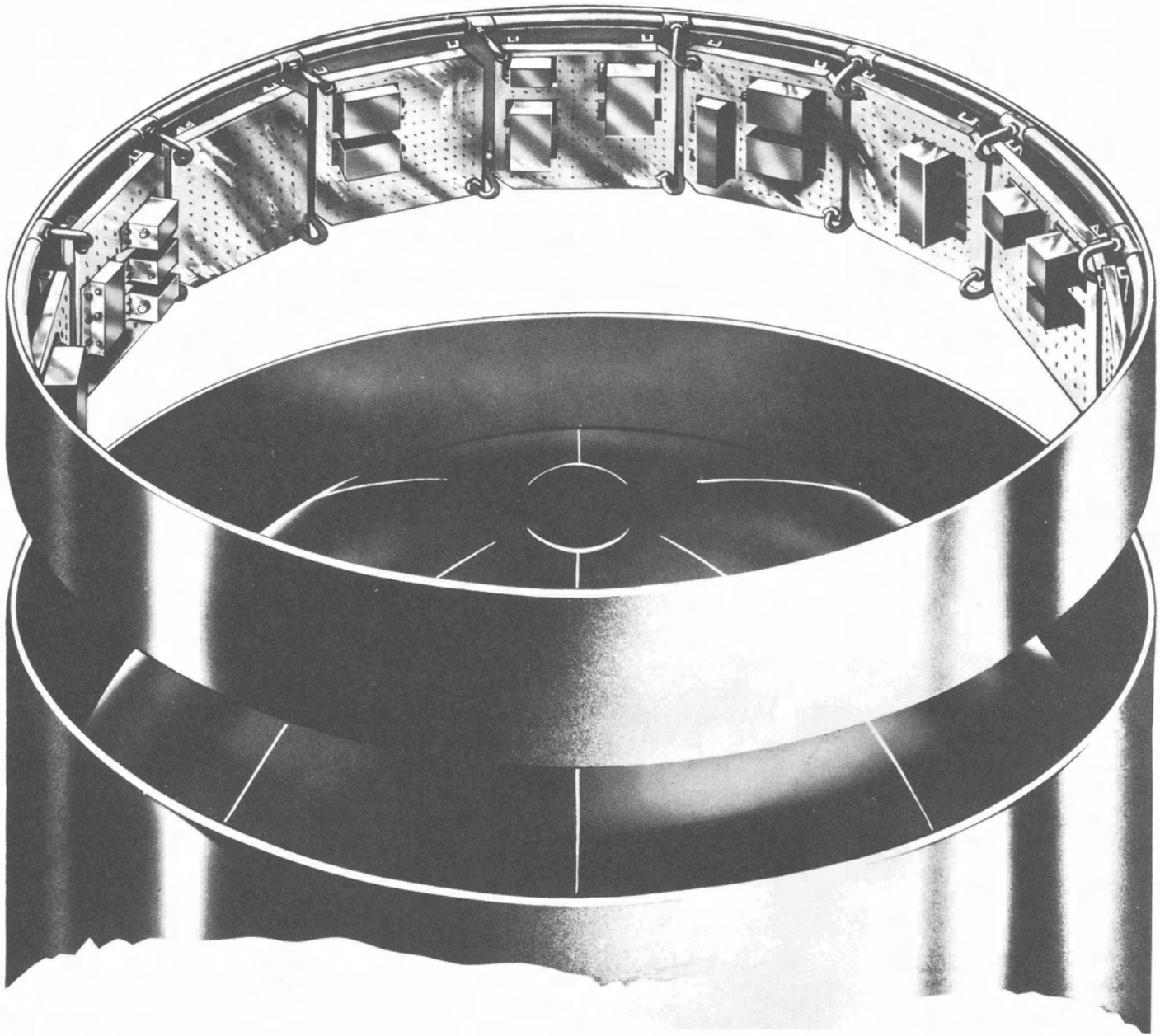




scope...

The Saturn IB and Saturn V **Instrument Units** are briefly described. Since both vehicles use almost identical astrionics systems, only minor differences will exist. To accomplish the Apollo mission, the astrionics system performs the following functions:

- **guidance and control during all phases of flight**
- **command and sequencing of vehicle functions**
- **insertion into earth orbit**
- **injection of S-IVB, IU, and spacecraft into lunar transfer trajectory**
- **stabilization of the S-IVB, IU, and LEM during turnaround of the command module and service module**
- **execution of maneuvers to remove the S-IVB and IU from the spacecraft orbit path**



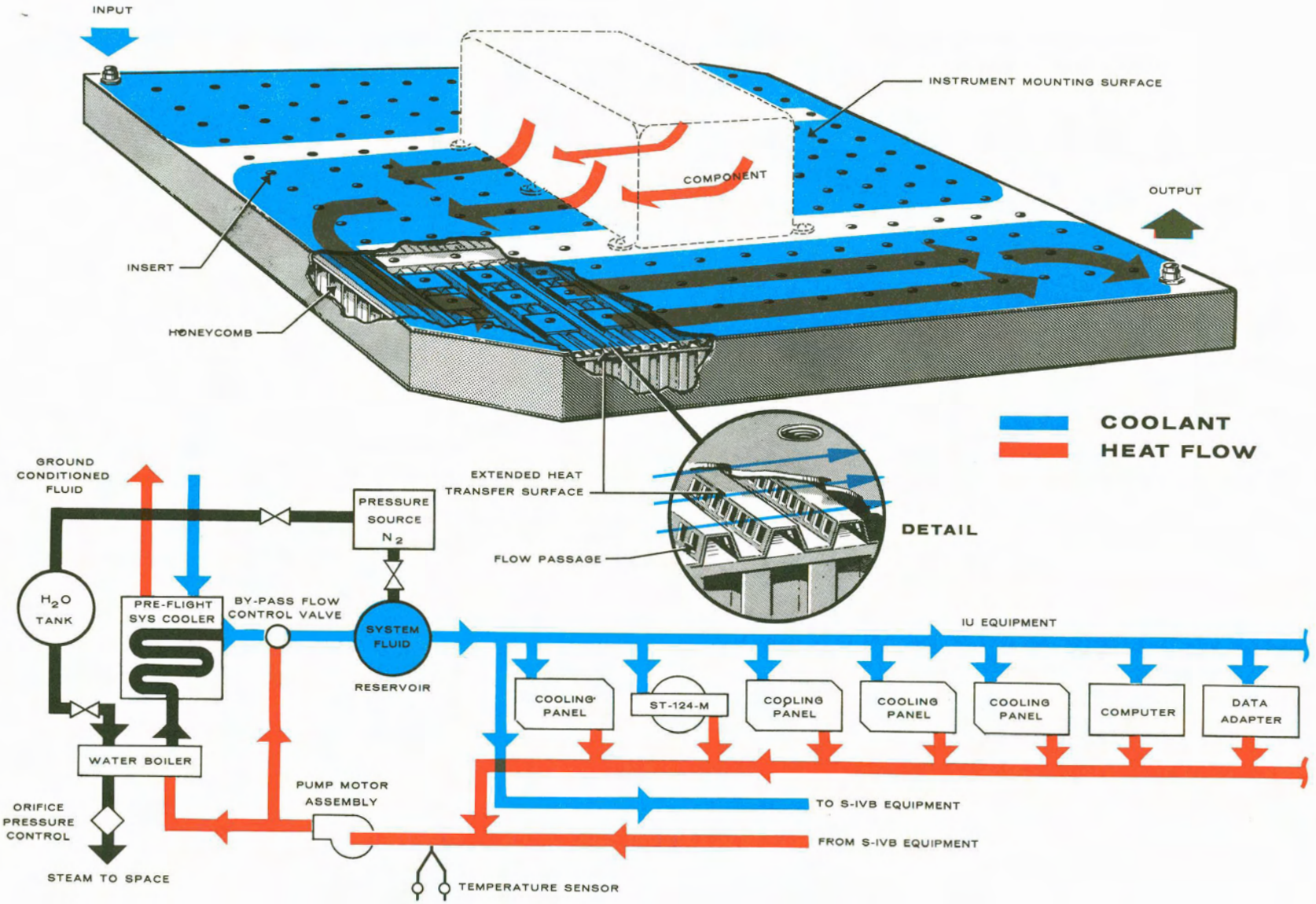
INSTRUMENT UNIT

structural system...

The structural system is designed for a field splice connection to the S-IVB stage and flight separation from the spacecraft. Characteristics of this system are a 660 cm diameter cylinder and a honeycomb structure of aluminum alloy for strength and light weight. It is fabricated in three sections for ease of handling.

● CONTROL RESPONSIBILITY / P & VE LABORATORY

ASTRIONICS LABORATORY


INPUT
INSTRUMENT MOUNTING SURFACE
COMPONENT
OUTPUT
INSERT
HONEYCOMB
COOLANT
HEAT FLOW
EXTENDED HEAT TRANSFER SURFACE
DETAIL
FLOW PASSAGE
GROUND CONDITIONED FLUID
PRESSURE SOURCE N_2
H_2O TANK
PRE-FLIGHT SYS COOLER
BY-PASS FLOW CONTROL VALVE
SYSTEM FLUID
RESERVOIR
IU EQUIPMENT
COOLING PANEL
ST-124-M
COOLING PANEL
COOLING PANEL
COOLING PANEL
COMPUTER
DATA ADAPTER
WATER BOILER
PUMP MOTOR ASSEMBLY
ORIFICE PRESSURE CONTROL
STEAM TO SPACE
TO S-IVB EQUIPMENT
FROM S-IVB EQUIPMENT
TEMPERATURE SENSOR

environmental control system...

An active environmental control system is provided for equipment cooling during ground operations and flight. Coolant is pumped through cold plates and ducts in the ST-124-M inertial platform, digital computer, and data adapter.

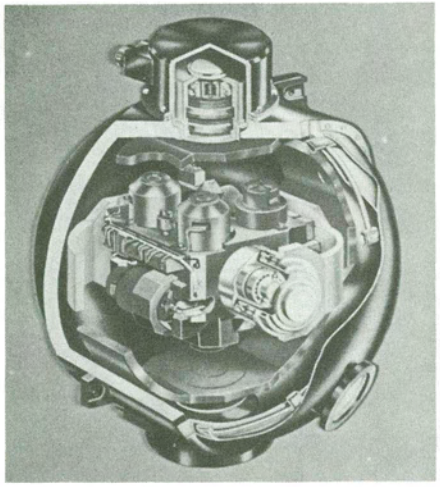
Functions and characteristics:

- **seventeen cold plates around periphery of structure provide for equipment mounting and cooling**
- **coolant is 60 percent methanol and 40 percent water by weight**
- **coolant flow rate is 2.7 kilograms per minute per cold plate**
- **each plate can dissipate approximately 420 watts**
- **heat removal is through a heat exchanger with water boiloff**

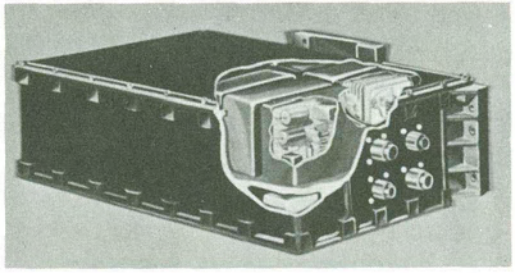
* CONTROL RESPONSIBILITY / P & VE LABORATORY

guidance and control systems...

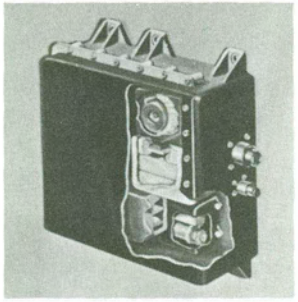
The guidance and control systems solve guidance equations and control the attitude of the Saturn IB/V vehicle. The system has the capability of accepting guidance commands from the spacecraft. Some IU components, such as the data adapter, function in both the guidance system and the control system, but are described only in the system which is most applicable.



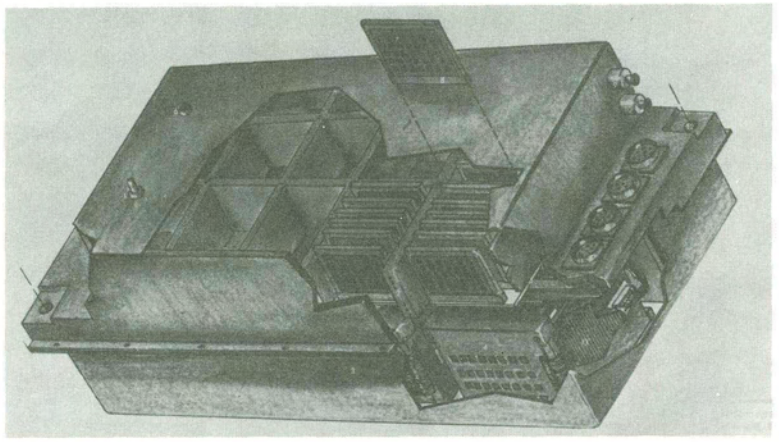
ST-124-M STABLE PLATFORM



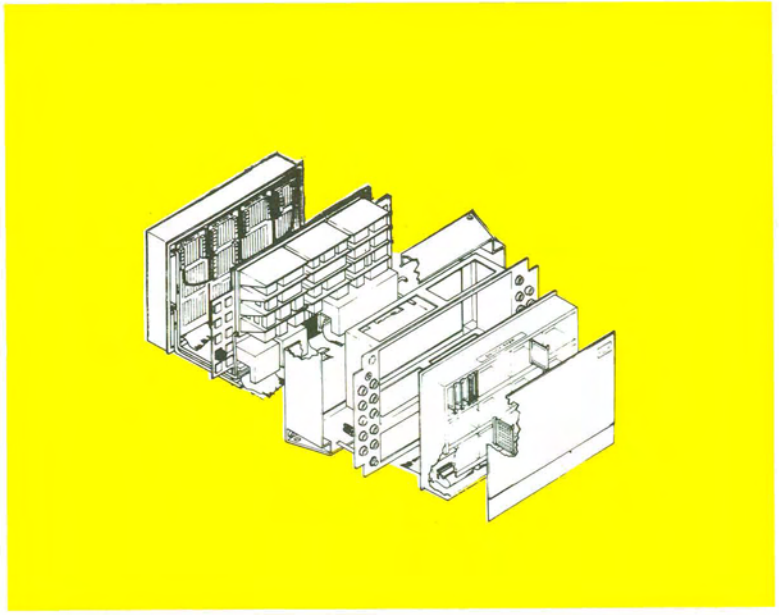
PLATFORM SERVO AMPLIFIER



POWER SUPPLY



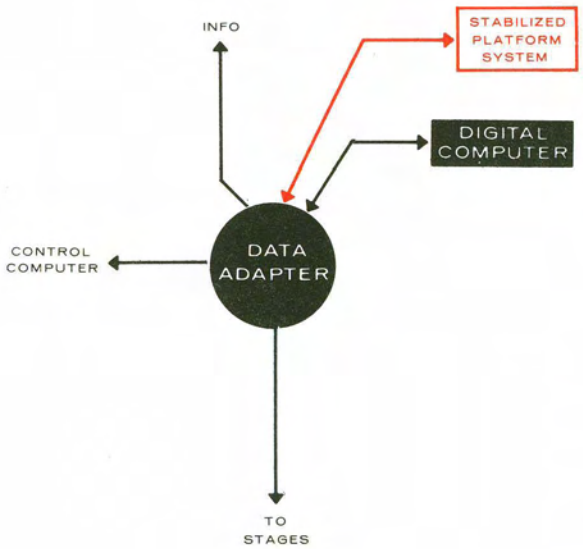
DIGITAL COMPUTER



DATA ADAPTER

ASTRIONICS LABORATORY

guidance system...



The Saturn guidance system instruments the equations for specific missions such as launch into earth orbit, rendezvous, reentry, escape trajectories, and determination of position.

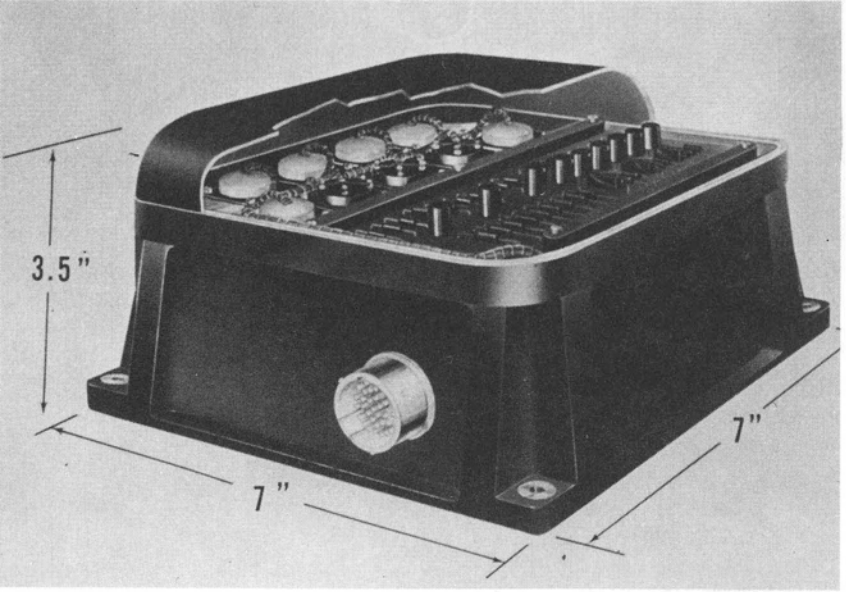
The **ST-124-M inertial platform system** provides:

- **the inertial reference for vehicle guidance**
- **the mechanics for pitch attitude programing**
- **platform gimbal positions for attitude and steering error computations**
- **velocity information for computing vehicle position and velocity**
- **azimuth alignment information**

The system is comprised of an inertial platform (three or four gimbal configuration depending on the particular mission requirement) platform electronic assembly, platform ac power supply, and air bearing supply.

The **digital computer** determines velocity and position, attitude errors and derived vehicle heading, computes thrust termination and reignition signals; and provides commands to guide the vehicle to cutoff conditions. It conducts those required orbital operations, such as orbital checkout of the space vehicle. Characteristics of the digital computer are: serial machine, random access magnetic core memory, micro-miniature packaging techniques, triple modular redundancy in the center computer, and multiple duplex memory modules for high reliability.

The **data adapter** is the input-output unit that accompanies the digital computer and provides an interface with nearly all components of the astrionics system. The data adapter has a digital section that buffers digital quantities and an analog section that converts analog to digital quantities and digital quantities to analog.

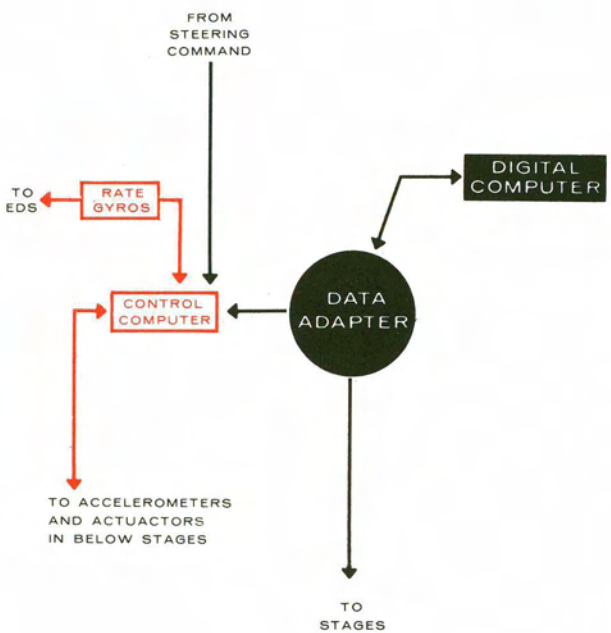

3.5"
7"
7"

RATE GYRO

S-IC & S-II STAGES (5 ENGINES EACH STAGE)
S-IVB STAGE
PITCH
PITCH
PITCH
NO 2 ENGINE
NO 3 ENGINE
ENGINE
YAW
YAW
YAW
NO 5 ENGINE
NO 1 ENGINE
NO 4 ENGINE
YAW
YAW
PITCH
PITCH
S-IC FLIGHT ONLY FROM S-II STAGE
PITCH, YAW
LATERAL ACCELERATION
CONTROL COMPUTER
FROM IU
PITCH, YAW, & ROLL
ATTITUDE RATE
ATTITUDE ERROR
PITCH, YAW, & ROLL
FROM SPACECRAFT
PITCH, YAW, & ROLL
ATTITUDE ERROR
PITCH
RELAY CONTROL PACKAGE
APS VALVES
YAW & ROLL
RELAY CONTROL PACKAGE
APS VALVES

ASTRIONICS LABORATORY

control system...



The **attitude control system** mixes signals from the digital computer, data adapter, rate gyros, and lateral control accelerometers to provide control signals to the vehicle engines. This system has the capability of accepting manual control commands from the astronauts.

The **control computer,** an analog device consisting of electronics required for attitude control, instruments and solves the vehicle thrust vector equation; controls the engines about the yaw, pitch, and roll axes; and controls the engines about the yaw, pitch, and roll axes; and controls the S-IVB auxiliary propulsion system.

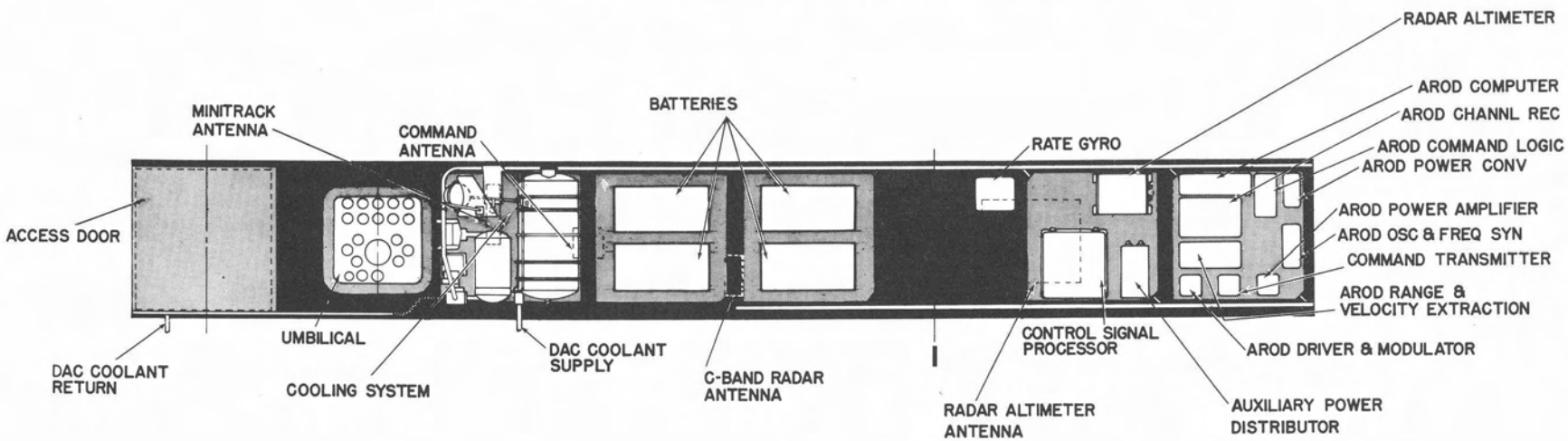
The **rate gyros** supply the control computer with data of the attitude rate change of the vehicle. The gyro outputs are also used to detect excessive angular rates for the emergency detection system.

The **control signal processor** contains the electronics associated with the rate gyro package.

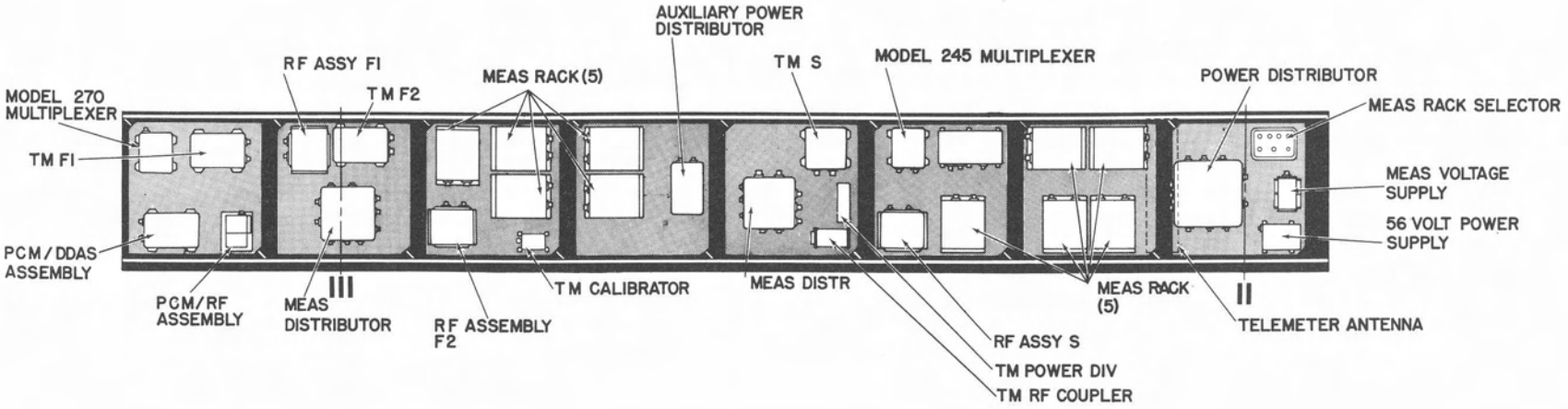
*CONTROL RESPONSIBILITY / ASTRIONICS LABORATORY

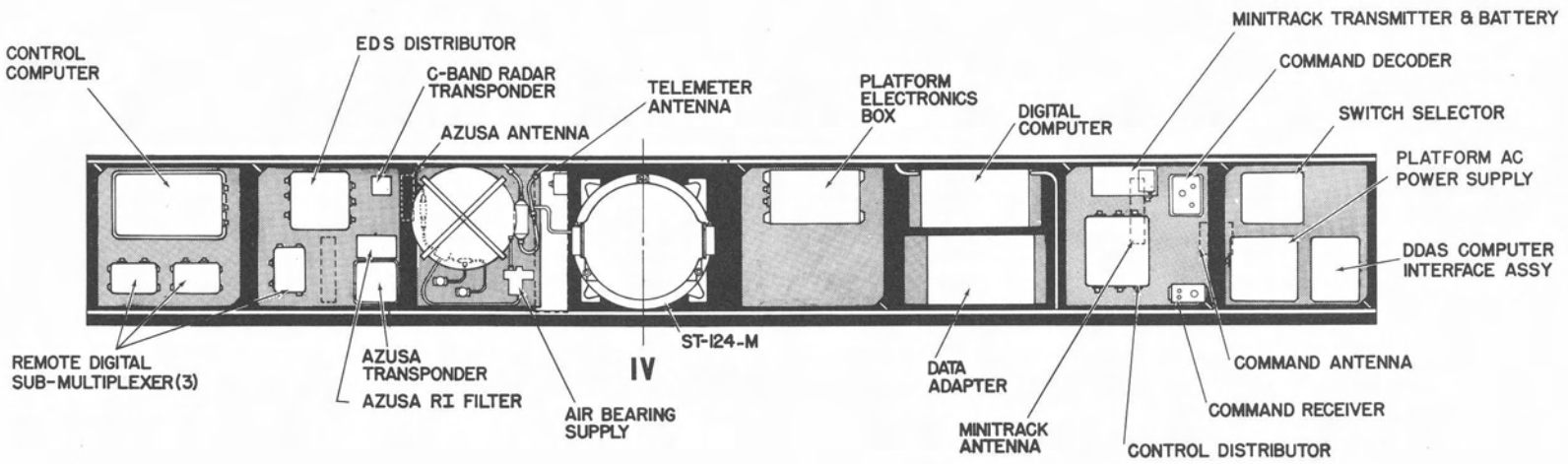
location of components...

TYPICAL SATURN IB/V INSTRUMENT UNIT



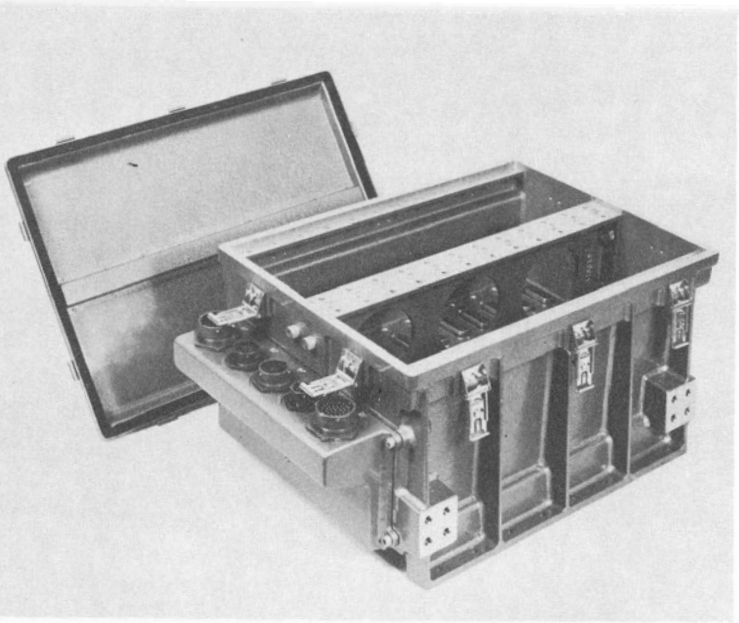
ASTRIONICS LABORATORY


AUXILIARY POWER DISTRIBUTOR
RF ASSY F1
MEAS RACK (5)
TM S
MODEL 245 MULTIPLEXER
POWER DISTRIBUTOR
MODEL 270 MULTIPLEXER
TM F2
MEAS RACK SELECTOR
TM F1
MEAS VOLTAGE SUPPLY
56 VOLT POWER SUPPLY
PCM/DDAS ASSEMBLY
PCM/RF ASSEMBLY
III
MEAS DISTRIBUTOR
RF ASSEMBLY F2
TM CALIBRATOR
MEAS DISTR
MEAS RACK (5)
II
TELEMETER ANTENNA
RF ASSY S
TM POWER DIV
TM RF COUPLER

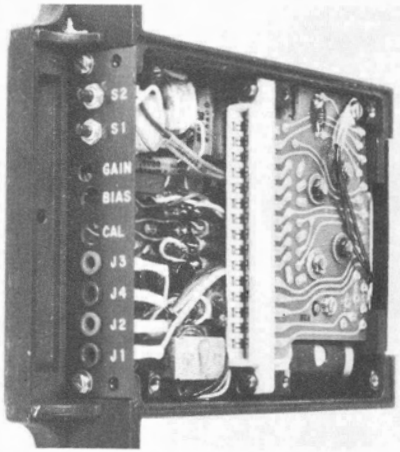

MINITRACK TRANSMITTER & BATTERY
CONTROL COMPUTER
EDS DISTRIBUTOR
COMMAND DECODER
C-BAND RADAR TRANSPONDER
TELEMETER ANTENNA
PLATFORM ELECTRONICS BOX
DIGITAL COMPUTER
SWITCH SELECTOR
AZUSA ANTENNA
PLATFORM AC POWER SUPPLY
DDAS COMPUTER INTERFACE ASSY
REMOTE DIGITAL SUB-MULTIPLEXER (3)
AZUSA TRANSPONDER
AZUSA RI FILTER
AIR BEARING SUPPLY
IV
ST-124-M
DATA ADAPTER
COMMAND ANTENNA
COMMAND RECEIVER
MINITRACK ANTENNA
CONTROL DISTRIBUTOR

measuring and telementry systems...

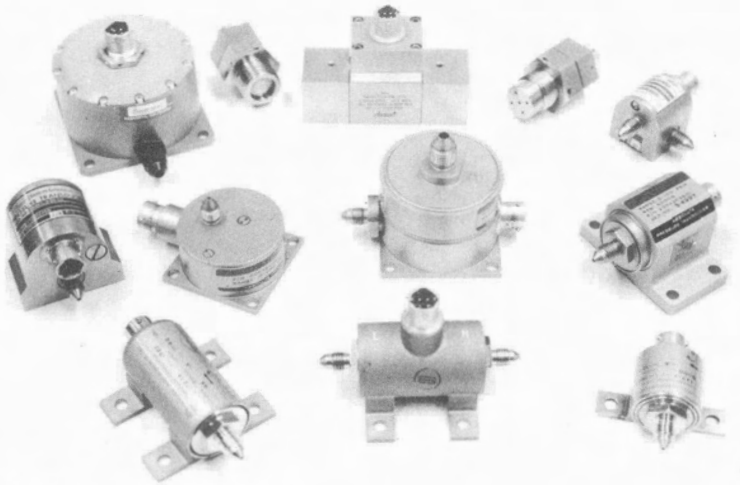
During launch and orbital phases of vehicle flight, parameters such as temperature, pressure, and vibration, are measured by appropriate transducers. Signals in the inertial platform, digital computer, and other pertinent equipment are measured to monitor vehicle operations. The combined measuring and telemetry system measures physical quantities and signals; the data is transmitted to ground stations to provide information for checkout during flight, and to verify commands received by the vehicle from ground stations.



MEASURING RACK



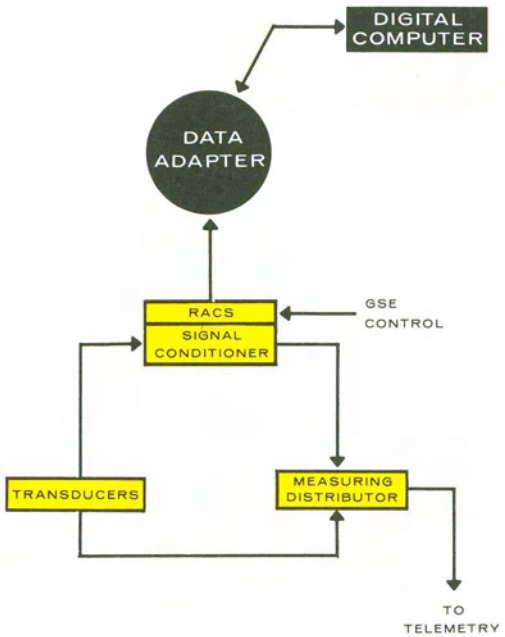
MODULE



TYPICAL TRANSDUCERS

ASTRIONICS LABORATORY

measuring system...

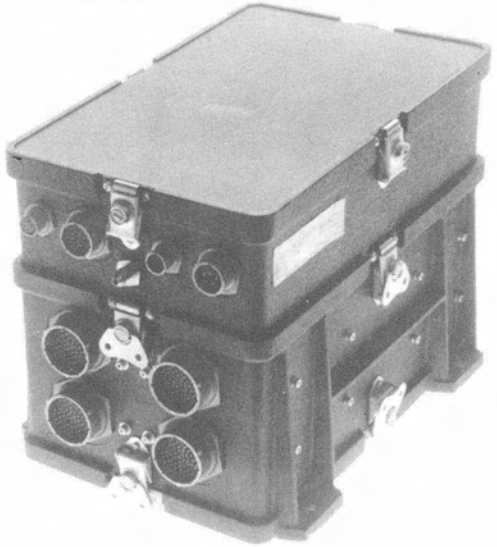


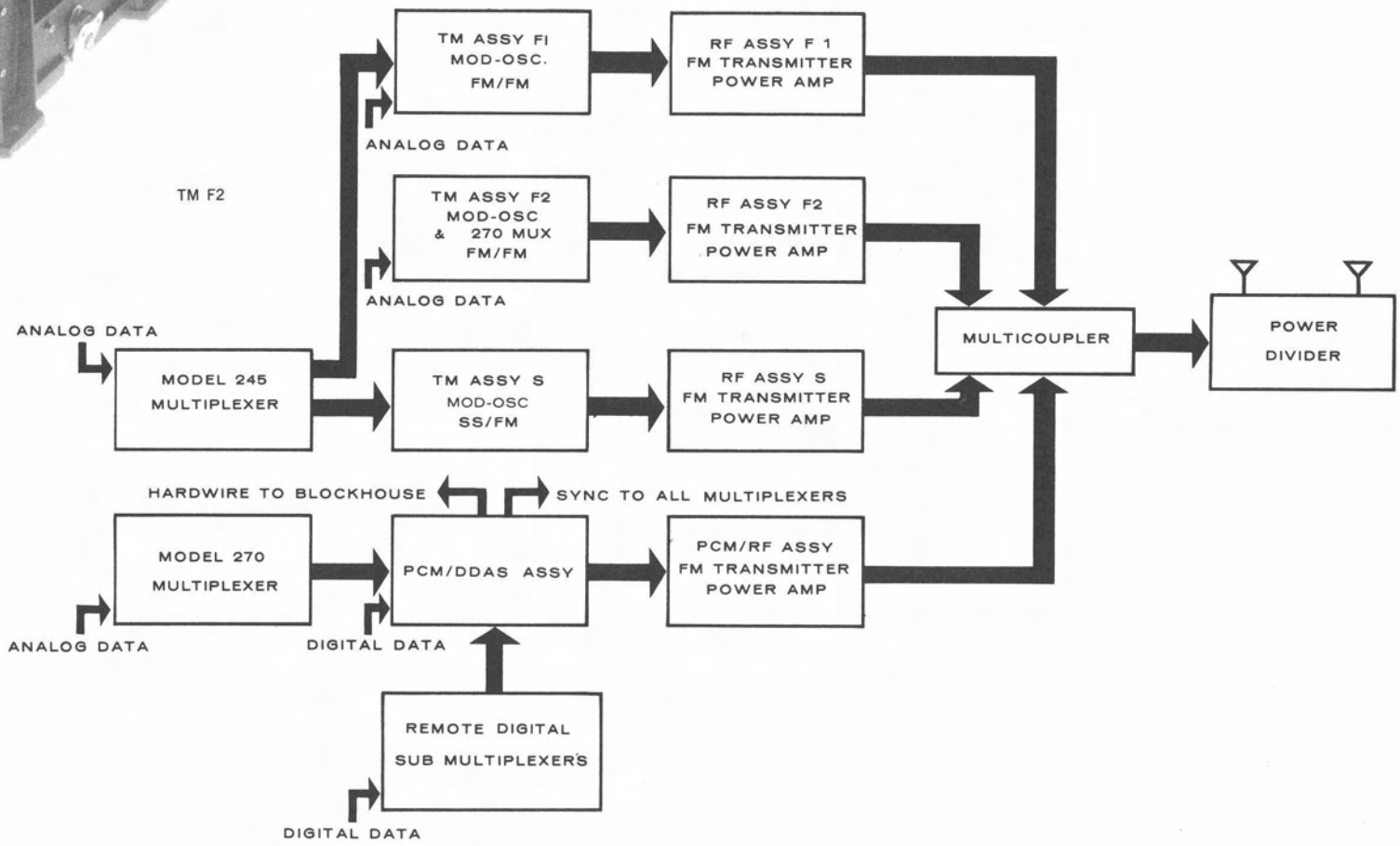
The **measuring system** includes electrical pick-offs, transducers, signal conditioners, and a measuring distributor. All measurement signals in this system are connected to the measuring distributor and are directed to preassigned telemetry channels. Printed circuit plug-in boards are used in the distributor to provide flexibility.

Transducers are electromechanical devices that convert physical quantities such as pressure and temperature into electrical signals. The transducers are designed for accuracy and reliability.

Measuring racks contain signal conditioning modules that adapt the outputs of transducers and some electrical circuits to the electrical input requirements of the telemetry system. A regulated power supply in each rack provides power for the modules.

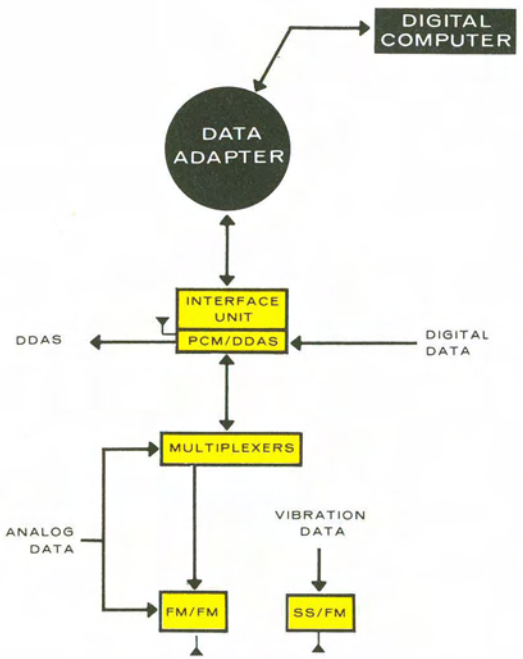
The **RACS (Remote Automatic Calibration System)** is used for calibrating selected measurements during ground checkout. The measuring rack selector provides a means of decoding a signal from the ground station during prelaunch to select the signal conditioning modules for calibration.




TM ASSY FI
MOD-OSC.
FM/FM
RF ASSY F 1
FM TRANSMITTER
POWER AMP
ANALOG DATA
TM F2
TM ASSY F2
MOD-OSC
& 270 MUX
FM/FM
RF ASSY F2
FM TRANSMITTER
POWER AMP
ANALOG DATA
ANALOG DATA
MODEL 245
MULTIPLEXER
TM ASSY S
MOD-OSC
SS/FM
RF ASSY S
FM TRANSMITTER
POWER AMP
MULTICOUPLER
POWER
DIVIDER
HARDWIRE TO BLOCKHOUSE
SYNC TO ALL MULTIPLEXERS
MODEL 270
MULTIPLEXER
PCM/DDAS ASSY
PCM/RF ASSY
FM TRANSMITTER
POWER AMP
ANALOG DATA
DIGITAL DATA
REMOTE DIGITAL
SUB MULTIPLEXERS
DIGITAL DATA

ASTRIONICS LABORATORY

telemetry system . . .



The telemetry system modulates radio frequency carriers with signals from the measuring system, which are in analog or digital form and require different bandwidths. For the most efficient use of the available telemetry frequency band, different modulation techniques are applied to transmit the variety of signals.

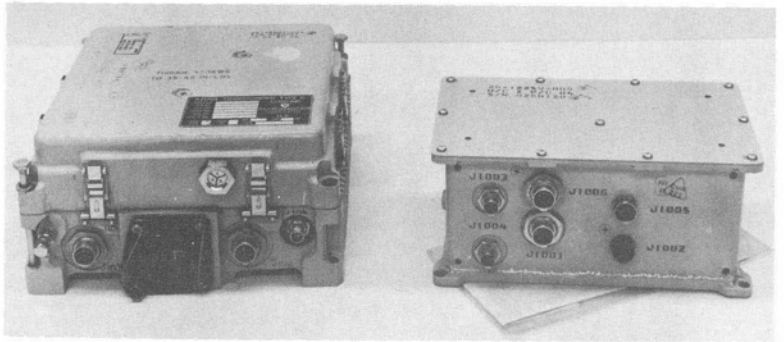
- **SS/FM (Single Sideband/Frequency Modulation) system transmits vibration and acoustic data that have wide frequency response (30 Hz to 3000 Hz) requirements**
- **PAM/FM/FM (Pulse Amplitude Modulation/FM/FM) or FM/FM/FM systems transmit analog data that have narrow frequency response requirements**
- **FM/FM system transmits analog data that have medium frequency response requirements**
- **PCM/FM (Pulse Code Modulation/FM) system transmits digital data**

The TM calibrator functions as calibration control and reference signal source for the telemetry system for preflight and inflight calibration.

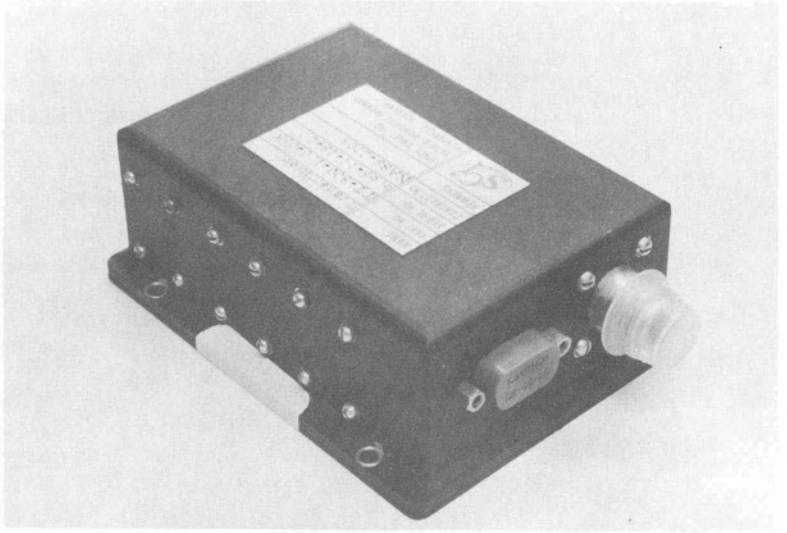
* CONTROL RESPONSIBILITY / ASTRIONICS LABORATORY

C-BAND RADAR

RADAR ALTIMETER

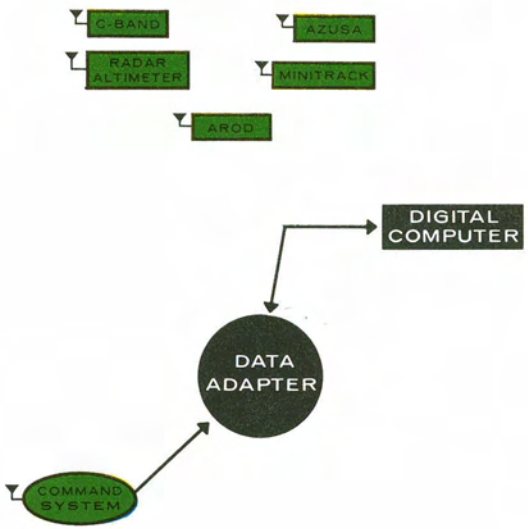


AZUSA TRANSPONDER



MINITRACK

radio frequency systems . . .



The **radio frequency (RF) systems** are available as required for various missions to provide tracking and command. With the exception of the radar altimeter, the onboard equipment is connected through RF links with the corresponding ground equipment.

The **radar altimeter** provides altitude data to supplement ground station tracking when the vehicle is not covered by land-based stations.

The **azusa transponder** is part of a system to measure slant range and direction from the ground station to the vehicle.

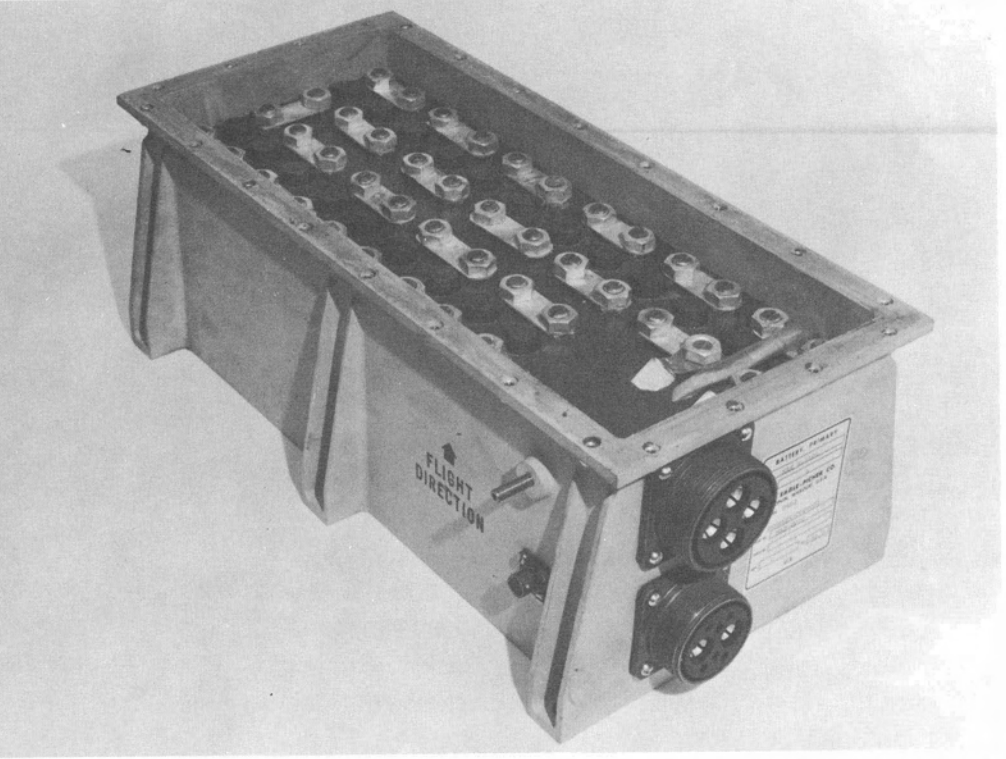
The **C-band radar transponder** aids the radar ground stations in measuring range, azimuth, and elevation.

AROD (airborne range and orbit determination) is a doppler and range tracking system. However, the conventional procedure has been reversed; the transmitter and receiver are on board the vehicle, while the transponders are located at various locations on the earth.

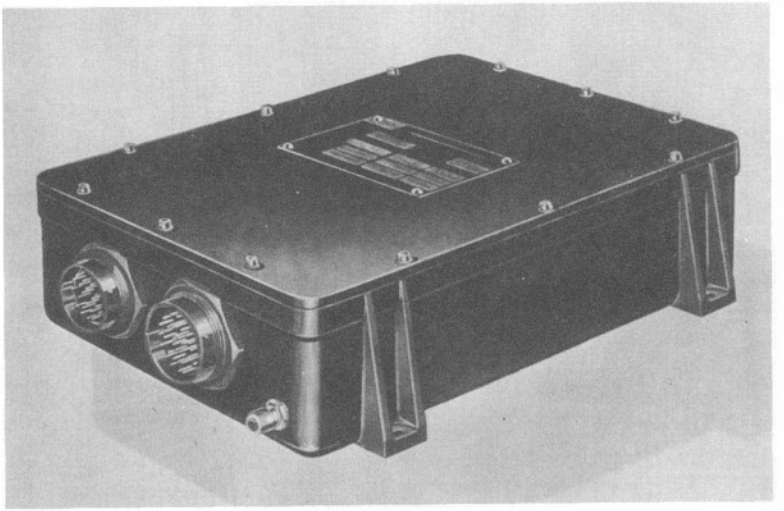
The **Minitrack** beacon provides information for computing the vehicle orbit.

The IU command system provides a means of receiving digital data or commands from a ground station. The information is supplied to the digital computer through the data adapter. Prior to execution, all data or commands are transmitted to the ground station for verification.

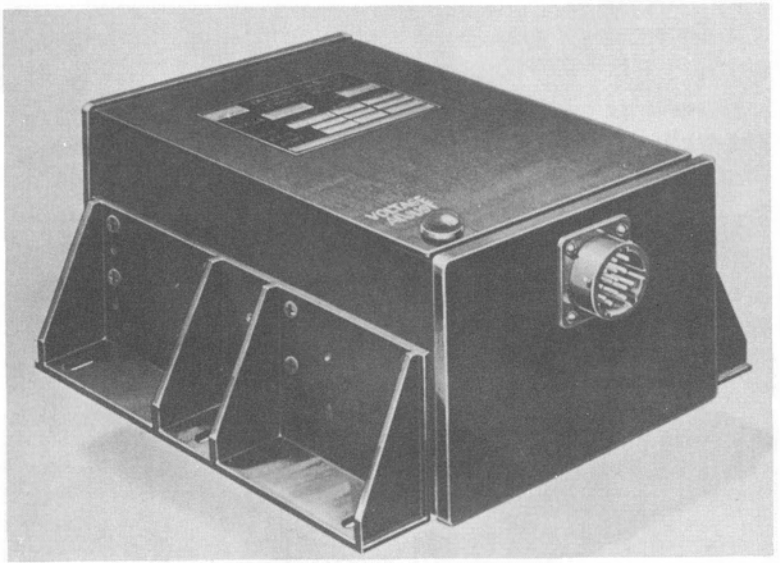
The principal functions of the IU command system are to initiate closed-loop tests in the vehicle, to provide ground computed orbital data to the digital computer, if desired, and to aid in an emergency situation.



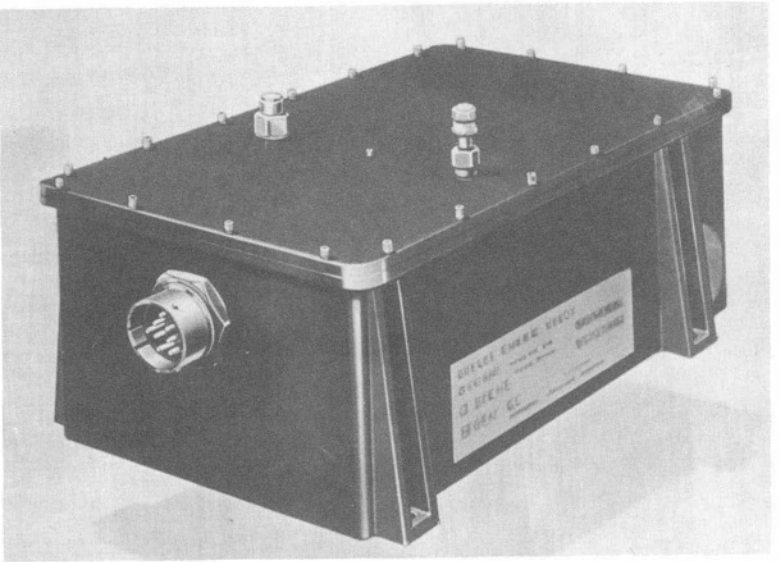
BATTERIES



SWITCH SELECTOR

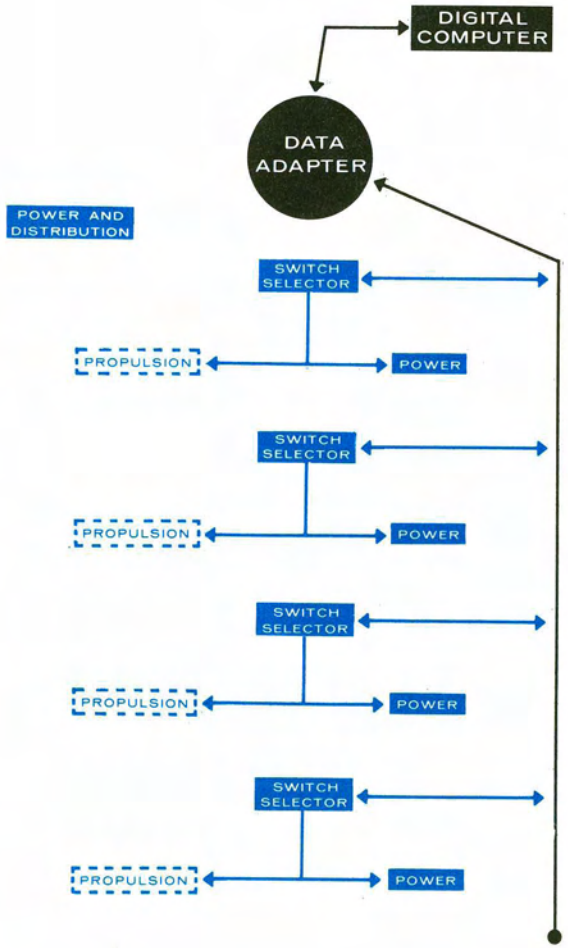


5 VOLT POWER SUPPLY



56 VOLT POWER SUPPLY

electrical system . . .



The electrical system of the IU generates and distributes all power required for operation of components during flight and controls the operation and sequencing of various functions during checkout, countdown, and flight. Connection to ground support equipment is provided through the umbilical for prelaunch checkout.

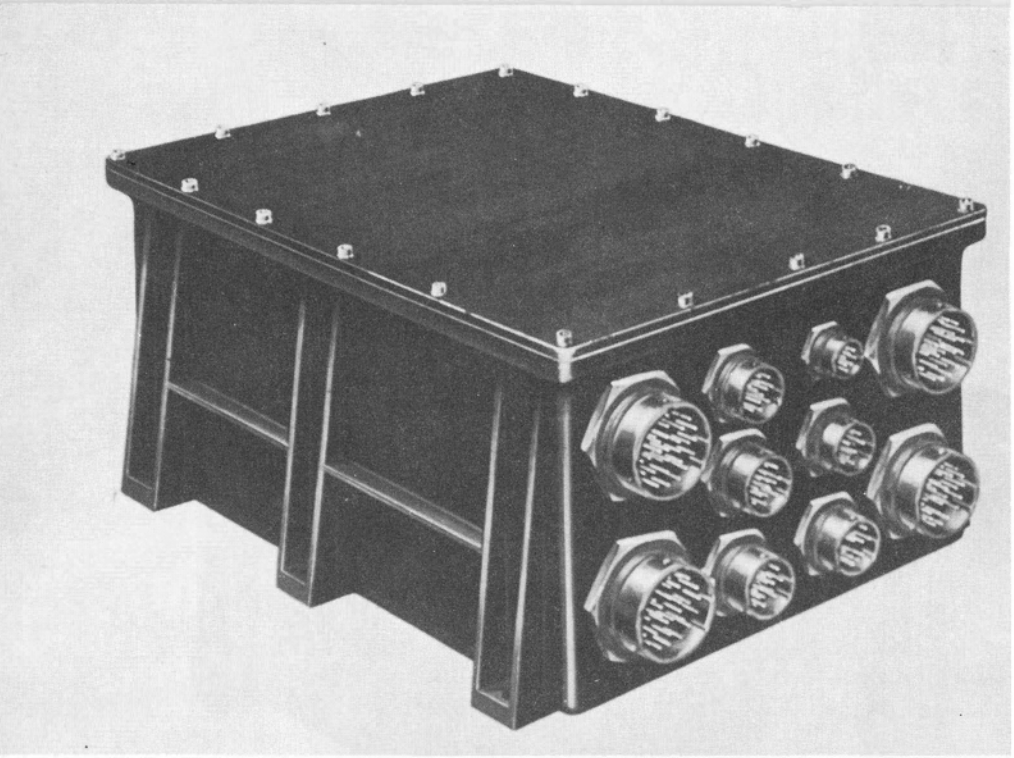
The power distributor is the junction where the power is routed to various components through the IU network cables.

The measuring voltage supply provides a calibration voltage for the measuring system as a reference for different types of sensing equipment. The 56-volt power supply provides dc power to the platform electronics assembly.

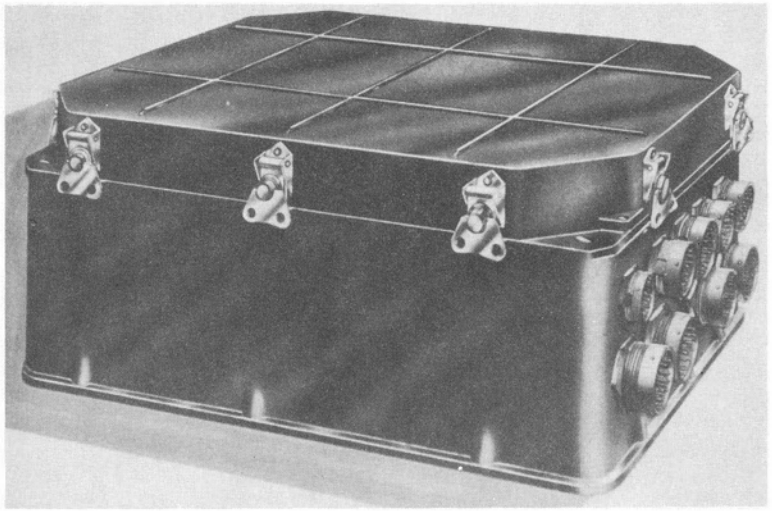
Two auxiliary power distributors, which handle only circuits under 10 amperes, supplement the main power distributor.

The control distributor receives commands from the switch selector and centrally controls the sequencing of equipment and distribution of power through contactors within the power distributor.

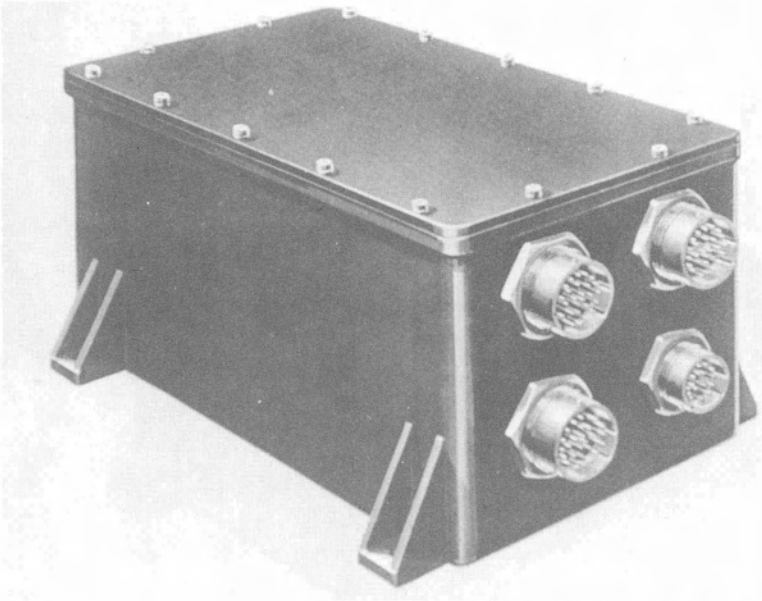
Switch selectors provide the communications link between the computer-data adapter and the control distributor in the IU and each stage. The digital computer controls the mode and sequence of functions in all stages through the switch selectors.



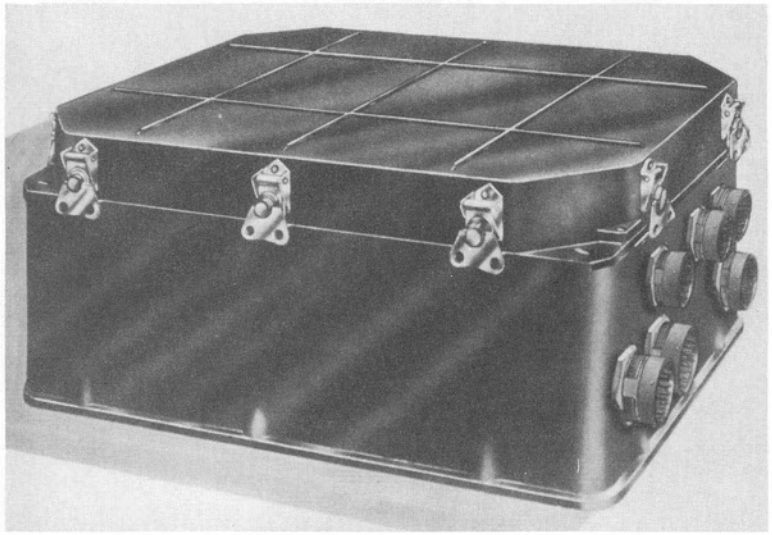
POWER DISTRIBUTOR



CONTROL DISTRIBUTOR

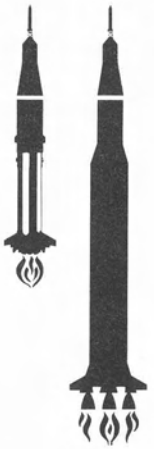


AUXILIARY POWER DISTRIBUTOR



EDS DISTRIBUTOR

electrical system (continued)...



The emergency detection system (EDS) senses certain malfunctions in the stages and determines when these malfunctions are of a critical nature through circuits in the EDS distributor, which is the interface box between the stages and the spacecraft. An emergency signal is transmitted by the distributor to the EDS display panel in the spacecraft. The emergency conditions can result in:

- **an automatically initiated abort when the time interval between sensing of an emergency condition and the required action is too short for human intervention**
- **a manually initiated abort when this time interval is sufficiently long for human evaluation and reaction**

Primary power is supplied by alkaline electrolyte batteries with silver oxide and zinc as the active plate material. The nominal output is 28 volts at a relatively high current rate. The batteries are activated by filling each cell with potassium hydroxide in water.

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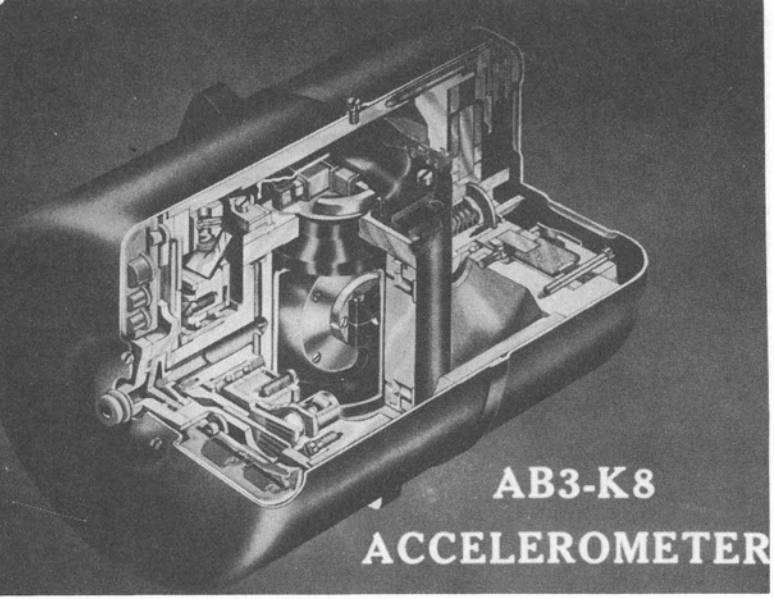
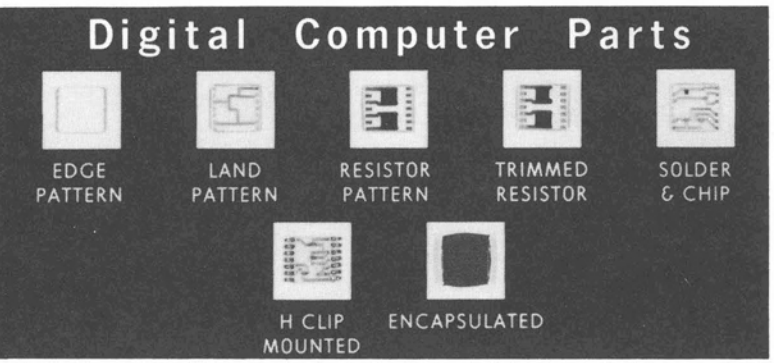




ASTRIONICS LABORATORY

conclusion...

Many additional pages can be filled with vital and interesting information on the Instrument Unit. For example:

- **the advanced design techniques used in the circuitry and packaging**
- **the very high precision of the gyros and accelerometers of the stabilized platform**
- **miniaturization used in the digital computer**
- **redundant modular circuits used to improve reliability**

Note that the very high reliability requirements as a consequence of the "man rating" place considerable emphasis on:

- **design practices**
- **parts and components qualification**
- **environmental, performance, and other test programs**
- **inspection and quality control, etc.**

All these efforts required to develop the Instrument Unit and its components and to provide the flight units are shared by a team of government and industry groups.

One should realize that only a few years ago programs like the Saturn were only wishful dreaming. Today, advanced technology and engineering have made these dreams become a reality.

SATURN IB/V IU ASTRIONICS SYSTEM

(color schematic)

STRUCTURAL

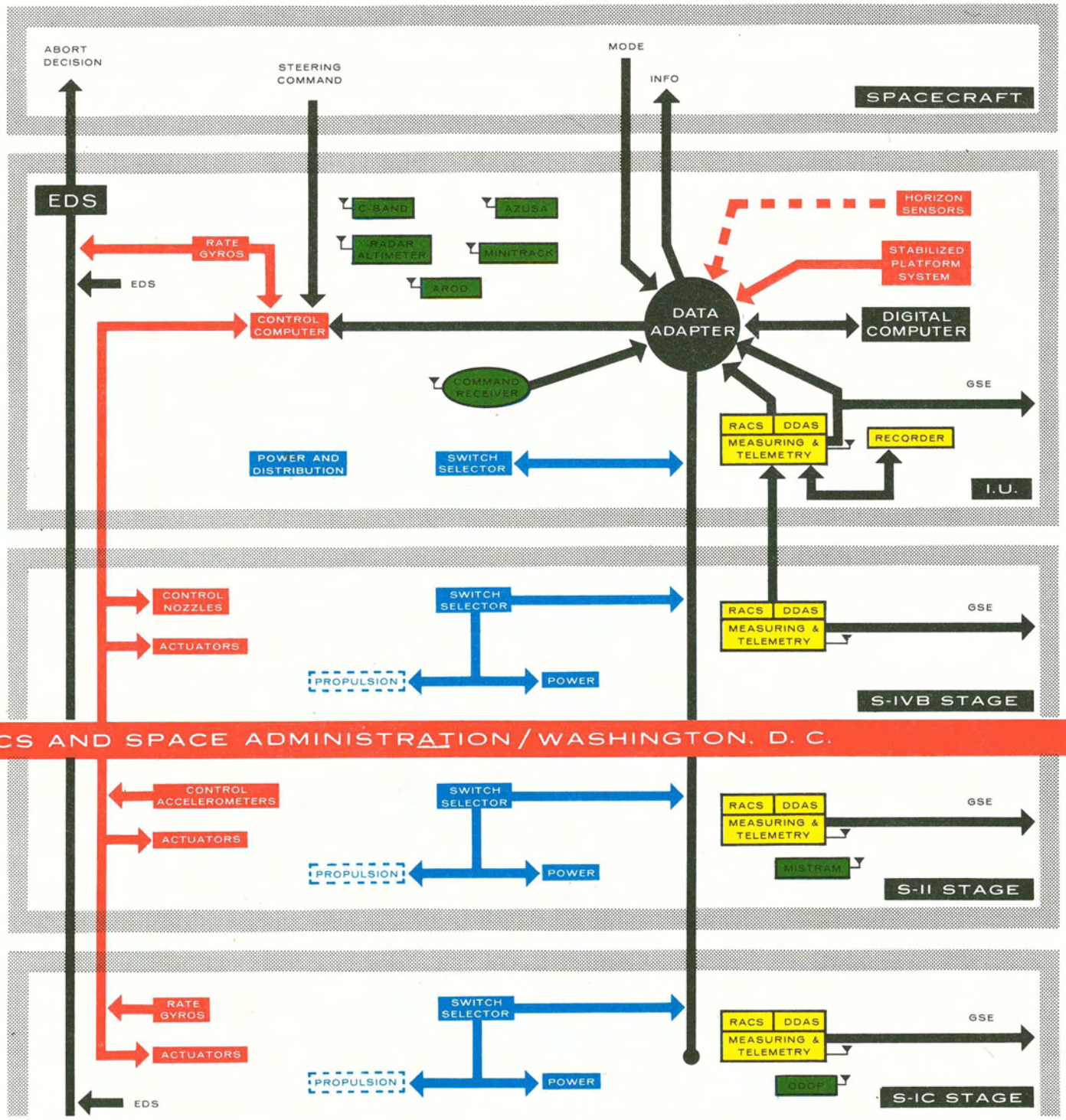
ENVIRONMENTAL CONTROL

GUIDANCE & CONTROL

MEASURING & TELEMETRY

RF

ELECTRICAL



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