

GRADY COX

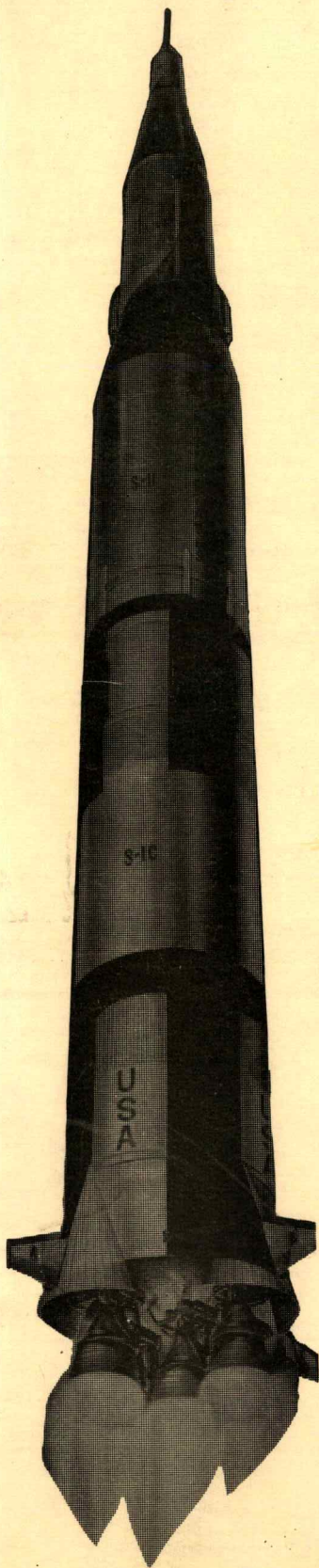
VOLUME 1

THE BOEING COMPANY

SATURN V

SYSTEMS ENGINEERING

TRAINING



COURSE NUMBER:

10-101

COURSE TITLE:

**SATURN V LVGSE
INTEGRATED SYSTEMS
ORIENTATION**

FOR TRAINING PURPOSES ONLY

STUDENT STUDY GUIDE

SATURN V LVGSE INTEGRATED SYSTEMS ORIENTATION

COURSE NUMBER 10-101

VOLUME 1 OF 3

LAUNCH VEHICLE ELECTRICAL SUPPORT EQUIPMENT

Prepared By T. N. Bass Date 3-1-66
T. N. Bass
Prepared By G. Baker Date 3-1-66
G. Baker
Supervised By Kenneth W. Hill Date 3-1-66
K. W. Hill
Approved By L. G. Pollard Date 3-2-66
L. G. Pollard
Approved By _____ Date _____

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FOREWORD

This study guide was prepared by the Saturn V Systems Engineering Training Unit of The Boeing Company. Its primary purpose is to support classroom instruction and on-the-job training for Saturn V personnel.

The information contained in this study guide was current at the time of publication, and was prepared for Training Purposes Only. No revision pages will be issued to supplement or update this material.

This document will be updated or revised as required to support current course content, or as equipment configuration changes dictate.

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REFERENCE DOCUMENTS

	<u>Title</u>	<u>Origin</u>	<u>Number</u>
1.	Saturn Ground Computer System Instruction Manual	RCA	TP1270 Vol. I & Vol. II
2.	RCA-110A Computer Programmer's Reference Manual	RCA	TP-1263
3.	Integrated Telemetry Ground Equipment Instruction Manual	Data Control Systems Inc.	640800
4.	Saturn Data Link Terminal	RCA	TP-1241
5.	General Description of ST-124M Inertial Platform System	NASA	TN-D-2983
6.	Astrionics Systems Handbook	NASA	1 Aug., 1966
7.	Operation & Maintenance Manual for Discrete Control System	NASA	
8.	Discrete Control Equipment Training Manual	NASA	
9.	Secure Range Safety Command System for Saturn	NASA	TM X-53162
10.	Digital Command System Technical Manual	Radiation, Inc.	MH-1012
11.	Saturn V Operational Display System	Sanders Assoc.	
12.	Electrical Reference Handbook ESE-LC-39	MILA	SP-166-D Jan. 10, 1965
13.	S-IC and Common GSE Systems Description Manual - MILA	MILA	D5-12922 Rev. A

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CHAPTER I

SECTION I

SATURN V VEHICLE

INTRODUCTION

The Saturn V launch vehicle is to serve as the launch vehicle for the Apollo Spacecraft lunar landing missions and for performing other types of missions for insertion of heavy payloads into earth orbit and escape trajectories. Some of the Saturn V applications include:

1. Transfer between earth orbits.
2. Rendezvous in earth orbit.
3. Direct ascent and injection into escape trajectory.
4. Injection into escape trajectory following extended earth-orbit phases.
5. Extended missions beyond injection.

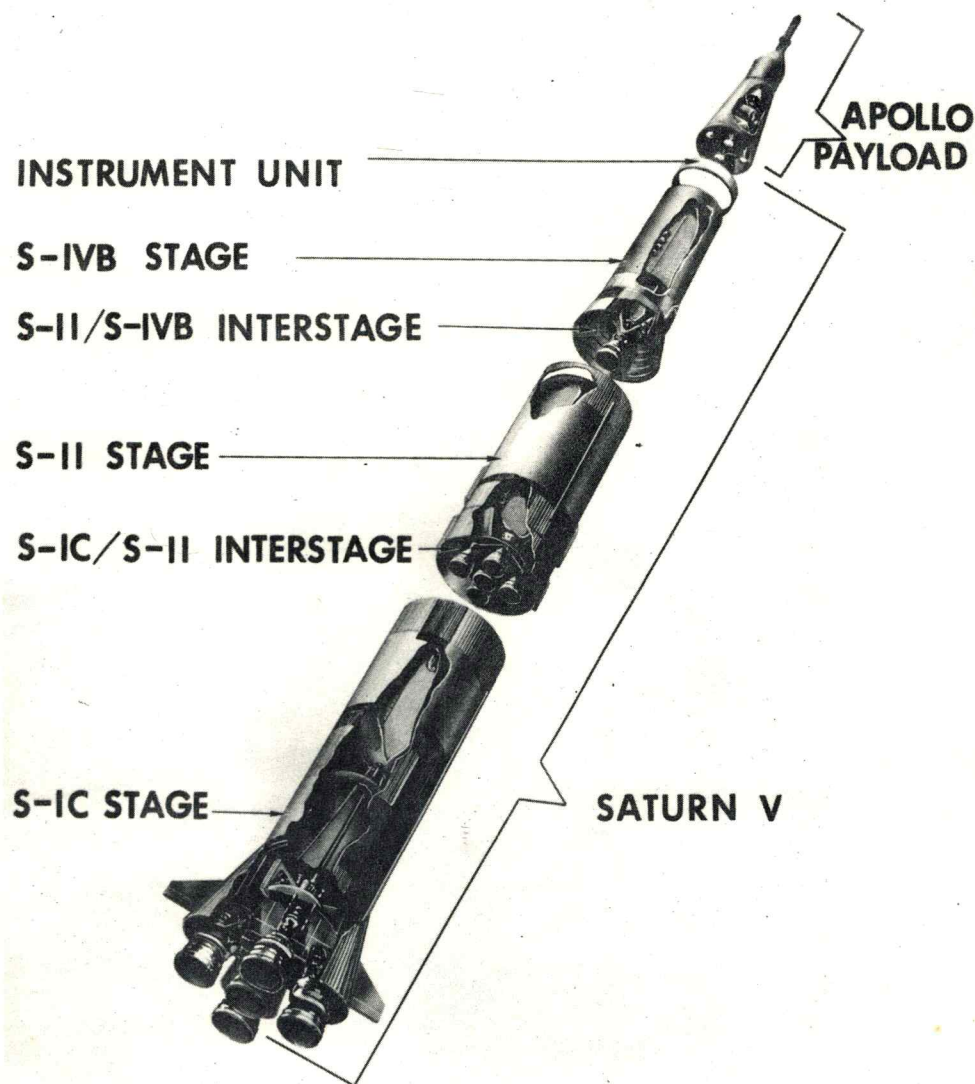
Saturn V vehicles are numbered sequentially, starting with SA-501 for the first flight vehicle. The first few vehicles of the series are considered as research and development vehicles.

The Saturn V vehicle is comprised of three powered stages plus the instrument unit as depicted in Figure 1, Saturn V Launch Vehicle. The payload as programmed for the Apollo missions included a Lunar Excursion Module, a Service Module, and a Command Module (reentry Capsule). Figure 1 provides the general characteristics of the Saturn V vehicle.

The S-IC booster stage is the largest known rocket stage in the world. It is 140 feet long and 33 feet in diameter and produces 7.5 million pounds thrust using five F-1 liquid rocket engines. The S-IC stage will power the Saturn V from lift-off through the lower atmosphere.

The S-II or second stage of the Saturn V uses five J-2 liquid rocket engines to power the vehicle from S-IC separation to place the vehicle in the outer atmosphere where the S-IVB (third stage) will place the payload in earth orbit.

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CHARACTERISTICS

LAUNCH VEHICLE

LENGTH _____ 281 FT
 LENGTH VEHICLE, SPACECRAFT, LES 365 FT
 WEIGHT AT LIFTOFF _____ 6,200,000 LBS
 PAYLOAD CAPABILITY APPROXIMATE
 TRANSLUNAR TRAJECTORY _____ 95,000 LBS
 EARTH ORBIT _____ 250,000 LBS

STAGES

S-IC

SIZE _____ 33X138 FT
 THRUST _____ 7,500,000 LBS
 ENGINES _____ 5 F-1
 PROPELLANTS _____ LOX & RP-1

S-II

SIZE _____ 33X81 FT
 THRUST _____ 1,000,000 LBS
 ENGINES _____ 5 J-2
 PROPELLANTS _____ LOX & LH₂

S-IVB

SIZE _____ 22X59 FT
 THRUST _____ 200,000 LBS
 ENGINES _____ 1J-2
 PROPELLANTS _____ LOX & LH₂

INSTRUMENT UNIT

SIZE _____ 22X3 FT
 GUIDANCE SYSTEM _____ INERTIAL

Figure 1. Saturn V Vehicle and Characteristics

The S-IVB stage is powered by one J-2 liquid rocket engine with restart capability. It will be used to inject the payload into an earth orbit and then to inject the payload into a lunar trajectory and again as the mission profile dictates.

The Instrument Unit (I. U.) connects to the upper adaptor of the S-IVB stage and contains the vehicle electronic packages such as the guidance system, telemetry packages, etc.

The payload modules provide the means for members of the Apollo three man crew to make a soft landing on the lunar surface, then return to the earth.

In order to achieve the goals of the Saturn V-Apollo program, ground support equipment is of necessity highly sophisticated. The ground support equipment to checkout and launch the Saturn V is automated in most cases and highly reliable. The following chapters present, at the orientation level, discussions of the various electrical/electronic and mechanical systems utilized to checkout and launch the Saturn V vehicle.

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CHAPTER I

SECTION II

ELECTRICAL SUPPORT EQUIPMENT

INTRODUCTION

The Saturn V Electrical Support Equipment (ESE) accomplishes the checkout and control of the Saturn V Launch Vehicle. Because of the complexity of testing, the total number of parameters to be processed, and the various unrelated functions of subsystems, the checkout is divided into four basic categories - S-IC Stage, S-II Stage, S-IVB Stage, and Instrumentation Unit (IU). During prelaunch and testing, each stage-related station will be performing separate functions of the S-IC, S-II, S-IVB, and IU checkout. These systems, which are independent to a high degree, must be checked out as an operational launch vehicle system; therefore, an additional function of ESE is to accomplish integrated systems checkout.

Additionally during prelaunch testing and countdown, the launch vehicle ESE will be in direct communication with the spacecraft acceptance checkout equipment to perform programmed coordination activities, such as milestones and specific parameter data relative to checkout integration. This relationship will achieve more coordination between the spacecraft and launch vehicle within milestone events, thereby resulting in a more highly integrated prelaunch test, rather than coordination of subsystem GO/NO GO status.

The performing of vehicle stage and subsystem checkout versus launch vehicle system checkout and the methods of integration and coordination between the launch vehicle checkout system and the spacecraft checkout system provide a more unified test of the equipment as a system, thereby producing a more capable and more reliable vehicle to perform mission objectives.

To adhere to this capability of stringent testing and integration, the following program objectives have been defined for the Saturn V Electrical Support Equipment:

- a. Perform checkout of launch vehicle using automatic ESE.
- b. Perform countdown and launch of launch vehicle using automatic ESE.

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- c. Provide optimum man-machine interface.
- d. Coordinate launch vehicle and spacecraft checkout sequence.
- e. Provide safety for launch vehicle.

In order to allow the student greater insight into the basic functions involved in the E. S. E. systems, listings of requirements, features, applications, relationships and equipment are provided in the seven (7) following tables. (Figures 2 and 3 provide the electrical support equipment and interconnection necessary to understand the scope of the following tables.)

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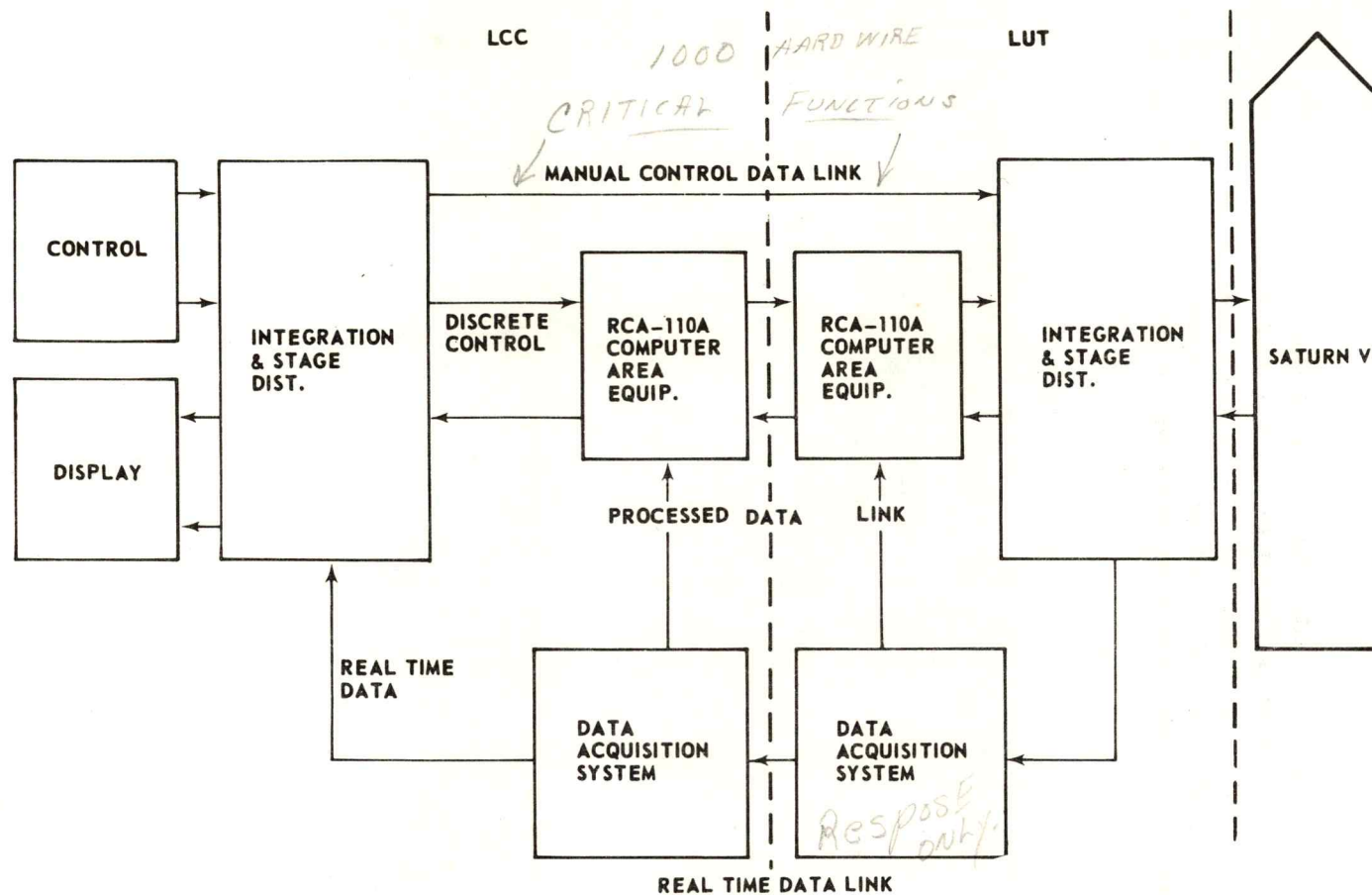


Figure 2. Electrical Support Equipment (Simplified Diagram)

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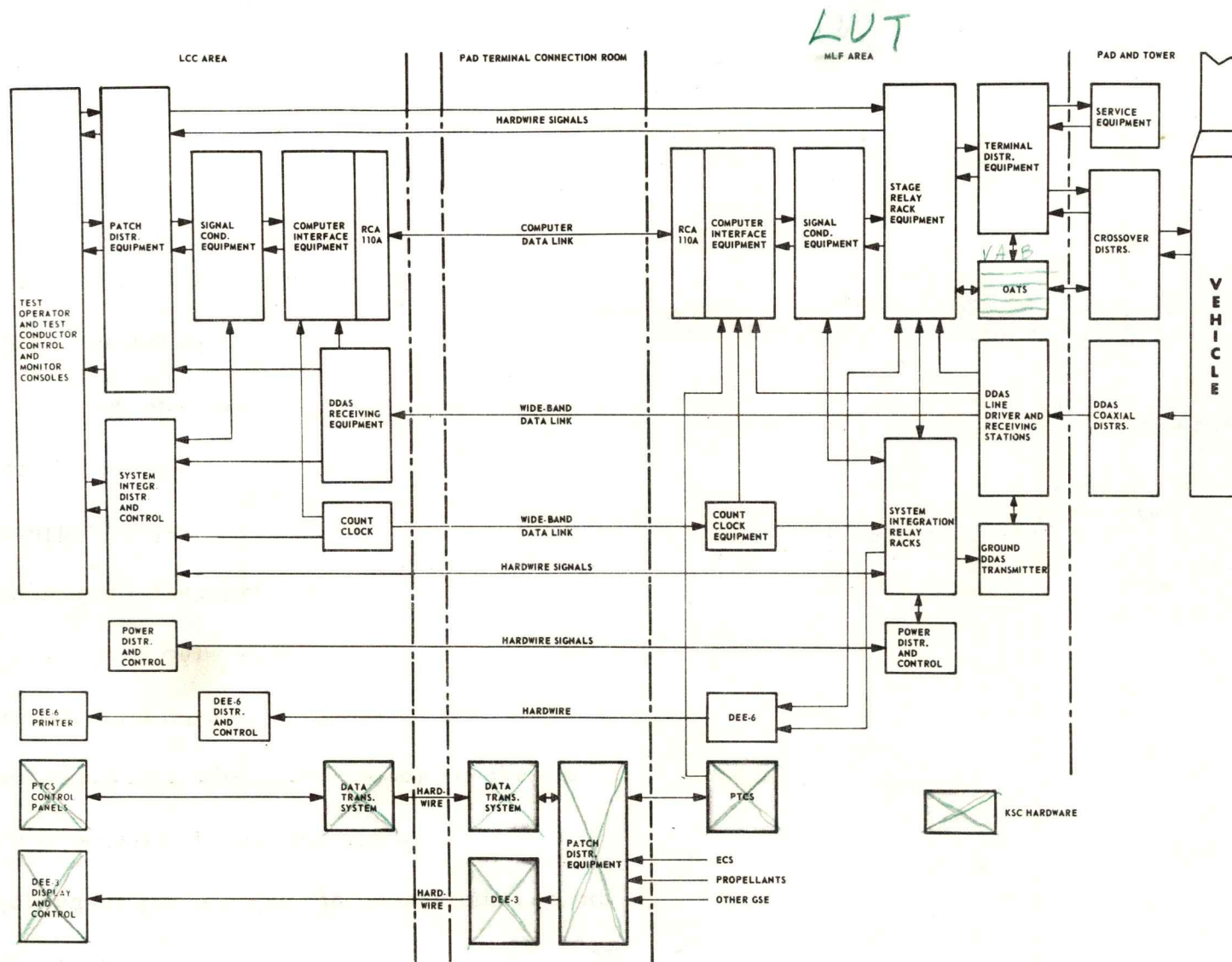


Figure 3. Functional Interconnect Diagram for LC-39-1 Saturn V ESE

TABLE 1. ESE SYSTEM REQUIREMENTS

1. Rapid Checkout
2. Independent Launch Vehicle Subsystem Testing
3. Testing across System Interfaces
4. Compatible with Spacecraft Checkout System
5. Test Documentation
6. Safe and Arm Capability
7. Automation Capability
8. Operating Modes
 - (a) Manual
 - (b) Semiautomatic
 - (c) Automatic
9. Fault Isolation and Troubleshooting

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TABLE 2. AUTOMATIC/MANUAL REQUIREMENTS

1. Automatic Interlocking of Vehicle Commands
2. Automatic operation of all systems associated with launch final 186 seconds
3. Automatic analysis of vehicle measurements
4. Sequencing of test steps in automatic, semiautomatic, or manual mode

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TABLE 3. SUBSYSTEMS/ESE REQUIREMENTS

STAGE	SUBSYSTEM	ESE REQUIREMENTS
S-IC	1. Hydraulics	(a) Check Temp
		(b) Check Press
		(c) Check Flow Rate
		(d) Operation of Engine Valves
		(e) Engine Gimbal & Control
	2. Engines	(a) Flush
		(b) Purge
		(c) Water-Glycol
	3. Fuel	(a) Load Initiate
		(b) Load Monitor
	4. LOX	(a) Load Initiate
		(b) Load Monitor
	5. Pneumatics	(a) Initiate Transfer
		(b) Valve Checkout

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TABLE 3. SUBSYSTEMS/ESE REQUIREMENTS (CONT.)

STAGE	SUBSYSTEM	ESE REQUIREMENTS
SII	Basically same as SIC	
SIVB	Basically same as SIC	
IU	1. Measurement System	(a) Checkout & Calibrate
	2. Telemetry System	(a) Checkout & Calibrate
	3. Guidance	(a) Engine Control
		(b) Computer Checkout

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TABLE 4. FEATURES OF ESE SYSTEM

1. Process and display real time data
2. Increased data accuracy
3. Continuous data evaluation
4. Provides a wide variety of stimuli
5. Provides test documentation
6. Data familiarity during all testing periods
7. Fully automated system
8. Program control
9. Launch control
10. Possess diagnostic capability

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TABLE 5. BASIC APPLICATIONS OF ESE

1. Hardwire Safing Control
2. EBW Firing Unit Charging
3. Bus Voltage Control
4. Turbo-Pump Speed Analysis
5. Ignition Sequence Enable
6. Tanking Monitoring
7. Coordinate Launch Vehicle/Spacecraft Countdown
8. Engine Gimbal Control and Monitoring

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TABLE 6. ESE/SATURN V RELATIONSHIPS

1. ESE Control and Display Grouped According to Subsystem Function
2. ESE Control for Stage Selection Versus Subsystem Function
3. Stage-Peculiar Tanking Monitoring
4. Stage-Peculiar Mechanical GSE/ESE Control
5. Stage-Peculiar Pneumatics
6. Stage-Peculiar Hydraulics
7. Stage-Peculiar Instrumentation
8. Stage-Peculiar Items Controlled from Central ESE Location
9. Stage-Peculiar Items Evaluated by Central ESE Location

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TABLE 7. ELECTRICAL SUPPORT EQUIPMENT

SYSTEMS	FUNCTIONS
1. Computer Complex	<ul style="list-style-type: none"> (a) Performs Programmed Routines (b) Processes Vehicle Data (c) Formats Processed Data for Display and Recording (d) Monitors Vehicle Data for Automatic Control
2. Telemetry (DDAS)	<ul style="list-style-type: none"> (a) Monitors Vehicle Parameters (b) Commutation (c) Decommutation (d) Analog & Discrete Distribution & Routing
3. Control and Display	<ul style="list-style-type: none"> (a) Discrete Control (b) Stage & System Integration Control (c) Manual Control (d) Processed Data Display (e) Real Time Data Display

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TABLE 7. ELECTRICAL SUPPORT EQUIPMENT (CONT.)

SYSTEMS	FUNCTIONS
4. Stage Peculiar	<ul style="list-style-type: none"> (a) ESE/Vehicle Interface (b) Application of Specific Stimuli (c) Patching (d) Measuring
5. Power Control and Distribution	<ul style="list-style-type: none"> (a) Power Switching (b) Power Distribution (c) Backup Capability

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CHAPTER 1

SECTION III

S-IC STAGE ESE

INTRODUCTION

The S-IC ESE provides the monitoring and control of the stage during prelaunch and launch operations to insure complete checkout of the vehicle systems. The following console panels, associated with the checkout of S-IC, provide automatic (computer) as well as manual control, exceptions will be noted:

- (a) S-IC Ground Pneumatics Panel (113A2) 2211.14.01.01 - monitors and controls the gaseous helium and gaseous nitrogen valves and pressure at the primary supply and at the pneumatic checkout rack.
- (b) S-IC LOX System Control Panel (117A2) 2211.14.01.02 - monitors and controls LOX duct bubbling, temperature, and pressure; stage interconnection valves; pressurization; and propellant status.
- (c) S-IC Fuel System Control Panel (117A1) 2211.14.01.03 - controls and monitors fuel systems and functions.
- (d) S-IC Control and Purge Panel (113A1) 2211.14.01.04 - controls and monitors vehicle purge circuits.
- (e) S-IC Prefill Panel (106A1) 2211.14.01.05 - controls the system start, stop, and topping, and monitors flow rate, jacket conditions and filter clogging.
- (f) S-IC Hydraulics Panel (106A2) 2211.14.01.06 - monitors and controls hydraulic pressure, flow, temperature, and valve openings and closures.

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- (g) S-IC Firing Panel (116A2) 2211.14.01.07 - provides firing control, emergency cutoff, interlocking and monitoring of S-IC stage firing sequence functions for preparation, liftoff, and cutoff.
- (h) S-IC Engine Heater Panel (106A3) 2211.14.01.08 - monitors the engine turbopump temperature and monitors and controls turbopump heaters.
- (i) S-IC Engine Panel (106A4) 2211.14.01.09 - monitors and controls Engine 101 through Engine 105 functions and provides an emergency preclude close capability.
- (j) S-IC Measuring and Radio Frequency Panel (111A1) 2211.14.01.10 - supervises the measuring voltages and calibration of telemeters. The panel also controls and monitors the telemeters and associated automatic equipment, tape recorders, ODOP, and provides means for transferring the instrumentation measurements from preflight to inflight status.
- (k) S-IC Exploding Bridgewire and Ordnance Panel (109A2) - 2211.14.01.11 - monitors firing unit charge voltage and pulse sensor firing for separation and retrorocket functions. The panel controls pulse sensor test and reset.
- (l) S-IC Propellant Dispersion Panel (109A1) 2211.14.01.12 - monitors and controls range safety command receiver and exploding bridgewire (EBW) power and indicates propellant dispersion system status.
- (m) S-IC Networks Panel (105A1) 2211.14.01.13 - provides supervision, control, and monitoring of the 28-volt dc buses, and also switch selector and test functions.
- (n) S-IC Sequence Panel (116A1) 2211.14.01.14 - monitors and controls sequence power, the terminal countdown sequencer, ignition sequencer, and cutoff reset.

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- (o) S-IC Camera Pneumatic Panel (111A3) 2211.14.01.15 - provides GN₂ control and monitor for camera lens purging. This panel provides for manual control only.
- (p) S-IC Camera Control Panel (111A2) 2211.14.01.16 - monitors camera frame rate and controls and monitors camera lights, relays, and timer.
- (q) S-IC Cutoff Sensors Panel (106A5) 2211.14.01.17 - monitors and controls the flight combustion, level sensors, pressure sensors, and fuel bi-level sensors.
- (r) S-IC FCM calibration Control Panel (6437A1A1) 2211.14.01.18 monitors and controls combustion sensors for all engines, channel simulation, and control status functions. This panel provides for manual control only.

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CHAPTER 1

SECTION IV

S-II STAGE ESE

INTRODUCTION

The S-II ESE provides monitoring and control of the stage during pre-launch and launch operations to insure complete checkout of the vehicle systems. The following console panels located in LCC are required for checkout of the S-II and provide for automatic (computer) as well as manual control, exceptions will be noted:

- (a) S-II Networks Panel (205) 2221.14.01.01 - controls test and monitors external and internal power buses.
- (b) S-II Exploding Bridgewire and Ordnance Panel (209A2) 2221.14.01.02 - monitors ullage rockets, second separation, S-II/S-IVB separation, and retrorocket charging voltage and EBW firing. The panel controls pulse sensor and separation system reset, pulse sensor test, and liftoff simulation.
- (c) S-II Propellant Dispersion Panel (209A1) 2221.14.01.03 - monitors and controls range safety command receiver and exploding bridgewire power and indicates propellant dispersion system status.
- (d) S-II Propellant Utilization Panel (206A7) 2221.14.01.04 - monitors vehicle 115-volt ac power, LOX fine and coarse mass percentage, LH₂ fine and coarse mass percentage, and engine propellant utilization valve positions and controls system activation and reset, and LOX and LH₂ mass test.
- (e) S-II Ground Pneumatics Panel (206A10) 2221.14.01.05 - controls and monitors gas flow and pressure, LH₂ heat exchanger condition, regulator dome venting, and LOX and LH₂ tank pressure regulation. This panel provides for manual control only.

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- (f) S-II Measuring and RF Panel (211A1) 2221.14.01.04 - supervises the measuring voltages and calibration of telemeters. The panel also controls and monitors the telemeters and associated automatic equipment and tape recorders. The panel provides means for transferring the instrumentation measurements from preflight to inflight status.
- (g) S-II All-Engine Panel (206A6) 2221.14.01.07 - simulates, monitors, and controls engine preparations and functions.
- (h) S-II Individual engine panels provide for the simulation, monitoring and control of engine preparation functions for the respective engines as listed below:
 - (1) S-II Engine No. 201 Panel (206A1) 2221.14.01.08
 - (2) S-II Engine No. 202 Panel (206A2) 2221.14.01.09
 - (3) S-II Engine No. 203 Panel (206A3) 2221.14.01.10
 - (4) S-II Engine No. 204 Panel (206A4) 2221.14.01.11
 - (5) S-II Engine No. 205 Panel (206A5) 2221.14.01.12
- (i) S-II Hydraulics Panel (206A12) 2221.14.01.13 - controls and monitors the hydraulic fluid temperatures and accumulator pressure to provide gimbal forces for engine motion that results in vehicle control. This panel provides for manual control only.
- (j) S-II Recirculation Panel (206A11) 2221.14.01.14 - controls and monitors the LOX and LH₂ circulation system. This panel provides for manual control only.
- (k) S-II Camera Pneumatics Panel (206A13) 2221.14.01.15 - monitors positions I and III helium pressure, controls positions I and III helium fill and vent valve opening, and indicates positions I and III ejection solenoid safe condition.

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- (l) S-II Camera Control Panel (211A2) 2221.14.01.16 - monitors camera from rate and control and monitors camera lights, relays, and timer.
- (m) S-II Propellant Monitor Panel (206A8) 2221.14.01.17 - controls and monitors ground and vehicle propellant systems during checkout operations and propellant tanking functions.
- (n) S-II Pressurization Panel (206A9) 2221.14.01.18 - controls and monitors pressurization supply, disconnect, purge, and vent valves.
- (o) S-II Propellant Depletion Panel (206A14) 2221.14.01.20 - provides the controls and displays required to test and verify condition of the S-II stage propellant sensing systems.
- (p) Leak Detection and Purge Panel (206A15 2221.14.01.33)
- (q) Leak Detection Recorder Select Panel (5980A5A4) 2221.14.01.34
- (r) Propellant Mass Decoder (206A8A2 and 206A8A3) 2221.14.01.36 and 2221.14.37 - take the LH₂ and LOX Binary Coded Decimal Number (BC DN) data from the propellant tanking computer system and converts it to a decimal code suitable for driving the automatic and manual mass readouts on the propellant monitoring panel. This panel provides for manual control only.

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CHAPTER 1

SECTION V

S-IVB STAGE ESE

INTRODUCTION

The S-IVB ESE provides monitoring and control of the stage during prelaunch and launch operations to insure complete checkout of the vehicle systems. The following console panels located in LCC are required for checkout of S-IVB and provide for automatic (computer) as well as manual control, exceptions will be noted:

- (a) S-IVB APS Launch and Monitor Panel (419A1) 2231.14.01.01
- controls and monitors fuel, oxidizer, and helium pressure functions.
- (b) S-IVB APS Servicers Control Panel (419A3) 2231.14.01.02
monitors and controls oxidizer and fuel status during loading operations and provides the necessary load abort command switches.
- (c) S-IVB APS Pneumatic Panel (419A2) 2231.14.01.03 -
controls and monitors the valves for facility line purge and checking the high-pressure switching. This panel provides for manual control only.
- (d) S-IVB Helium Control Panel (406A10) 2231.14.01.04 -
monitors and controls that portion of the ground pneumatics which operates from the helium supply.
- (e) S-IVB GH₂/GN₂ Control Ground Panel (406A8) 2231.14.01.05 -
controls and monitors the hydrogen and nitrogen supplies. The hydrogen is utilized to remove heat in the heat exchanger and the nitrogen is utilized to purge the system. This panel provides for manual control only.

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- (f) S-IVB Propellant Utilization Panel (406A2) 2231.14.01.06 - provides the necessary controls and monitoring facilities for the inflight, closed-loop Propellant Utilization (PU) system. The inflight PU system minimizes the amount of propellant residual by controlling the propellant flow rate to the engine. This panel provides for manual control only.
- (g) S-IVB Engine Test Panel (406A5) 2231.14.01.07 - controls and monitors engine functions.
- (h) S-IVB Engine Preparation Panel (406A6) 2231.14.01.08 - contains the necessary controls and monitors to assure proper engine preparation for launch. (Figure 4) This panel provides for manual control only.
- (i) S-IVB Networks Panel (405) 2231.14.01.09 - The S-IVB networks panel monitors and controls bus supervision, power control, power transfer, switch selector, and test functions.
- (j) S-IVB Stage Pressure Panel (406A7) 2231.14.01.10 - controls and supervises vehicle valves and engine components associated with the propulsion system.
- (k) S-IVB Hydraulics Panel (407A1) 2231.14.01.11 - controls and monitors auxiliary hydraulic pump, hydraulic reservoir oil level, main and hydraulic pump inlet oil temperature, and hydraulic system pressures and temperature.
- (l) S-IVB Recirculation Panel (406A1) 2231.14.01.12 - controls and monitors the LOX and LH₂ circulation system. This panel provides for manual control only.
- (m) S-IVB Propellant Dispersion Panel (409A2) 2231.14.01.13 - monitors and controls range-safety command-receiver and exploding-bridgewire power and indicates propellant dispersion system status.

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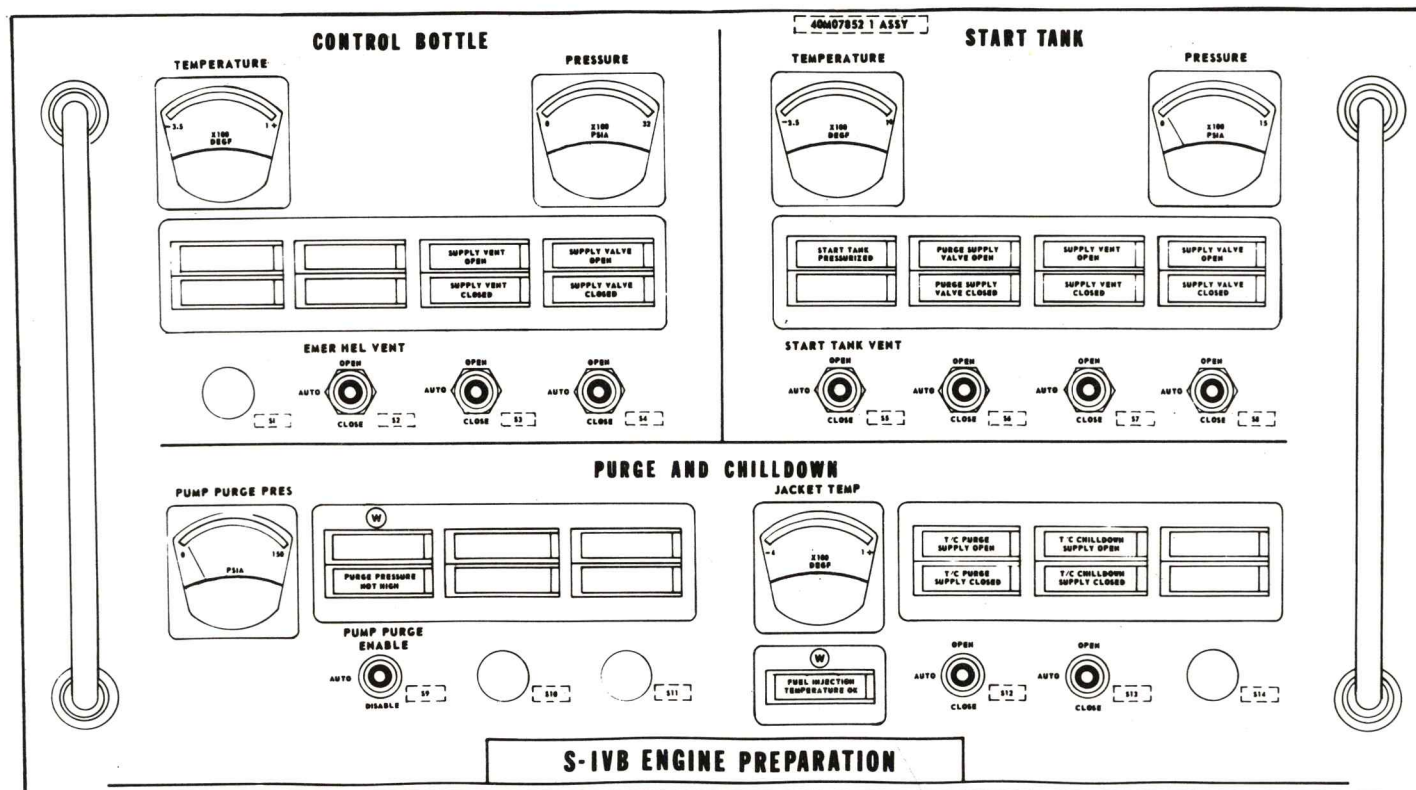


Figure 4. S-IVB Panel Assembly (Typical of All Discrete Panels)

DDAS - (ANALOG SIG)

- (n) S-IVB EBW and Ordnance Panel (409A1) 2231.14.01.14 -
The separation of the S-IVB stage from the preceding stage requires a short, uncontrolled coast prior to ignition of the S-IVB stage main engine. A separation system disengages the two stages, and ullage rockets on the S-IVB stage and retrorockets on the lower stage are fired to effect separation. This panel provides the necessary controls and indicators for this action in a manual mode only.
- (o) S-IVB Measuring and Radio Frequency Panel (411A1) 2231.14.01.14 - provides control of power to the vehicle instrumentation equipment, selection of calibration mode, control of recorder operation, and indications as required. The measuring and RF panel provide the means to monitor the stage conditions prior to flight for checkout purposes and during flight for performance evaluation. This panel provides for manual control only.
- (p) S-IVB Bulkhead Vacuum Monitor Panel (418A1) - monitors pressure of stage components associated with the S-IVB bulkhead and controls those functions necessary for maintenance of the bulkhead vacuum through a manual control only.
- (q) S-IVB Propellant Monitor Panel (406A8) - controls and monitors stage and ground propellant tanking operations for LOX and LH₂.

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CHAPTER 1

SECTION VI

INSTRUMENT UNIT (IU) ESE

INTRODUCTION

The IU ESE provides monitoring and control of the IU stage during prelaunch and launch operations to insure complete checkout of the vehicle systems. The following console panels located in the LCC are required for checkout of the IU and are equipped with switches for selecting manual or Automatic (computer) Control, exceptions are noted:

- (a) Control Accelerometer Panel (607A1) 2241.14.01.01 - operates and monitors the flight control accelerometer system. The panel provides stimulus signals to the control accelerometers for a subsystem test of the flight control system loop.
- (b) Control Rate Gyro Panel (607A2) 2241.14.01.02 - controls and monitors the rate gyros. The panel controls gyro power, monitors gyro output, and applies torquing currents for calibration and control.
- (c) ESE/Control Rate Gyro Panel (607A5) 2241.14.01.03
- (d) Control Computer Input Substitute Panel (607A6) 2241.14.01.04 - provides substitute commands to the flight control computer for redundancy checks, stage control selection, and system simulation selection. The panel controls and monitors input stimulus simulation and provides comparator monitoring and reset of attitude control jet spare channel utilization and S-IVB engine spare channel utilizations.
- (e) Flight Control Computer Panel (607A7) 2241.14.01.05 - monitors pitch, yaw, and roll attitude error signals from the ST-124M platform system; attitude rate signals from the rate gyros; and controls and monitors the control attenuator timer and voltages to engine actuator feedback potentiometers and checks redundant circuits A and B.

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- (f) S-IC Engine Deflection Panel (607A8) 2241.14.01.06 - monitors the yaw, roll, and pitch positions of the four deflectionable engines of the S-IC and monitors the differential current to the servo valves that control the hydraulic actuators.
- (g) S-II Engine Deflection Panel (607A9) 2241.14.01.07
- (h) S-IVB Engine Deflection Panel (607A10) 2241.14.01.08 - monitors engine yaw and pitch, engine servo valve current, actuation of attitude control jet servo valves and associated relays, and firing of attitude control jets.
- (i) Theodolite Control Panel (608A1) 2241.14.01.09 - controls and monitors functioning of theodolite equipment for preflight IU alignment.
- (j) ST-124M Checkout Panel (608A2) 2241.14.01.10 - controls inertial platform checkout, including servo damping and attitude alignment tests. For the servo damping test, controls provide transient response tests for each of the six servo loops associated with the inertial platform gyros and accelerometers. For the attitude alignment test, controls provide a closed-loop alignment test for each of the three platform axes in order to align the platform with positions predetermined by inertial data box command modules.
- (k) ST-124M Control Panel (608A3) 2241.14.01.11) - monitors the IU inertial platform providing reversible torquing of platform gyros, analog readout of steering commands and platform response, and establishment of prelaunch or launch platform readiness.
- (l) Inertial Data Box Control Panel (608A4) 2241.14.01.12 - controls and monitors inertial data box performance, including selection of command modules, activation of command module brakes, selection of "drive" or "follow" mode of operation, application of power, and zeroing the command modules with the inertial platform axes.
- (m) Azimuth Remote Control Panel (608A8) 2241.14.01.13 - controls selection of digital data and input of digital data to the azimuth computer simulator for verification of inertial platform azimuth alignment capability.

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- (n) CMR Remote Control Panel (608A7) 2241.14.01.14 - controls selection of digital data and input of digital data to the Control Module Repeater (CMR) computer simulator for verification of CMR alignment capability.
- (o) Switch Selector Panel (605A2) 2241.14.01.15 - provides prelaunch control and checkout of vehicle switch selectors over hardwires between the LCC, MLF, and the vehicle. The switch selectors, one in each stage, provide communication between the IU flight computer-data adapter and control distributors in the IU and each stage. The switch selector panel directly controls the switch selectors by bypassing the flight computer-data adapter.
- (p) IU Networks Panel (605A1) 2241.14.01.16 - operates and continuously monitors certain IU and ground power buses; monitors certain IU switch selector functions; and operates and monitors devices and functions associated with the IU networks system.
- (q) IU Ground Pneumatics Panel (613A2) 2241.14.01.17 - monitors and controls the IU pneumatics console.
- (r) IU Cooling/GN₂ Systems Panel (613A1) 2241.14.01.18 - controls and monitors the preflight functioning of the IU stage cooling system and the ESE cooling unit.
- (s) IU Measuring and Tracking Panel (611A1) 2214.14.01.19 - simulates, monitors, and controls the radar tracking and vehicle measuring and telemetering equipment of the IU. The controls provide on-off commands for telemetering equipment, radio frequency transmitters, tracking devices, tape recorders, calibration equipment, and stage measuring equipment. The measuring and tracking system selects telemetry calibration modes, sets preflight calibration levels, and controls input of calibration signals.
- (t) EDS Flight Monitor Panel (C10AZ) 2241.14.01.21

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- (u) EDS Preparation Panel (G10A3) 2241.14.01.22
- (v) Q angle of Attach Panel (610A4) 2241.14.01.23
- (w) IU Events Display Panel (615A1) 2241.14.01.24
- (x) Theodolite Error Panel (608A16) 2241.14.01.27 -
monitors moving prism alignment error and inertial prism
alignment error detected by the theodolite system.
- (y) APS Display 2241.14.01.36
- (z) Analog Recorder Control Panel No. 1 (607A14)
2241.14.01.39
- (aa) Analog Recorder Control Panel No. 2 (608A14) 2241.14.01.
41 - controls the recording, including range selection
polarity selection; calibration; and timing of 31 channels of
analog signals.

Figures 5, 6, 7, 8 and 9 are block diagrams of the ESE and the Firing Room layout.

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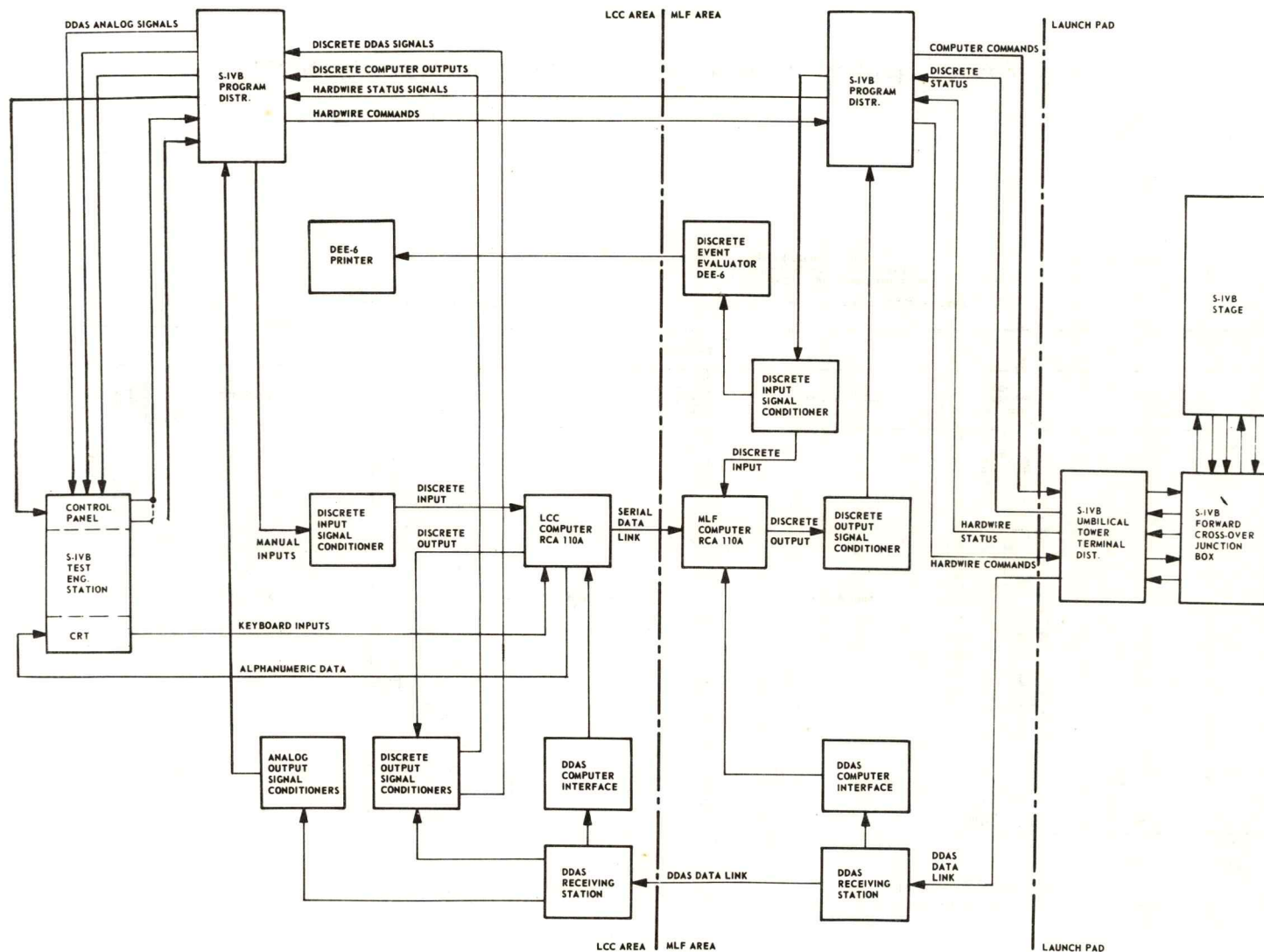


Figure 5. Saturn V ESE Signal Flow Diagram (Typical)

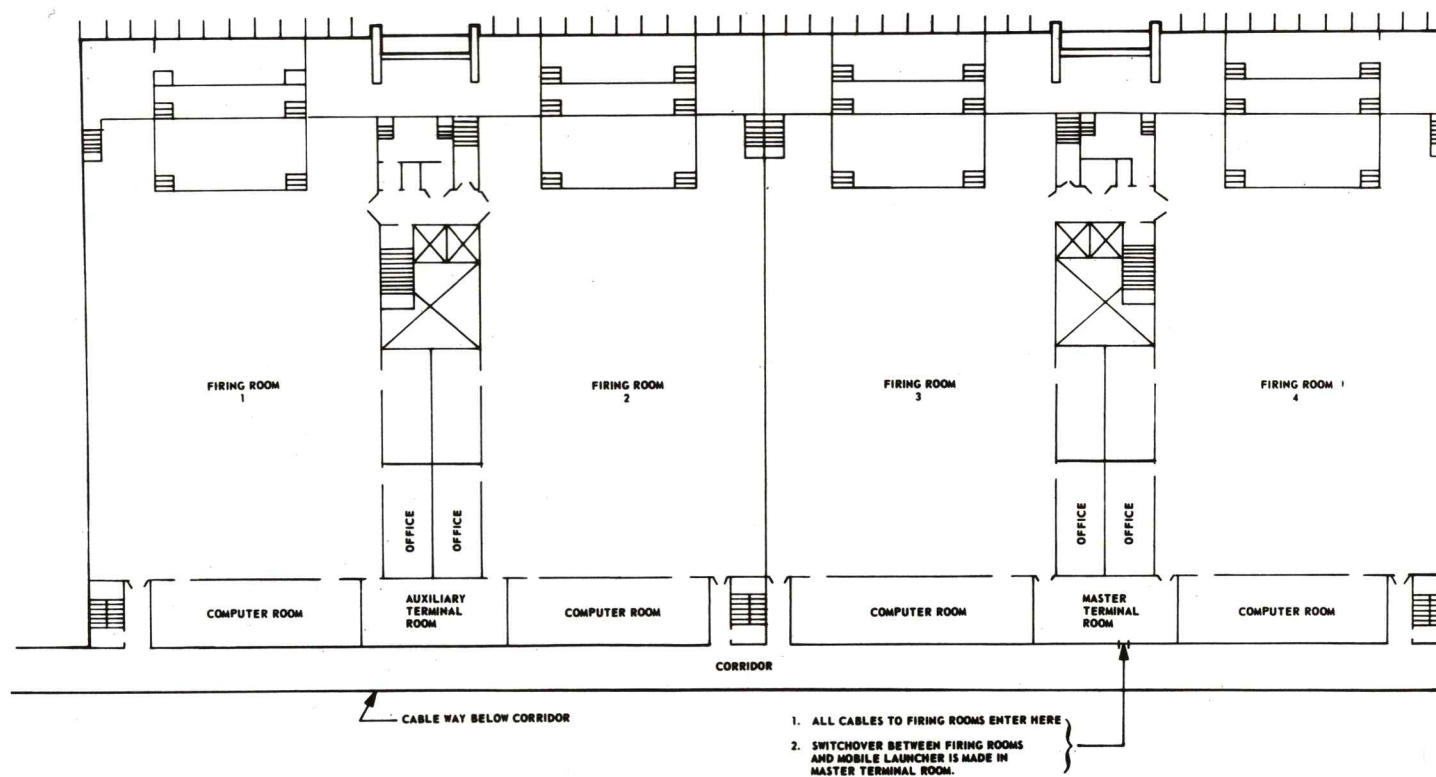


Figure 6. Firing Rooms, Third Floor, Launch Control Center

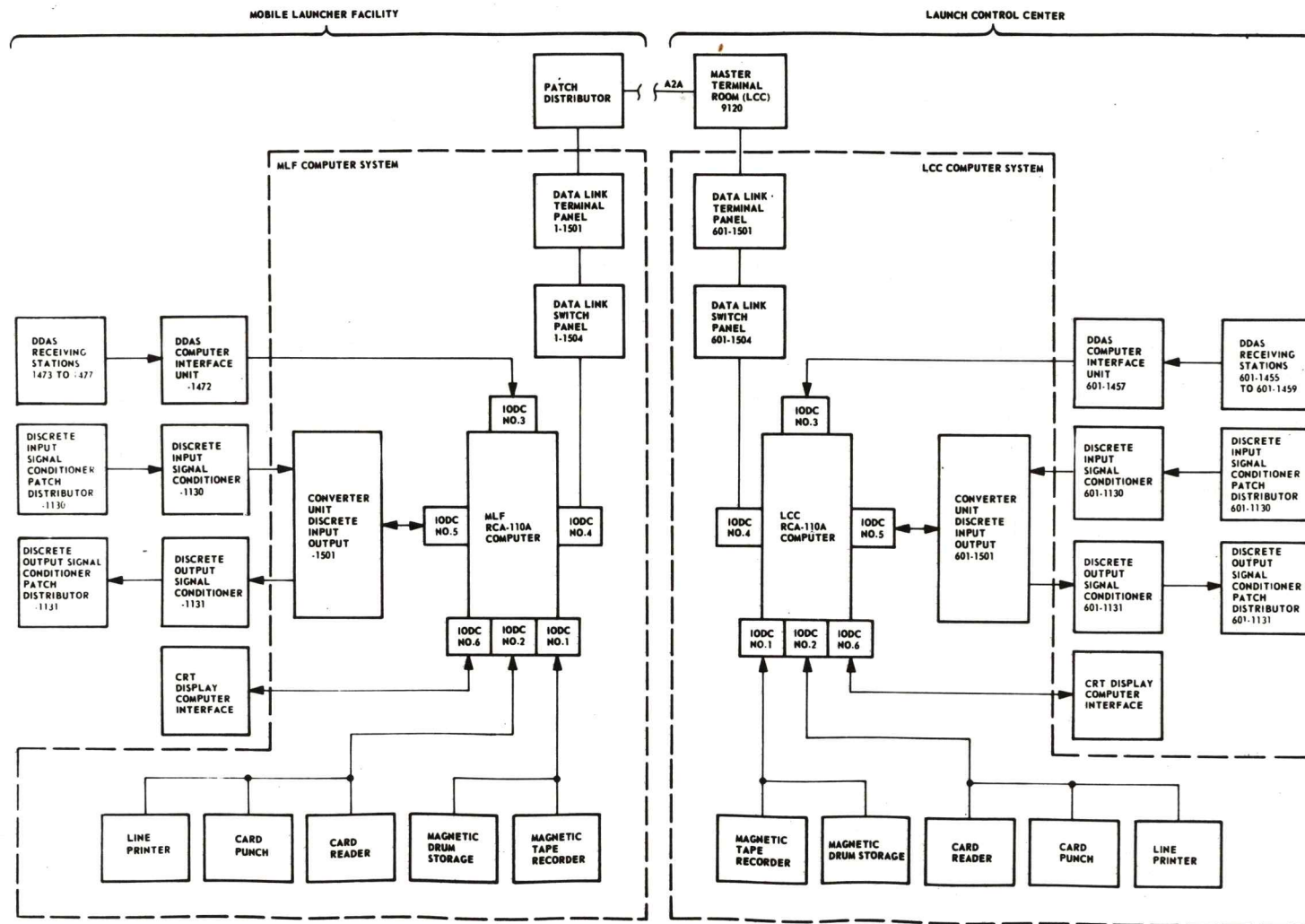


Figure 7. RCA-110A Computer Complex Block Diagram

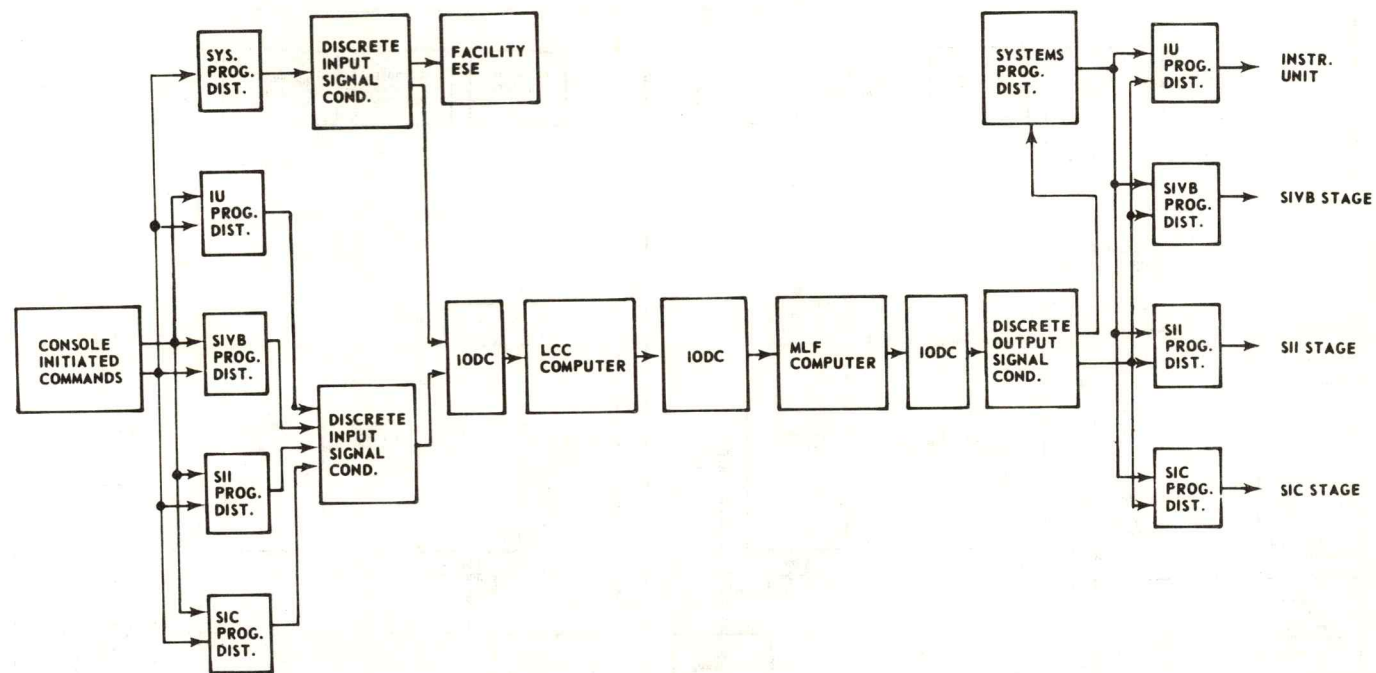


Figure 8. Saturn V ESE Discrete Command Loop

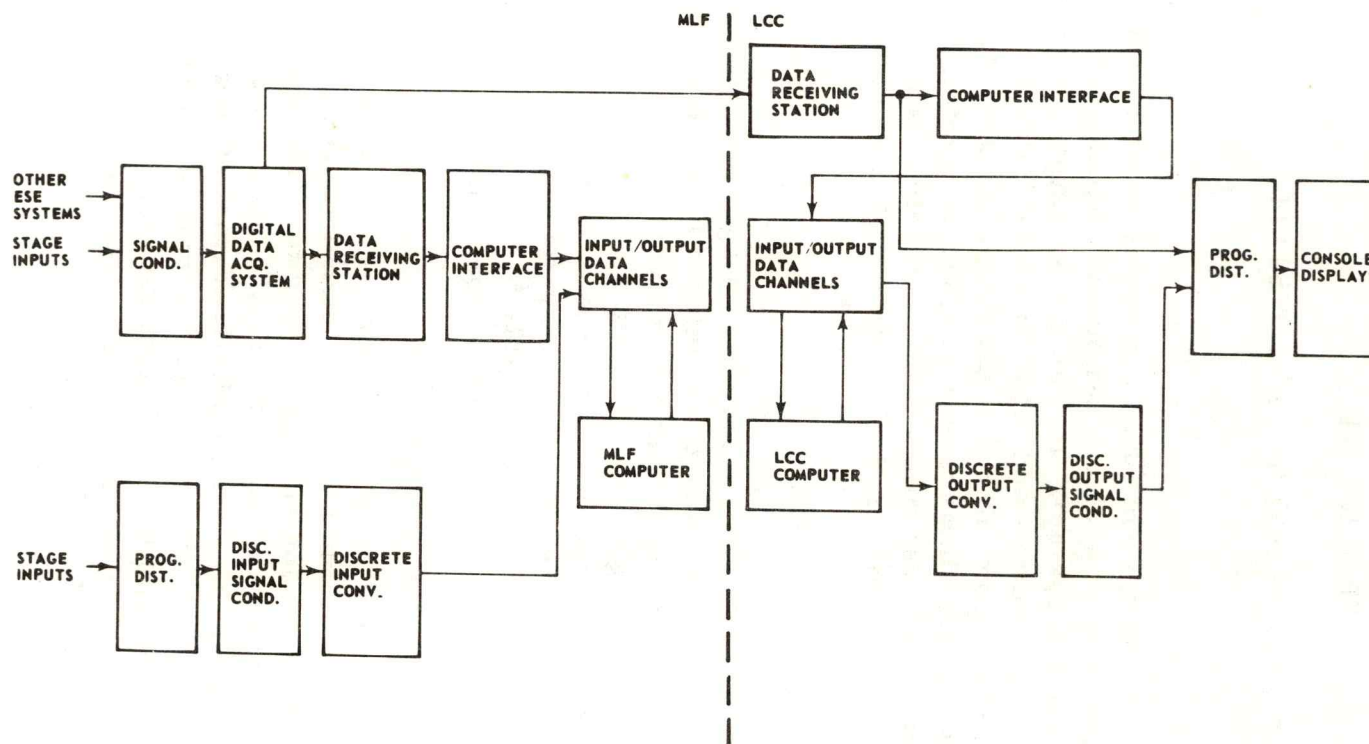


Figure 9. ESE Discrete and Analog Response Loop

CHAPTER I

SECTION VII

DIGITAL DATA ACQUISITION SYSTEM

INTRODUCTION

The digital data acquisition system (00A5) is inclusive of both the missile-borne telemetry and the electrical support equipment decommutation and routing system. Its basic function is to periodically sample vehicle parameters and make these available in a form usable for distribution and computer processing. This system is in parallel with the basic computing systems of ESE, thus eliminating time sharing degradation of system operation and releases the processing systems for use in the more critical areas of vehicle checkout.

DESCRIPTION

The digital data acquisition system consists of stage telemetry systems and ground decommutators. An additional telemetry system is utilized in conjunction with a ground decommutator to monitor the ESE functions. As indicated in Figure 10, the data collected from the telemetry systems is also transmitted to the launch control center (LCC) digital data acquisition system. This system is utilized for updating console displays and makes available to the LCC computer analog and discrete information to be utilized for monitoring and controlling.

Each stage telemetry system commutates formats and transmits to a ground data receiving station, a PCM/FM signal representing stage parameter values of both analog and digital origin. The applicable data receiving station synchronizes on the PCM signal and performs decommutation and addressing of the digitally formatted words. The data receiving stations located in the launch control center (LCC) (Figure 11) provide all data to the local computer for use in parameter processing and control of various programs pertaining to the automatic checkout operation by the MLF computer.

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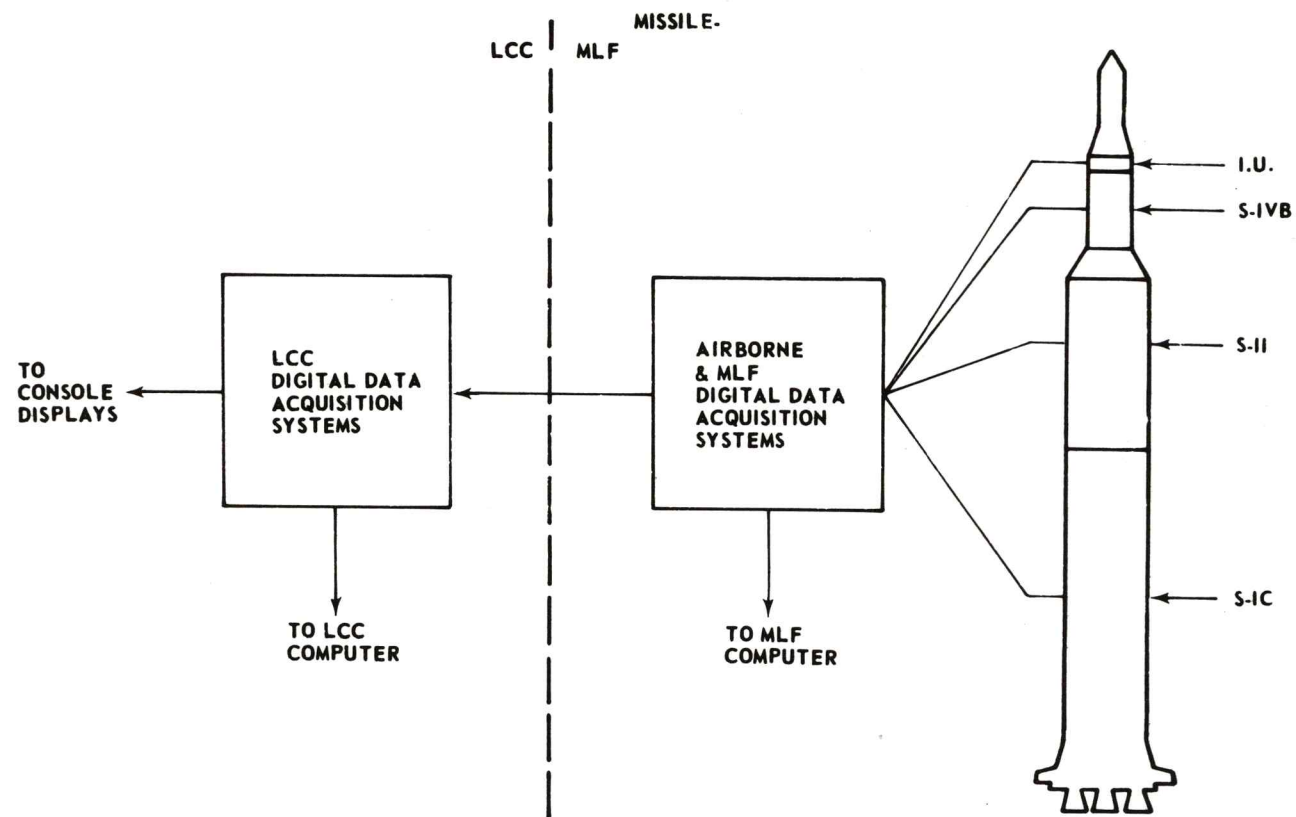


Figure 10. DDAS Locations and Interconnect

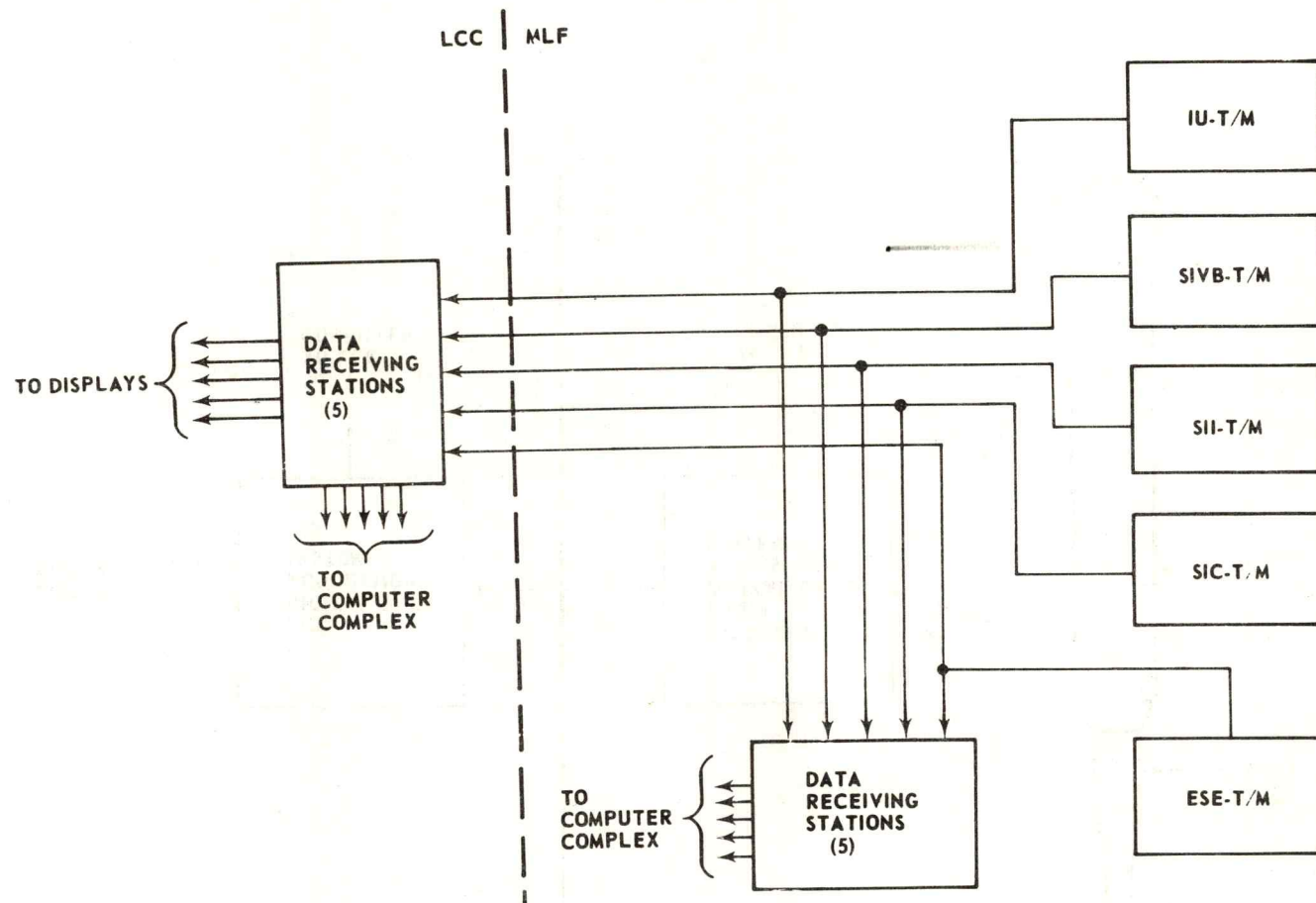


Figure 11. Digital Data Acquisition System (DDAS)

The data transmitted to the LCC data receiving stations is of the same content and format transmitted to the MLF data receiving stations; however, based upon program philosophy, the utilization of the data is slightly different. The LCC computer uses the data as stated earlier, for monitoring and controlling certain programming functions relative to supervisory program control. Also, outputs are made available to console displays for both analog and digital parameters.

The stage DDAS equipment collects data applicable to stage functions and status and transmits this as a PCM/FM 9600kc) data train to line drivers. The line drivers perform the function of accepting PCM/FM signals from five sources and transmitting this data over separate video hardlines to distant receiving stations. The line receivers function as a terminal for the video hardlines and also to demodulate the PCM/FM signals, thus outputting a PCM digital data train to the data receiving stations. The line receivers also output PCM data to analog magnetic tape recorders for recording during decommutation.

The DRS equipment decommutates the PCM data and presents to the computer interface unit decommutated words in a format usable by the RCA-110A computer for processing. The computer interface has a capability of scanning all five decommutators and storing the data in specific locations for use by the computer as determined by the operating program. Both the data receiving stations and the computer interfaces in the MLF and LCC function in the same manner. The DRS equipment in the LCC has an added function of converting selected digital words for analog conversion for output to recorders, meters, and lights.

The telemetry receiver functions as a demodulation device to demodulate the PCM/RF data to a digital PCM data train for use by the data receiving stations. This transition from hardline to RF transmission occurs prior to liftoff and gives the capability of passive monitoring by the LCC data equipment.

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The digital data acquisition system interfaces with other ground support equipment to aid in performing checkout and countdown as described below: (Refer to Figure 12).

- a. The stage and ground support DDAS (telemetry functions) equipment provides analog signals to the measuring station that is utilized in support of test and checkout operations of the launch vehicle in the vehicle assembly building (VAB) and in the launch complex.
- b. Interface with an input/output (I/O) data channel of the RCA-110A computers to provide decommutated data in a form usable by the computers during a processing and control program.
- c. Interfaces with the tail service masts subsystem to provide discrete signals relative to tail service masts operation.
- d. Interfaces with the Q-Ball cover removal system to provide digital data to the control room for monitor and control functions.
- e. Interfaces with launch equipment firing circuits subsystem to provide digital data to the control room for monitor and control functions.
- f. Interfaces with propellant tanking computer system to provide the computer complex with data relative to tanking operations and for Mass ratio calculations.

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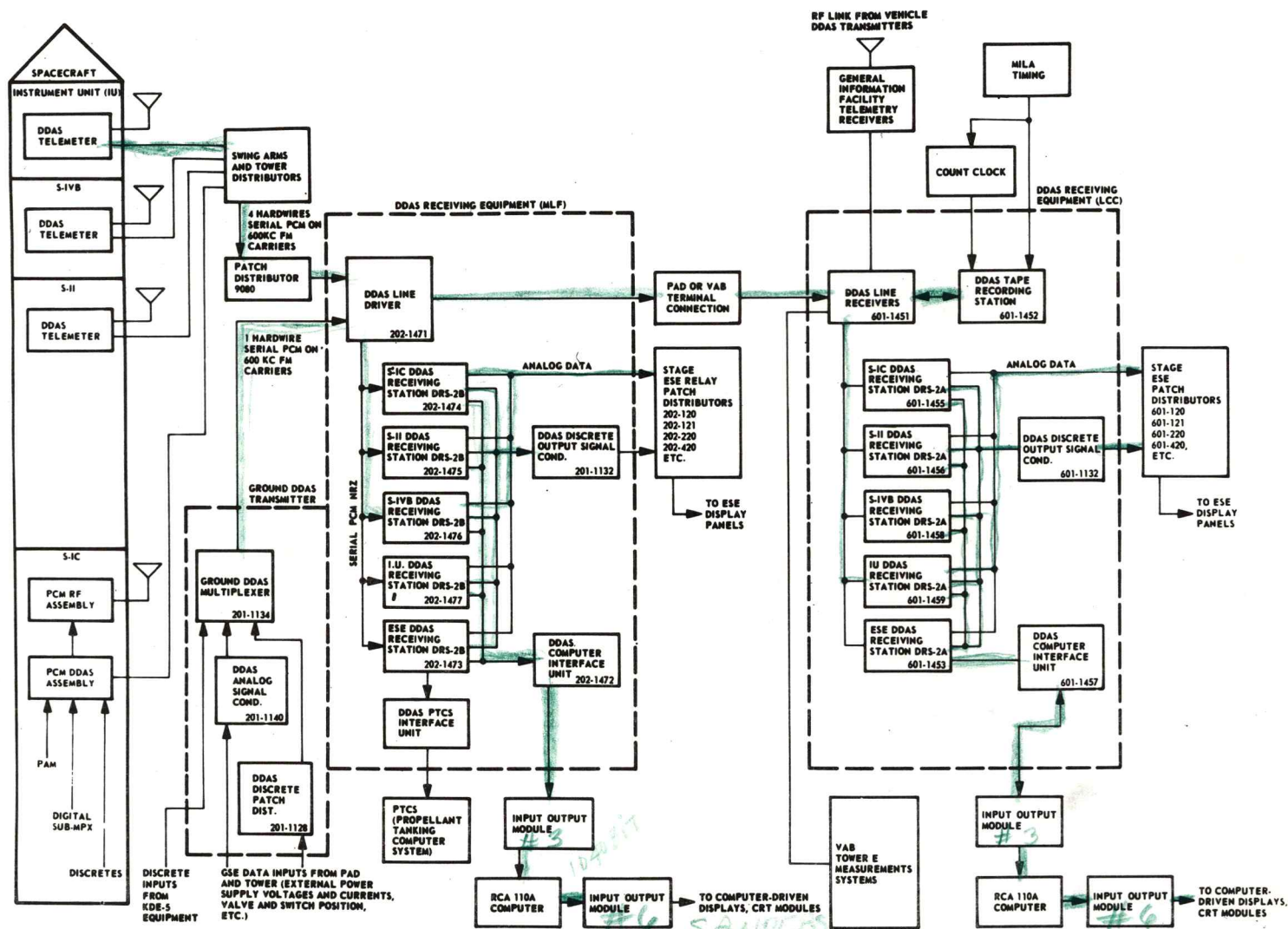


Figure 12. DDAS Block Diagram

CHAPTER I

SECTION VIII

DIGITAL EVENTS EVALUATOR

INTRODUCTION

The digital event evaluators continually monitor the status of the input data lines and generate a time tagged printout for each detected change in input status. The result is a printed record of the order of discrete event occurrence and the time at which each event actually takes place. High-speed printers, which are located in the LCC, are connected to the DEE to provide a means for real time or post-test evaluation of discrete data. There are two DEE systems utilized in the Saturn V checkout and launch support equipment. The two systems, DEE3 and DEE6, are essentially the same in their internal operations and use in the Saturn V checkout system. The basic differences between these two devices are the number of input signals that can be accepted and their speed of operation. The DEE3 is connected to the Propellant Tanking Computer System and the Environmental Control System and will not be discussed in this document.

The DEE6 can accept up to 2160 discrete signals, which are represented by 0 or 28 vdc. These discrete signals are routed through the patch distributors that are indicated in Figure 13. These discrete signals are from the vehicle stage umbilicals, the pad and tower GSE, and the ground DDAS receiving stations.

The DEE is a solid-state device that includes a digital computer, associated logic, and input/output devices. The primary purpose of the DEE is to provide a means of recording discrete events from a large number of input lines. (A discrete event is defined as a change in voltage on a line either from 0 to +28 vdc, or from +28 vdc to 0.) The opening or closing of relay contacts are examples of discrete events. The operation of the DEE6 system (see Figure 13) involves three basic cycles:

- a. Scanning cycle.
- b. Alarm recording cycle.
- c. Output cycle.

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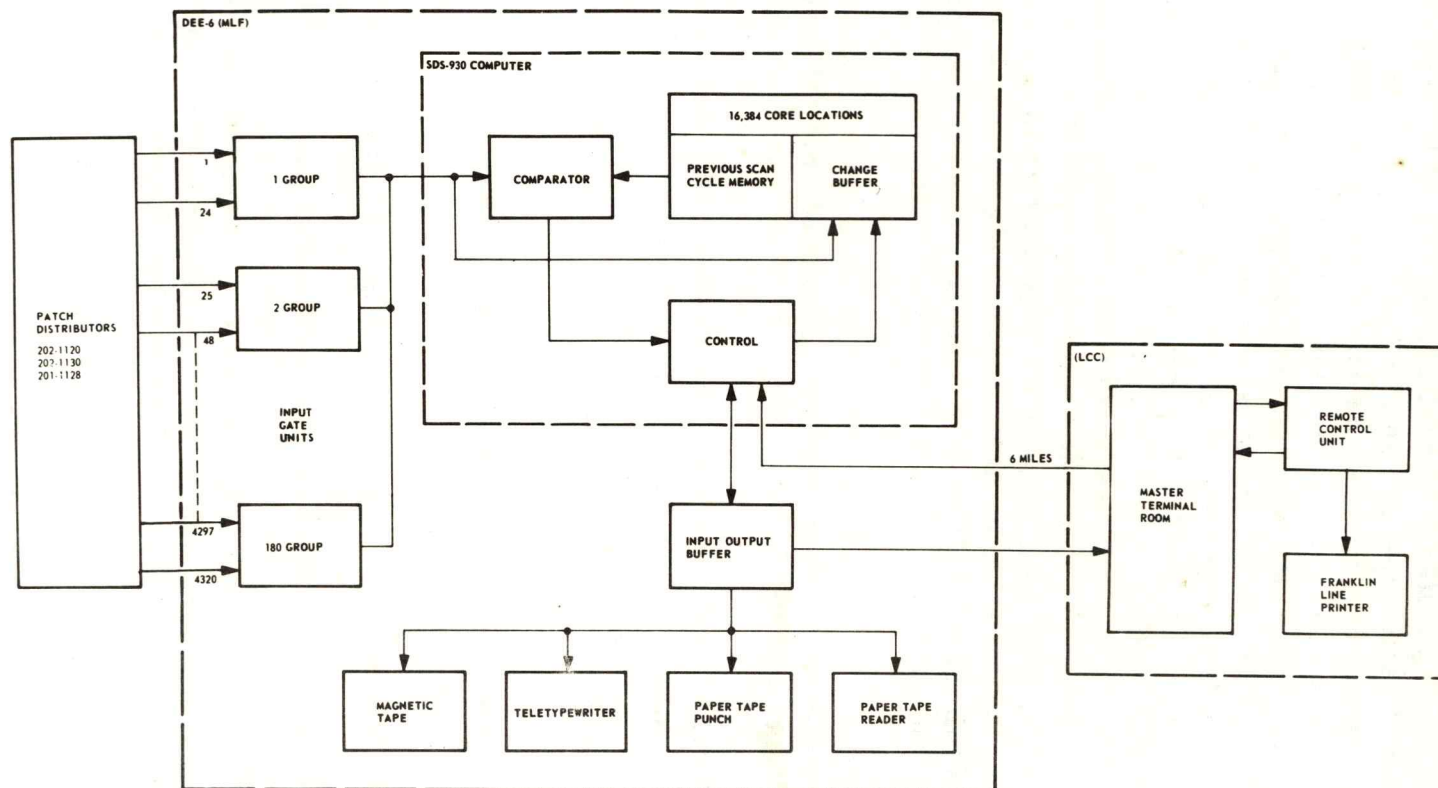


Figure 13. DEE-6 Systems Block Diagram

These basic cycles are performed under control of an SDS-930 digital computer; the computer program can be varied to provide different operational sequences as desired for specific tests. The most common operating program is one which causes the DEE to begin a scanning cycle every millisecond; this known as the 1-ms interrupt program. Under control of the scan control program, discrete event data enters the DEE through the input gate units, from the appropriate relay rack or the discrete input signal conditioners. Filters in the input gate units reject all pulses of 0.5 millisecond or less, thus eliminating line noise spikes.

A strobe signal generated by the control unit will "enable" a selected input gate unit, which will then present the status of 24 input lines (one group) to one side of the comparator. At the same time, the last previous state of this group will be gated out of computer memory to the other side of the comparator.

If the current status of the lines compare (bit for bit) with the stored status, no further action is required and the control unit will advance to the next group of 24 input lines.

If the current status of each line being tested does not compare with the status of that line during the previous cycle, a discrete event has occurred and must be evaluated. The following information of this discrete event will be stored in the change buffer portion of computer memory:

- a. Time of detection (range time in milliseconds) of the discrete event.
- b. An index number defining the group that did not compare.
- c. Previous status of the 24 input lines in this group.

In addition, the current status of the group will be used to update the previous scan cycle memory, which will be used as the basis for future comparisons.

During the output cycle, the stored change data is converted in the output buffer to a format which is compatible with the selected output devices, that is, line printer or typewriter and magnetic tape.

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Since the output devices are relatively slow compared to the computer speed, the computer cycle need only operate once every few milliseconds. Once the data has been placed in the output buffer, the computer is free to initiate another scan sequence.

Synchronous operation with other systems and scan cycle initiation is provided by inputs from the clock and timing system. Internal timing is provided by an independent clock.

Each discrete event is processed through the output buffer and is printed out and/or recorded on magnetic tape. The data contains information on channel number, present status, and time of change detection. If no event has occurred in the last minute, only the range time will be printed out. The DEE6 may be controlled by a remote control panel located in the LCC adjacent to the Franklin high-speed printer. The printer is capable of printing 40 lines per second with 20 columns per line. The following is an example of a typical printout:

```

                                2254
                                2255
                                2256 Range Time: Hours, Minutes

740          OFF              12. 700
741          OFF              12. 700
723          ON                12. 724
743          OFF              12. 724 Range Time: Millisecond

                                Discrete Status 2257
Discrete Number                2258 Range Time: Seconds
```

Special programs can be used during the output cycle to produce a printout of only those lines in the "ON" state, if desired. Another special printout can be programmed to list only those discrete events which occur out of a previously established sequence.

Various combinations of discrete events and recorded times can be so formatted as to produce time and cycle information for component evaluation. The data formats previously described are a function of programming the DEE's general-purpose digital computer.

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CHAPTER II

SECTION I

BASIC DIGITAL COMPUTER DESCRIPTION

GENERAL

To adequately understand the operation of the various computers utilized in the ESE, it is necessary for the student to have an understanding of basic digital computers. A digital computer is defined as a machine that represents information in a discrete manner in contrast to an analog computer that represents information in a continuous manner. A digital machine that stores both its program and data to be used and also executes the stored program automatically, is generally referred to as an automatic digital computer.

A set of devices that are utilized to retain the information being processed is referred to as the memory of the computer. Most machines use several different types of devices in their memory, and the different types are usually classified according to their speed and the particular use for which they are intended.

Many of the memory devices utilized in digital computers are such that information can be read from, or stored in, them at the operating speeds of the particular machine. This means that the machine can both read information from, and store information in, those devices during operation, and it can write over information previously stored. A set of devices with these characteristics is called internal memory and is, thereby, distinguished from input storage media (perforated paper cards and tape etc.) and output storage media (line printers etc.). A machine which can store both its program and the data which is used in its internal memory is called a stored program computer.

A digital system is a data or information processing system which performs a major portion of its processing operations, by the use of a digital machine or a set of inter-related digital machines. When reference is made to a digital system, we not only include the machine, but also the operators and all the peripheral equipment associated with the system.

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Automatic digital computers are usually separated into two general classes: (1) general purpose computers and (2) special purpose machines. A general purpose machine is designed to perform a wide variety of functions, whereas a special purpose machine is designed to perform a specific function. Typically, a general purpose computer is a stored program processor in that it stores the sequences of instructions comprising a given program in its internal memory. This makes it possible to read a particular program and the associated constants and data into the computer's memory, have the computer perform the calculations specified by the program, and then read in and execute another and, perhaps a different program.

A general purpose digital computer consists of four major sections: memory, arithmetic, control, and input/output. Any functional part of a general purpose digital computer can be included in one of these major sections. Figure 14 details the functional breakdown of a digital computer and illustrates the relationship among the various sections.

MEMORY

The memory section of a computer consists of an array of permanent or semi-permanent storage devices as its primary element. In modern high-speed computers, this device has generally been the ferrite core. The ferrite core has the capability of retaining information in one of two magnetic states, making it capable of storing one bit (binary digit) of information. The magnetic properties of the core allow it to maintain a magnetic state without the application of power, and these properties also allow this state to be changed upon the application of magnetic field of the proper intensity and direction. The core can be switched from one magnetic state to the other very rapidly; approximately one to two microseconds. Since the cores are small in size (30 mils or so in outside diameter), a memory containing 100,000 cores or more can be built into a package not much larger than a textbook.

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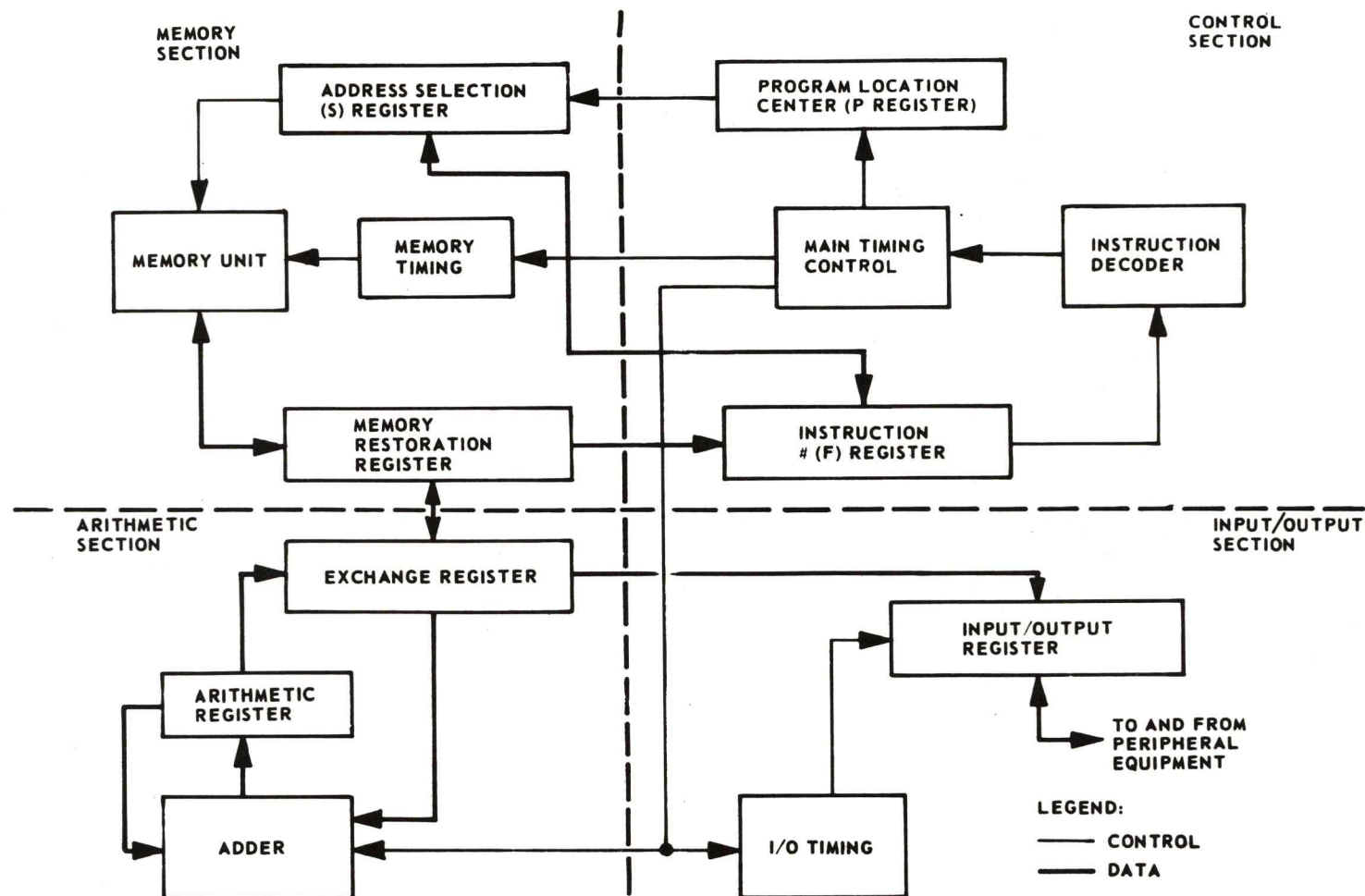


Figure 14. Digital Computer Block Diagram

A common configuration for a core memory has 4096 cores mounted in a 64 by 64 matrix on each of a number of planes, the number of planes being equal to the number of bits (length) of the word to be stored. Each plane stores one bit of the data word in any one of 4096 locations, as determined by the address associated with that data word. The complete memory for a computer would be made up of one or more of these banks of memory.

Each core in a plane is threaded by four wires: (1) a horizontal drive line, (2) a vertical drive line, (3) a sense line, and (4) an inhibit line. For each plane of the memory described, there are 64 horizontal drive lines, each threading 64 cores; 64 vertical drive lines, each threading 64 cores; a single sense line, threading all 4096 cores; and an inhibit line threading all 4096 cores. To complete the wiring of the memory, the corresponding horizontal line of each plane are connected together in series.

A given memory address, specifying a single core in each of the 13 planes, is selected by translation of the output of the memory address register to select one horizontal drive line and one vertical drive line. Only one core in each plane is threaded by the selected horizontal and vertical drive lines, and is, therefore, the core selected by that memory address. When information is to be stored in memory or read out of memory, a half current (a current having only approximately one-half the amplitude required to switch a core) is applied to the selected drive lines.

All the cores that are threaded by only one of these wires will be disturbed by a current that is not sufficiently large enough to switch the cores, while the single core on each plane that is threaded by both of these wires will be disturbed by a current that is of sufficient amplitude to switch the magnetic state of the core.

During the readout of information from the memory, the magnetic state of each of the selected cores is switched to the zero state. If the selected core was initially in the one state, a voltage of approximately 50 millivolts will be induced in the sense line when the core is switched to the zero state. If the selected core was initially in the zero state, it remains in that state and virtually no voltage is induced in the sense line. Therefore, by examining the sense line at an appropriate time after the drive lines are energized, it can be determined whether the selected core contains a zero or a one. The voltage pulses on the sense lines are amplified, shaped into standard logic pulses, and gated

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into the memory data register, from which they are transmitted to the other sections of the computer as needed. This method of reading the information from a core memory is known as destructive readout.

In a memory with destructive readout, the circuitry associated with the memory automatically takes the word from the memory data register after readout and restores it in the selected cores in memory during the write portion of the memory reference. During the write operation, the direction of current through the selected horizontal and vertical drive lines is in a direction opposite to that during the read operation. Thus, the selected core on each plane will be set to a one state unless an inhibit current equal to a half current and in a direction opposite to that of the write current is applied to the inhibit winding of the plane. The inhibit current is controlled by the contents of the memory data register, and, therefore, a zero is written into memory for those data bits of the memory data register that are a zero.

For a computer operation which is to write new information into memory, the memory again goes through both a read and a write cycle. During the read cycle, however, the transfer of information from the sense amplifiers to the memory data register is inhibited. Instead, the data register is set by a transfer of data from the computer or an input/output chassis to the data register. During the write portion of the memory reference, then, the new information is written into the selected memory location.

The selection of the horizontal and vertical drive lines is controlled by the address associated with the word. Six address bits are necessary to select one of the 64 horizontal drive lines, and six address bits are necessary to select one of the 64 vertical drive lines. The time from the initiation of a memory reference cycle until the information is in the memory data register is known as the access time of the memory; the time required for the complete memory reference is known as the memory cycle time. A typical computer memory is constructed of a number of these 4096-word banks of memory. The address is then composed of more than 12 bits. The upper bits are decoded to determine the bank of memory to be referenced, while the lower 12 bits specify the location in the selected memory bank.

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In summary, the memory section requires only three things from the control section of the computer. These are the following:

- a. A transfer into the memory address register of the number indicating which word in memory is to be selected.
- b. An indication of the direction of the transfer of this work, either into or out of the memory.
- c. A signal to start the memory cycle, which in turn, will energize the appropriate selection and drive signals to perform the transfer.

ARITHMETIC

The arithmetic section contains the circuitry necessary to perform mathematical and logical calculations on information. For this purpose, it has several registers to hold numbers and wired-in logic to allow the mathematical and logical manipulations of the numbers. The operation of any digital circuitry follows a pre-arranged set of logical steps. The logical operations of the arithmetic section of the computer are simple combinations of these logical steps, while the arithmetic operations are more complicated combinations of these basic steps. The shifting of an operand left or right in a register is one of the simpler applications of these basic steps.

The arithmetic section obtains the timing signals necessary to perform its various functions from the control section, and it obtains the information on which it performs its various functions from the memory section. The results of its functional operations are generally transferred back to the memory section for storage in core memory.

Central to most computers is the adder. Arithmetic, as mentioned above, is one of the more difficult operations to perform with the basic logical steps available in a digital computer. The adder is an optimum combination of these basic logical functions which performs an addition (or, by an inversion of one operand, a subtraction) in a near minimum time, with a near minimum number of active components.

In the case where certain control signals are not activated as two operands flow through the adder, various logical combinations of the two operands result. Multiply, divide, and shift instructions also make use of this adder portion of the arithmetic section.

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CONTROL

The words stored in the memory of a computer can be classified as either instruction words or data words. The program of a computer consists of one or more series of instruction words; the control section of the computer reads these instruction words one by one and executes the instruction specified. If by mistake, a data word is read by the control section instead of an instruction word, the computer has no way of knowing that it is not an instruction word; the control interprets the bits of the word as an instruction and executes whatever instruction is specified. (This is why the operation code 00 is interpreted as a stop instruction in many computers; if the program jumps by mistake to a section of memory which has neither data nor instructions in it, the program will stop.)

The control section has the primary function of providing timing signals for the various internal information transfers. It provides these timing signals by translating or decoding the numerical computer instruction which it receives from the memory core storage. The instruction (word or words) is held in an instruction register, frequently referred to as the F register, while the translation and execution is taking place. The control section has its own register to determine the location in memory where each instruction is to be found. This register is called the program address register, abbreviated as P register. Since the computer instructions are found in sequential memory locations, the P register is incremented each time an instruction is executed. In some computers the incrementing is done by using the adder, and, in others, special circuitry is provided for this purpose.

The control section requires a signal from the computer operator to start; once this is done, it relies on instruction information from the core memory to determine which of the control and timing signals it should generate. These signals regulate the flow of information at all times within the computer and also control the initiation of information transfer external to the computer.

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INPUT/OUTPUT

The input/output (I/O) section provides the temporary storage facility for information being transferred into or out of the computer. Incoming information is retained by the I/O section until that information has been stored in core memory. Outgoing information is retained by the I/O section until the receiving device is able to accept it.

The timing for information transfers is provided from within the I/O section, but it is initiated by the control section. A primary function of the I/O section is one of compensating for the vastly different information flow rates found in the computer and external peripheral devices. It enables a computer, operating at transfer rates of several hundred thousand words per second, to communicate with peripheral devices operating as slowly as several words per second.

COMPUTER PROGRAMMING

At the present state of the art, the term "Electronic Brain" for a general purpose digital computer is a complete misnomer. Research is progressing on how to build a computer that will "think," but computers currently available are incapable of doing anything which could be called, by any stretch of the imagination, thinking. They merely work out what has already been thought of beforehand by the designer and supplied to them in the form of instructions.

The current digital computer, therefore, is capable of doing only those operations which the programmer tells it to do. It is safe to say that any problem whose solution can be described, step by step, before the solution is begun, can be programmed for a digital computer. It immediately follows that the best person to program a mathematical problem is a mathematician, the best person to program an engineering program is an engineer, and the best person to program a medical problem is a doctor (unless the engineer or doctor can reduce this problem to one of solving equations, in which case a mathematician is better qualified to program the problem).

Two significant advantages of a digital computer are: (1) the computer is several orders of magnitude faster than a human being in solving a problem, and (2) a computer does not make errors. These advantages make it sound as if a digital computer is nothing but a super adding machine; it is this, but much more. A third advantage makes the digital computer considerably more than a super adding machine: (3) the ability to make (preprogrammed) decisions.

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The programming of a digital computer is comprised of the following three basic steps: ← ✓

- a. Analyzing the problem.
- b. Reducing the problem to separate simplified portions for ease of handling.
- c. Writing instructions that will solve each portion and combining these.

An obvious means of translating these steps into the instructions which the computer uses is for the programmer to program the problem directly in the machine's language. Machine-language coding, also known as absolute coding, can give a program of maximum efficiency; the resulting program will run in a minimum length of time. Unfortunately, a program written in machine language takes an unreasonable amount of computer time to check out; fewer and fewer programs are being written in machine language.

One interesting attempt to simplify the job of programming is through the use of compilers. A compiler is a computer program which allows the programmer to write his program in a series of steps which are easily understood by him, but which have little or no relation to the machine-language instructions. Many of these compiler languages are so independent of machine language that they can be used on a variety of computers. (A separate compiler program has to be written for each computer.) An example of a compiler is FORTRAN (a contraction of FORMula TRANslation), which uses a formula-type language to program the problem.

These are, for example, FORTRAN compilers written for the Control Data 1604 and the IBM 7090 computers. The same problem, written in FORTRAN, can be computed to be run on either computer by using the appropriate compiler. A major advantage of compilers is this independence of the specific computer; a major disadvantage is that the programs written in compiler language will not run at the maximum speed, due to the divorcement of the compiler language from the computer language. A compiler-generated program, assuming a well-written compiler, and a computer well suited to the compiler language, will run 10 to 15 percent slower than if the program has been written in machine language. FORTRAN, ALGOL, and COBOL are examples of well-known compilers.

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Between the two extremes of machine-language coding and compilers come assemblers. An assembler is like a compiler in that it puts a machine program between the writing of the program and the generation of the machine-language instructions. Strictly speaking, an assembler contains only pseudo-instructions which correspond, one to one, with the machine-language instructions. (Actually, most assemblers have some pseudo-instructions which go beyond the instruction list of the computer, and hence are simple compilers.) Writing in assembly language is essentially writing in machine language, with the corresponding advantage that programs so written will run at the maximum possible speed. The advantage of using an assembler is that it relieves the programmer of a considerable amount of drudgery, helps in debugging the program, and saves machine time. Assemblers are obviously not independent of the machine they are to be run on.

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CHAPTER II

SECTION II

RCA-110A COMPUTER SYSTEM

INTRODUCTION

The electrical support equipment, located in the Launch Control Center and the Mobile Launch Facility, will be utilized in accomplishing Saturn V launch vehicle checkout. The Saturn V Ground Computer Complex is the central network through which commands to the launch vehicle and support equipment are transmitted and responses are received, evaluated, and displayed. The Saturn V Ground Computer Complex is composed of two RCA-110A computers and their associated peripheral and data link equipment.

The RCA-110A Computer, utilized in Saturn V Electrical Support Equipment (ESE), is a solid state, stored program, general purpose, digital computer system that utilizes coincidental current cores for high speed memory and magnetic tape units and a magnetic drum for high capacity bulk storage. The computer system operates upon 24-bit words at a 936 kilocycle per second rate, utilizing serial flow processing and parallel flow input/output transfers. Input/output operations are performed through data channels, which provide controlled data buffering and permit the input/output data transfers to be accomplished simultaneously with the computer system processing operations.

The RCA-110A utilizes a system of priority interrupts. Four priority levels are assigned to external systems, with two independent Saturn ground computer system programs assigned to each level. Each program, except the one with the highest priority may be interrupted, while computation is in process to allow servicing of a higher priority program. When the higher priority program has been completely serviced, the computer system automatically returns to the interrupted program and then continues processing in that program.

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EQUIPMENT CONFIGURATION

The equipment that comprises the LUT computer complex is illustrated in Figures 7, 15 & 16. The focal point of the LUT computer complex is the RCA-110A digital computer, which has provision for eight sets of I/O registers. In addition, seven independent IODC are provided. Associated with the LUT computer are standard peripheral and data link equipment.

The LCC computer complex is essentially the same as the LUT computer complex with the exception of the programs that are utilized. Figures 7, 15 & 16 delineates the equipment configuration for the LCC computer complex. (Figures 15 and 16 are foldouts pages 227 and 228).

GENERAL DESCRIPTION

RCA-110A COMPUTER SYSTEM

The LCC computer serves as the main control for the system by accepting control data from display console keyboards as well as standard card and tape equipment inputs. These are utilized, under computer program control, to generate test commands or to complete test routines that, in turn, are channeled to the LUT computer. The LUT computer interfaces, through peripheral units, with the system and the launch vehicle to provide discrete signal commands to the latter equipment.

The LUT computer receives discrete status and analog data signals from the vehicle and portions of the ESE as well as from the Digital Data Acquisition System (DDAS). Some of the data received by the computer is used as checkpoints in the control of automated test routines. Other data is processed for display on the control and display panels of the LUT test engineering consoles or is transferred to the LCC computer for similar processing and/or display.

The LCC computer system is housed in a total of 41 cabinets located in Area A (computer room) of the LCC third floor. This room is directly behind the LCC firing room. The LUT computer is housed in 22 cabinets located in Room 15A (second floor) of the LUT.

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The block diagram (Figure 15) shows the interfaces by which data are transferred into and out of the RCA-110A computer. At the LCC, discrete data (test commands) from the test engineering consoles is applied to specific discrete input signal conditioners via discrete input signal conditioner patch distributors.

At the LUT, discrete data signals (event data) are handled in the same manner as previously described. The signals are first patched to the desired channel locations by the discrete input signal conditioner patch distribution. From this unit, the signals are fed to the signal conditioner, to the Discrete Input Converter Unit (PEN 2251.04.01-07), and to the RCA-110A IODC's No. 5 and 7 modules.

Discrete output signals from the computers are handled in the reverse order of that previously described. For example, a discrete output signal (test command) from the LUT computer (used to energize some launch vehicle system in response to a test command input at the LCC) is directed from the MLF computer to IODC No. 5 or 7 modules, then to the Discrete Control Equipment (PEN 2251.04.03), of which there are two output racks. The Discrete Control Equipment employs triple redundant voting logic. If in the voting logic two or three output circuits vote alike, and if the vote is the same as the input from the IODC, then the command is fed to output signal conditioner patch distributor. The Discrete Control Equipment is another relay that switches the relatively heavy load currents required by the launch vehicle system in response to the low-power computer signal level. The patch distributor provides the necessary flexibility in patching a particular computer channel output to any desired launch vehicle system without reprogramming the computer.

At the LCC, data responses are fed from the computer to lamp displays or event recorders using the same system of IODC modules, Discrete Input Converter Units, Discrete Control Unit, signal conditioner, and patch distributor as previously described.

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The two Discrete Input Converter Units (PEN 2251.04.01-07) senses up to 1512 discrete input signals each of 0 to 28-volt signal levels and scales the signals to the -6.5 volt and 0-volt logic levels of the computer system. Additionally, the Discrete Input Converter Units provide for the transfer of Eastern Standard Time and countclock time signals to the computer system. The Discrete Control Equipment, consisting of 3 racks, one control and two output racks of 1008 outputs each generates the signals necessary to select and activate up to 2016 discrete output circuits in the Saturn V checkout system. IODC's are also capable of initiating priority interrupt requests when specific discrete input signals selected by the computer system program change state.

The RCA-110A Computer is equipped with an Analog Converter Unit (PEN 2251.04.01-06) which provides for analog outputs, analog inputs, LVDC interface and Count Clock inputs. Of 186 possible analog input signals, two are sensed upon command of the computer through the IOA's lines. The two input analogs are converted to two eleven bit digital words and input into the RCA-110A via the IOS lines. The analog output is provided via the IOA lines. A 24 bit word provides ten bits which are converted from digital to analog, and the remainder of the bits are used to set up controls and select voltage ranges.

A two-way digital communication link is used to transfer test commands and data responses between the LUT and LCC computers. The Data Link Terminal Unit (PEN 2251.04.01-16) interfaces with the computers via IODC Module No. 4 at each computer. The complete data patch is shown in Figure 7. The portion of the link that runs between the PTCR and the LCC (approximately 6 miles) is a Western Electric A2A wideband system. Data transfer between the computers takes place at a rate of 133 kilobits per second (serial transmission) and actual bit rates on the transmission system are 250 kilobits per second to accommodate word accuracy tests and word retransmission for detected bit errors.

The DDAS provides test data to the LUT and LCC computers via DDAS/computer interface units. DDAS data enters the LUT and LCC computers via IODC Module No. 3 in each case.

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Input/Output Data Channel Modules No. 1 and No. 2 provide interface between each RCA-110A computer and its respective peripheral devices, namely:

- a. Magnetic Tape Transports. (PEN's 2251.04.01.04 and 2251.04.01.12)
- b. Drum Storage Unit. (Contained in Main Frame Converter Unit PEN 2251.04.01.02)
- c. Line Printer. (PEN 2251.04.01.13)
- d. Card Punch. (PEN 2251.04.01.15)
- e. Card Reader (PEN 2251.04.01.14)

The IODC Module No. 6 provides an interface between the RCA-110A and the CRT display equipment and keyboard control equipment.

COMPUTER SYSTEM OPERATION

There are two basic methods by which data and control signals may enter and leave the computer system: by Input/Output (I/O) channels or by the IODC subsystem. Each I/O channel is under the direct control of the computer program. Each channel of the IODC subsystem can perform a series of simple operations upon instruction from the main computer. These operations can be carried out as an "off-line" function, permitting the central processor to be free for other processing. The central processor responds to requests from the IODC's on a priority basis, with each IODC having an assigned priority level.

The I/O channels, as a general rule, handle high-priority information, such as control of the airborne guidance system and the routing of signals to the ACE-S/C computer. The IODC channels are used for the more routine functions, such as processing discrete signals and controlling the magnetic tape and drum storage equipment.

The LUT computer has all tests sequences of operation stored within one of its memory banks. These sequences are called into working memory and performed as requested by the LCC computer. The test sequence of operations directly determines the order of exercising the test equipment and the vehicle.

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The LUT computer reports equipment status, test sequence status, data responses, results of tests, and other pertinent data to the LCC computer. It is through this link that the control equipment and personnel in the LCC are informed as to progress being made by the LUT test equipment. The LUT computer receives commands, control signals, and data from the test engineers, and the programmed sequence of testing via the LCC computer. Complete control of the LUT computer operation is effected through a two-way digital communication link. The quantity of information transferred at one time may be as small as a few words or as large as a complete program.

In addition to the specific response evaluation capability previously outlined, the LUT computer is able to monitor in a more general sense all discretes and analogs to detect out-of-tolerance or alarm conditions. This function is effected by internal logic, and results of the monitoring process are utilized in the activation of display and alarm indicators, as well as in the generation of alarm-response signals where appropriate.

There are two principal types of data that require storage in the computer complex, namely: reference data and historical data. Reference data consists of constants, tabulations, subroutines, etc., while historical data consists of test results and status information. Reference data is stored principally either on the magnetic drum or on magnetic tape, depending upon the desired speed of access. This data may also be temporarily stored in the CRT display stations. Historical data is recorded principally by the activity printer and the magnetic tape station.

The LUT computer has the capability of generating stimuli to aid in checkout of the launch vehicle. Included in this category are the following:

- a. Discrete commands to control relays and valves in the GSE and on board the vehicle.
- b. Voltage signals to test servo system functions, such as engine gimbaling.
- c. Digital signals for checkout of the airborne computers and other digital devices.

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The LUT computer has the capability of evaluating certain types of responses from the vehicle, including the following:

- a. In conjunction with the discrete activity indicator (DAI), discrete level indications in the GSE and on board the vehicle can be monitored to determine whether the signals are in the proper state.
- b. Analog voltages can be measured and compared with predetermined or calculated values (based on tolerances programmed into the computer). The computer will indicate an out-of-tolerance condition and halt the program.

The LCC computer is the central source of control for the test system. Through it, the LUT computer is directed what to do and when to do it. The LCC computer, in turn, is under the control of subsystem engineers and the test conductor at the display consoles. The computer uses the countdown clock and Eastern Standard Time at time references.

The function of the LCC computer in the reception of data from the LUT computer, transmission of commands to the LUT computer, monitoring of response test data, evaluation of response data, and the recording and storage of test data are all similar to that previously described for the LUT computer.

The LCC computer may be commanded by the subsystem test engineers to provide the display stations with such data as test results, troubleshooting aids, or real-time curve-plotting of vehicle functions. The computer storage has a large quantity of data that may be supplied to the CRT displays upon demand of the subsystem test engineer. This data may be updated by the engineer and returned to storage as he considers necessary.

The normal method for transmitting discrete information to indicating lamps on ESE operator panels will be from the computer in the LCC. This information can emanate from any source available to the computer, such as from the stages and IU via the storage ESE and LUT computer with its associated data link.

Selected analog information via the DDAS will be available to the CRT displays through the computer.

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Noncritical manual operation via computer control will be with a three-position, lever-locked switch with the following switch positions: "on", "off", and automatic. When placed in the "on" or "off" positions, the switch will signal the LUT computer to interrupt its program and perform the required function within a response time of about one millisecond. The switch can also be used to run certain tests or operations while maintaining selected components in an abnormally "on" or "off" condition. An example of this type of switch is "Telemeters."

COMPUTER INPUT/OUTPUT DEVICES

The computer (central processor) communicates with other equipment through input/output devices. Four types are used:

- a. Address lines (IOA).
- b. Input/Output sense lines (IOS).
- c. Input/Output registers (IOR).
- d. Input/Output Data Channels (IODC).

The IOA's are used to transmit command signals from the computer system to external devices through the general input/output interfaces. There are eight IOA sets, IOA 0 through IOA 7, each consisting of 24 data lines corresponding to the 24 bit positions of the computer system data word. The IOA's are individually activated by the set up input/output device instruction. This instruction transfers the 24-bit contents of a stored data word in parallel through the 24 lines of the IOA specified by the octal code of the instruction.

The IOS's are used to detect the status of external devices and transmit the information to the computer system for processing and storage. There are eight IOS sets, IOS 0 through IOS 7, each consisting of 24 data lines corresponding to the 24 bit positions of the computer system data word. The IOS's are individually activated by the sense device instruction. This instruction transfers the sensed data through the general input/output interfaces to the memory transfer register of the central data processor.

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The IOR's are 24-bit, serial, shift registers which are used as general-purpose buffers to send data to and receive data from external devices. There are eight IOR's, IOR 0 through IOR 7, IOR 0, IOR 2, IOR 3, and IOR 4 are output registers that are supplied with data destined for external devices under control of the load input/output register instruction. IOR 1, IOR 5, IOR 6, and IOR 7 are input registers that are used to store data received from external devices under control of the store input/output register instruction.

The IODC subsystem provides for buffered input/output data transfers, but unlike the input/output address lines, sense lines, and registers, the IODC transfers are not performed under program control and may be accomplished simultaneously with the normal computer system processing operations. The IODC subsystem comprises six IODC's (with provisions for a seventh), each of which provides the necessary monitoring, buffering, and control of the devices with which it operates. The IODC's (and their devices) are set up to the proper operating modes by the read data channel and write data channel instructions; once they are set up, they perform their tasks without further computer intervention. The IODC's are individually addressed by the octal N code of the IODC instructions.

The IODC subsystem includes the following IODC's:

- a. IODC 1.
- b. Magnetic Tape (IODC 2).
- c. DDAS (IODC 3).
- d. Data Link (IODC 4).
- e. Discrete (IODC 5).
- f. Display (IODC 6).
- g. Discrete (IODC 7).

An IODC 2 provides buffering and control for data transfers between the central data processor and the following devices, and is selected when the octal N code of the IODC instruction equals two:

- a. Magnetic tape equipment.
- b. Line printer.
- c. Card reader.
- d. Card punch.

The DDAS IODC provides buffering, and control for data transfers between the central data processor and Saturn DDAS equipment is selected when the octal N code of the IODC instruction equals three.

The data link IODC provides buffering and control for data transfers between the central data processor and the Saturn data link equipment. The data link equipment, in turn, provides a communication link between the two computer systems that are separated by a distance of up to seven miles. The data link is selected when the octal N code of the IODC instruction equals four.

The discrete IODC provides buffering and control for the generation of discrete output signals and for monitoring and activity of the discrete input signals. The discrete IODC is selected when the octal N code of the IODC instruction equals five.

The display IODC provides buffering and control for data transfers between the central data processor and the Saturn display equipment and is selected when the octal N code of the IODC instruction equals six.

GENERAL INPUT/OUTPUT INTERFACES

The general input/output interfaces provide communication paths between the input/output address lines, sense lines, and registers and external input/output devices and systems. Among these are clock inputs, the airborne computer input, and the airborne computer output.

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The clock inputs transfer 24-bit data words from the timer, the countdown clock, or the Eastern Standard Time clock, under program control, to the central data processor utilizing input/output sense line set 3 (IOS 3) or the discrete IODC.

The airborne computer input logic, under program control, provides the switching for the transfer of 48-bit data words from an external airborne computer to the central data processor, utilizing input/output sense line set 2 (IOS 2). The airborne computer output equipment, under program control, provides buffer storage and switching for the transfer of 27-bit data words to an external airborne computer from the central data processor. Input/output address line set 9 (IOA 3) is utilized.

The standard peripheral equipment provides bulk storage, hard-copy production capability, and a means of loading programming and operating data into the central data processor. The standard peripheral equipment consists of the following devices, with interface and control logic additionally supplied for an electric typewriter:

- a. Magnetic drum.
- b. Magnetic tape equipment.
- c. Line printer.
- d. Card reader.
- e. Card punch.

The magnetic drum provides bulk storage for the Saturn computer system and has a capacity of 32,768 25-bit words. Data is stored in 256 tracks of 128 words each and is transferred serially under control of IODC 1. The drum rotates at a nominal speed of 3600 revolutions per minute and has a bit transfer rate of 214 kc, producing a maximum access time of approximately 17 milliseconds. Average access time is approximately 8.5 milliseconds.

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The magnetic tape equipment provides external bulk storage for the Saturn ground computer system. Data is stored on and read from half-inch-wide magnetic tape at a rate of 15,000 characters per second. The magnetic tape equipment includes two master magnetic tape units and up to 18 slave magnetic tape units. One master magnetic tape unit interfaces with IODC 1 and the other interfaces with the magnetic tape IODC (IODC 2). Buffering and interface circuits are contained in each master magnetic tape unit through which data and control signals are distributed to up to nine slave magnetic tape units, both master and slave.

The line printer, under control of the magnetic tape IODC (IODC 2), prints 120 characters per line of an alphabet of 46 alphanumeric characters and symbols, at a maximum rate of 1000 lines per minute.

The card reader, under control of the magnetic tape IODC (IODC 2) reads standard 12-row, 80-column or 51-column, EAM cards column by column at a maximum rate of 800 cards per minute. The card reader is capable of reading both binary and Hollerith card codes.

The card punch, under control of the magnetic tape IODC (IODC 2), punches standard 12-row, 80-column, EAM cards column by column at a maximum rate of 450 cards per minute, and 12-row, 51-column cards at a rate of 650 cards per minute. The card punch is capable of punching in both binary and Hollerith card codes with either continuous or single-column advancement. Table 8 provides the characteristics of the RCA-110A computer.

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TABLE 8
SATURN V GROUND COMPUTER SYSTEM
COMPONENT CHARACTERISTICS

(Refer to Figure 15.)

1. Power Supply Unit (PEN 2251.04.01.01)
 - a. Automatic power-on and power-off sequencing
 - b. Automatic thermal and power monitoring
 - c. Input primary power requirements:
 - (1) 208 vac. 60 cps, 3 phase
 - (2) 76 kva/62 kw power dissipation for typical system
 - d. System dc power:
 - (1) +26 v @ 250a
 - (2) +13 v @ 3a
 - (3) +6.5 v @ 1a
 - (4) -6.5 @ 150a (current sink)
 - (5) -13 v @ 10a
 - (6) -19.5 v @ 5a
 - (7) -26v @ 500a
 - (8) -48 v @ 1a
2. Main Frame Converter Unit (PEN 2251.04.01.02)
 - a. Serial Logic
 - b. 936 KC Clock Rate

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- c. 25-bit Words (24 Data Bits Plus Parity)
- d. 28.9 microsecond Word-Time
- e. 121-Instruction Repertoire
- f. Single-Address Instructions
- g. Direct and Indirect Addressing Plus 6 Index Registers for Address Modification
- h. Parallel Memory Transfers via Data Trunk Lines
- i. Fixed-Point Binary Arithmetic
- j. 58 microsecond Add Time, 779 microsecond Multiply Time
- k. 4 Priority Interrupt Levels - 2 Programs per Level
- l. 32,768-Word Internal Bulk Storage Magnetic Drum
- m. Input/Output Address Lines (IOA's) for Transmitting Command Data to External Devices
- n. Input/Output Sense Lines (IOS's) for Sensing the Status of External Devices
- o. Input/Output Registers for Buffering Data to and from External Devices
- p. Input/Output Data Channel for Input/Output Transfers Simultaneous with Normal Processing
- q. IODC 1

Services the following devices:

- (1) Magnetic Tape Units (15,000 characters per second)
- (2) Magnetic Drum (Serial data at 214,000 bits per second)
- (3) Paper Tape Reader (400 characters per second)

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- (4) Paper Tape Punch (150 characters per second)
- (5) Electric Typewriter (15 characters per second)
- r. Interval Timer Subsystem for Programmed Time Interval Measurements
- 3. Data Input/Output Switching Unit (PEN 2251.04.01.10)
 - a. Multiple input/output transfers simultaneous with normal computer processing
 - b. Parallel memory transfers via data trunk lines
 - c. 4 independent input/output data channels (IODC's)
 - d. Each IODC provides the necessary controls for the device or subsystem with which it operates
 - e. Each IODC capable of data transfers in blocks of 1 to 4,096 words
 - f. Discrete IODC
 - Monitors the Discrete Input signals
 - 4 monitoring modes:

Mode I	-	Scans all discrete input signals and stores status in specified memory block
Mode II	-	Scans all discrete input signals and updates memory block
Mode III	-	Scans all discrete input signals senses and stores only changes in status
Mode IV	-	Same as Mode III. Also initiates priority interrupt if change in status occurs in preselected word

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g. Data Link IODC

Provides buffering and control for data transfers to and from the Data Link Terminal Unit

Transfers data serially at rate of 250,000 bits per second

h. Magnetic Tape IODC

Servises the following devices:

1. Magnetic Tape Units (15,000 characters per second)
2. Line Printer (2,000 characters per second)
3. Card Reader (1,000 characters per second)
4. Card Punch (600 characters per second)

i. DDAS IODC

Transfers data between the computer system and the Saturn Digital Data Acquisition System (DDAS)

3 Transfer modes:

- | | | |
|----------|---|---|
| Mode I | - | Alternately transfers data from each of two multiplexer groups of the DDAS |
| Mode II | - | Continually transfers updated data into a status table stored in high-speed memory |
| Mode III | - | Transfers updated data into consecutive high-speed memory location blocks (provides a data history) |

4. High Speed Memory Switching Units (PEN 2251.04.01.11)

- a. 4 individually addressable coincident-current magnetic-core memory banks per unit

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- b. 4,096-word capacity per memory bank
 - c. 25-bit words (24 data bits plus parity)
 - d. Data available to system via 25 parallel data trunk lines
 - e. 3.5 microsecond memory access time
 - f. 10.25 microsecond memory cycle time (Clear/Write and Read/Regenerate operations)
 - g. One input/output data channel per unit
 - h. Display IODC (Unit 1101 Only)
 - (1) Provides buffering and control for data transfers between the computer system and the Saturn Display Equipment
 - (2) Transfers data serially at 312,000 bits per second
5. Magnetic Tape Units (Master PEN 2251.04.01.04, Slave PEN 2251.04.01.12)
- a. AMPEX Model RCATM4
 - (1) Operates under control of IODC 1 and Magnetic Tape IODC
 - (2) 15,000 characters per second
 - (3) IBM-compatible (IBM 729 II-low density); zero/blank conversions performed in magnetic tape buffer logic
 - (4) Any one of up to nine slave magnetic tape units may be selected and controlled through one master magnetic tape unit.
6. Line Printer Converter Unit (PEN 2251.04.01.13)
- a. ANELEX Model 4-1000

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- (1) Operates under control of the Magnetic Tape IODC
 - (2) Prints 1000 lines (120 characters per line) per minute single spaced
 - (3) 46-character alphabet
7. Card Reader Converter Unit (PEN 2251.04.01.14)
 - a. Burroughs Model B124
 - (1) Operates under control of the Magnetic Tape IODC
 - (2) Reads 12-row 80-column or 12-row 51-column cards at rate of up to 800 cards per minute column-by-column
 - (3) Reads either standard Hollerith or binary data
8. Card Punch Converter Unit (PEN 2251.04.01.15)
 - a. Soroban Model EP-4-CON
 - (1) Operates under control of the Magnetic Tape IODC
 - (2) Punches up to 450 12-row 80-column cards per minute
 - (3) Punches up to 650 12-row 51-column cards per minute
 - (4) Punches either standard Hollerith or binary data.
9. Data Link Terminal Unit (PEN 2251.04.01.16)
 - a. Provides time-shared transfer of command and data messages under control of the Data Link IODC
 - b. 250 kc bit rate
 - c. 133 kc information rate
 - d. Two-dimensional parity check of each computer word.
Deleted errors corrected by retransmission

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- e. Terminal separation of 2,000 feet to 7 miles via balanced data link cable

10. Discrete Control Equipment (D. C. E.) (PEN 2251. 04. 03)

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- a. In automatic mode receives instructions from Saturn V Ground Computer, converts the instructions to discrete outputs, and energizes appropriate Network Relays.
- b. In manual code may be operated by using the D. C. E. Control Assembly which may be located in D. C. E. Console or in a remote area (up to seven miles).
- c. Decodes the 48-bit instruction word from computer to select and activate (or de-activate) up to 24 discrete outputs at a time for a total of 2016 discrete outputs.
- d. D. C. E. consists of the following:
 - (1) Input/Output (I/O) Logic
 - (2) Communications Registers
 - (3) Decoder
 - (4) Encoder
 - (5) Control Panel (local or remote)
 - (6) Power Sequencer
- e. The I/O Logic gates information into and out of the D. C. E. , in manual mode, but performs no functions in the automatic (computer) mode.

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- f. The Communications Register is a 48 bit serial/parallel register. Computer data is entered serially and manual data is entered in parallel.
 - g. The Decoder accepts the voted information from the Communications Register, decodes the Address and Data Words and signals the selected discrete output or outputs.
 - h. The Decoder, a 2016 matrix of four multiplexed 504 matrices, is composed of NAND gates for decoding, amplifiers to provide logic driving power, and an output section.
 - i. The Encoder, utilizing the discrete outputs, feeds back to the D.C.E. Control Panel (manual mode) and to the Saturn Operational Computer (computer mode) the group address and bit pattern for the selected group.
11. Discrete Input Converter Units (PEN 2251.04.01.07)
- a. 1512 Discrete input lines
 - b. Maintains in core memory current status of each discrete input line
 - c. Maintains log in core memory of all discrete input state changes and time of each change
 - d. Notifies system when program-selected discrete input signals change state
 - e. Input circuit distinguishes between levels of OV +4.5V (or open) and +28V \pm 6V -2 V
 - f. Lines selected for monitoring in groups of 24
 - g. Discrete IODC furnishes group address and accepts data
 - h. Each line driven by a transistor relay driver, providing an open circuit or ground return for relay operation
 - i. Each line's relay driver driven by a separately controlled flip-flop

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- j. 1008 flip-flops accessed for change in groups of 24 flip-flops, 42 groups in total
12. Analog Converter Unit (PEN 2251.04.01.06)
- a. 186 analog input signals
 - b. 72 analog output signals
 - c. Ac and dc conversions
 - d. 7 dc and 3 ac input voltage ranges
 - e. 5 dc and 1 ac output voltage ranges
 - f. Separate isolated ground for each range
 - g. Ac conversions, 10 bits
 - h. Dc conversions, 10 bits plus sign
 - i. Solid-state and relay circuits
 - j. $\pm 0.5\%$ or greater full-scale accuracies
 - k. Maximum dc selection, conversion and system input rate of 8700 line per second
 - l. Maximum ac selection, conversion and system input rate of 90 lines per second
 - m. Simultaneous operation of one ac and two dc digital-to-analog converters
 - n. Dc output voltage can be changed full-scale every 60 micro-second
 - o. All outputs capable of driving 1,000 ohm load
 - p. Interfaces with system via IOA's and IOS's
 - q. Programmable loop self-testing

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CHAPTER II

SECTION III

COMPUTER TEST PROGRAMS

INTRODUCTION

The RCA-110A computers serve the functions of communicating discrete events and, most importantly, bringing into operation vehicle test programs for the various stages. The test routine is generated by a team consisting of test engineers and computer programmers who design the test program to check out specific vehicle hardware functions. While the test program must fulfill the test engineer specifications, it must also interface with the operating system (internal computer executive program) and the ESE in a manner suited to the real-time checkout operations.

The majority of the test programs will be run in the MLF computer. The following discussion describes these computer programs in their environments. The computer in the LCC processes the requests communicated to it from the display control consoles and ESE control panels and communicates these requests to the MLF computer.

All test programs contain a first step which is to scan all the discretes associated with the particular program. The purpose of the scan is to determine that the required switches have been placed in the proper positions, in most cases, in the automatic code. If the switches are not in the proper positions as indicated in the discrete scan, the test routine will not commence. A message will be presented on the CRT stating the reasons for the program not commencing.

A particular test program may combine any or all of the following functions: power sequencing, integrated hardware testing, monitoring and recording vehicle information, and processing of vehicle input/output signals.

Sequencing power up or power down on a hardware system initiates a predictable chain of events. Test programs will monitor these events by checking voltages, pressures, temperatures, etc., depending upon the particular hardware. Testing of a specific hardware operation may be programmed if a command and feedback loop is available.

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For monitoring and recording vehicle information, the Saturn V vehicle is capable of transmitting data rapidly through DDAS channels. The speed of transfer, in many cases, precludes processing this information as it is received. Some test programs will function as data collectors, storing the data for later reference and reduction.

In the processing of vehicle input/output information, the test programs format the information so that it is acceptable to the vehicle interface. These programs also interpret and correlate information received from the vehicle.

The operational modes previously discussed require the presence in the computer of several types of programs:

- a. The programs necessary to accomplish the basic operations required when ESE panel switches are actuated, lamps are energized, etc.
- b. The programs necessary to allow automated procedures to interweave with other automated procedures, switches to interrupt automated procedures, etc.
- c. The programs that accomplish the automation of manual procedures.
- d. The programs that accomplish prelaunch and launch operations that cannot be performed using manual procedures; that is, those for calculations necessary for propellant loading, those for azimuth alignment of the stabilized platform.

The program types described in paragraph c. and d. are the automated procedures (previously mentioned) directly associated with automatic checkout or control of the ESE or vehicle hardware. These automated procedures are commonly called test programs although test routines are often used.

The program types described in paragraphs a. and b. (together with others not noted) constitute what is called the "operating system." Test programs (types c. and d.) are controlled by this operating system.

The operating system properly includes all those routines that can be standardized and made independent of a specific vehicle (for example, the master scheduler, input/output routines, mathematical subroutines, system self-test routines, etc.). Such programs need be written only

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once, thus reducing chances of error, duplication of effort, the program changes necessary from the one vehicle to the next, etc. For instance, a standard print routine is made a part of the operating system and is used each time a printout is required. Similarly, whenever a discrete signal is to be sent to the vehicle, a single standard discrete output routine, shared by all automated procedures, is used. Adequate safeguards and error checks are included in all standard input and output routines. Another important feature of the operating system is the monitoring and recording of selected parameters needed for historical purposes. The operating system also records each keyboard entry, each message transmitted over the data link, etc. Checkout and validation of vehicle subsystems is accomplished using the programs specified. Test, as well as monitor programs, operate under executive control of the operating system program. The programs stimulate the system under test through activation of appropriate vehicle discretely and monitor and record system reaction to these stimuli. These data are used for interpretation and evaluation by system test engineers.

The following specific programs are provided for test and checkout of the ST-124M platform:

- a. Azimuth laying program.
- b. Accelerometer monitor program.
- c. ST-124M automatic null check program.
- d. ST-124M turn-on program.
- e. ST-124M turn-off program.

The following specific programs are provided for test and checkout of the Launch Vehicle Digital Computer (LVDC):

- a. Load data and verify test program.
- b. Vector sum check test program.
- c. LVDC switch selector test program.
- d. Pseudo flight test program.

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- e. Simulated flight pre-flight monitor (plug in) program.
- f. Simulated flight post-processor program.
- g. LVDC/DDAS test program.
- h. Accelerometer pulse count test program.
- i. Gimbal angle read test program.
- j. LVDC/LVDA* ladder output test program.
- k. Power and/or redundance test program.
- l. LVDC/LVDA* discrete output test program.
- m. LVDA*/LVDC discrete input test program.
- n. LVDA*/LVDC self-test program.

The following specific programs are provided for the measurements system:

- a. DDAS/RACS pre-processor program.
- b. DDAS/RACS tolerance update program.
- c. DDAS/RACS calibration program.

The following specific programs are provided for EDS:

- a. Engine out abort test program.
- b. Rate excessive test program.
- c. Space vehicle abort test program.
- d. Command module indicator verification test program.

The propellant loading and monitoring program is provided for vehicle propellant loading and control.

*LVDA's - Launch Vehicle Data Adapter

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The following programs provided for the switch selectors are capable of validating the operational status of each stage switch selector from the RCA-110A computer without use of the LVDC:

- a. Switch selector interface test program.
- b. Switch selector channel test program.

The GETS discrete activity monitor program and the WET test monitor program are provided for use while these tests are being conducted.

A variable scan rate monitor program is capable of monitoring the major areas of the S-IVB system.

The following programs are provided for flight control system:

- a. S-IC overall steering test.
- b. S-IC A_0 gain test.

Figure 17 page 230 depicts the Stage and ESE Orientated DDAS equipment. Figure 18 provides the DDAS/Computer interface.

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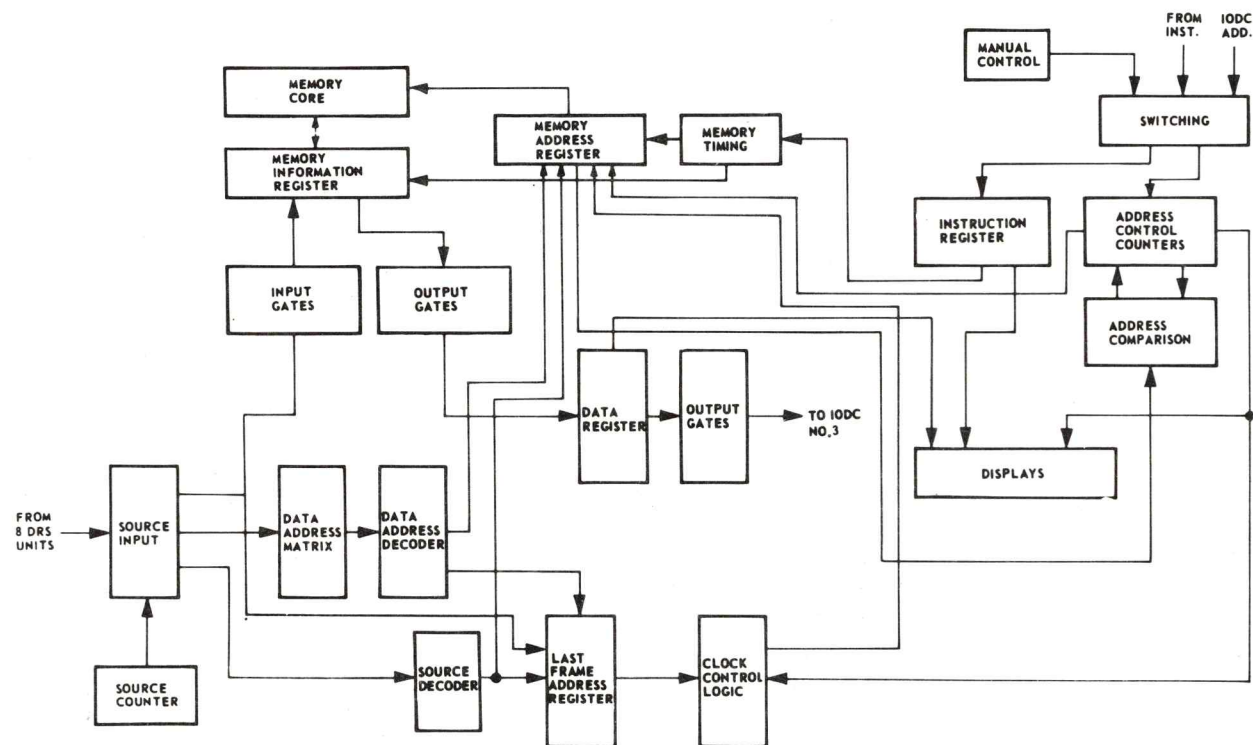


Figure 18. DDAS/Computer Interface

CHAPTER II

SECTION IV

TIMING

INTRODUCTION

The timing system of Launch Complex 39 is utilized as a central time standard for correlation of launch, checkout, and flight activities pertaining to the Saturn V program. The system consists of two units, a real-time code unit and a countdown time generator (Figure 21).

The countdown time code generation equipment generates the count time utilized to control countdown activities and to aid the RCA-110A computers in program control. The real-time code equipment utilizes inputs from the Kennedy Space Center Central Timing Facility (Figure 19), to display real-time of year, to aid the RCA-110A computer in real-time program activities and to correlate recorded equipment and launch vehicle parameter in respect to real-time. A clock system is located in each LCC control room with a repeater station located in each MLF.

Secondary functions of the timing system are as follows:

- a. Demodulation of external generated time code signals (IRIG).
- b. Generation of internal clock signals that will enable continued operation in the event of failure of the external IRIG timing source.
- c. Generation of mark time signals representing preselected count times.
- d. Generation of up to eight preselected discrete timed-output-command signals.
- e. Conversion of real-time information into Gray code for transmission to a computer.
- f. Conversion of real-time and count-time information into display codes suitable for driving wall clock displays.

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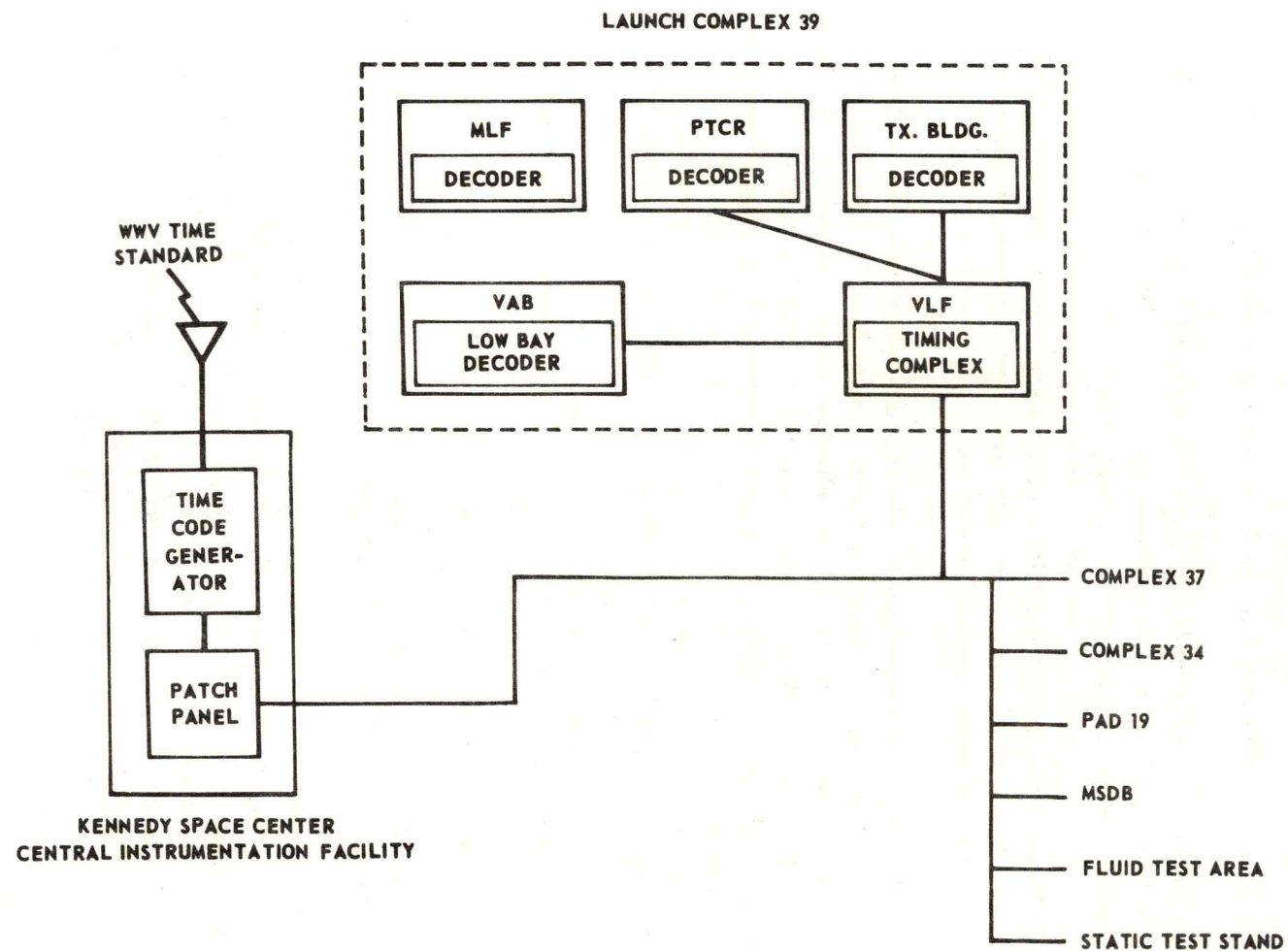


Figure 19. KSC Time Distribution

- g. Display of real time at the time code unit and display of countdown time at the countdown unit.
- h. Storage and display of the real-time at which liftoff occurs.

The clock system to be utilized in Launch Complex 39 is known as the Type I clock. This clock requires as an input the IRIG B time code from the Kennedy Space Center timing complex.

The countdown time for the Type I clock produces a parallel time code ranging from -99 days, 23 hours, 59 minutes, and 59 seconds to +99 days, 23 hours, 59 minutes, and 59 seconds.

The IRIG serial time code accepted by the clock system is simultaneously recorded on the analog magnetic tape recorders of the DDAS equipment for realtime data correlation Figure 22. The recorded time code can be selected from the recorder during playback operations; however, the normal operating mode is when the time is input from the KSC timing facility.

The IRIG serial unmodulated time code is input via interface circuits for logic level conversion, then to the demodulation circuits for detection of the width modulated pulses containing the coded data. Refer to Figure 20. The output of the demodulator is in two forms; one is straight binary which is converted to Gray code and the other is Binary Coded Decimal (BCD), which is decoded by the display generator for decimal display. The display generator converts the BCD time of year to a seven line display format and drives logic-to-display BCD real-time in decimal format. This display is time of year to one second.

The second output, the straight binary time of day contained in the IRIG time code, is a serial shift pulse width modulated wave train, which is input to the multiplexer. The multiplexer has a two-fold purpose: (1) to apply the IRIG time of day from the demodulator to the Gray code generator and (2) to generate time of day to the Gray code generator in the event that the KSC IRIG time code is lost. The selector, dividers, and oscillator are used in this backup capability.

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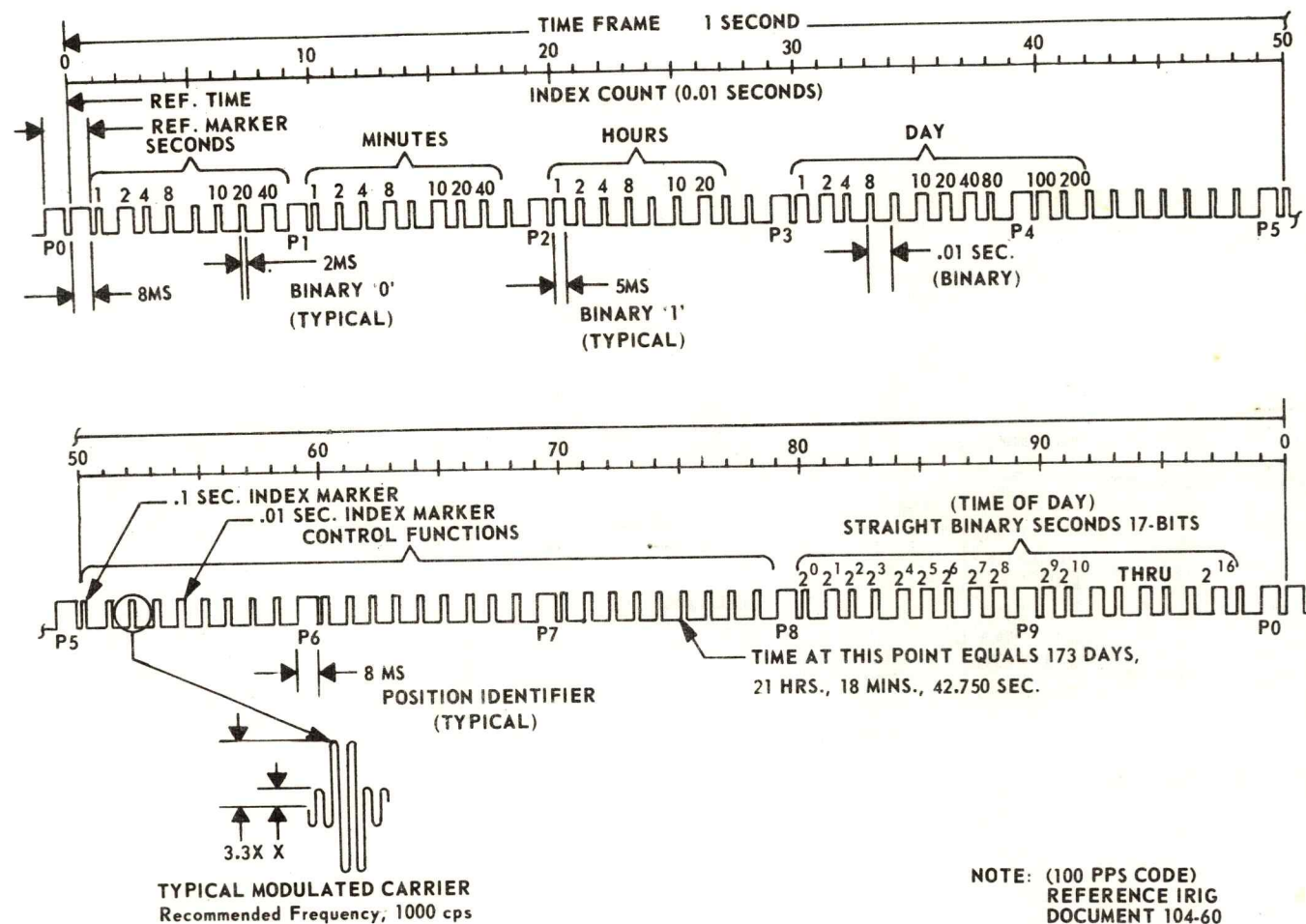


Figure 20. IRIG Standard Time Code, Format "B"

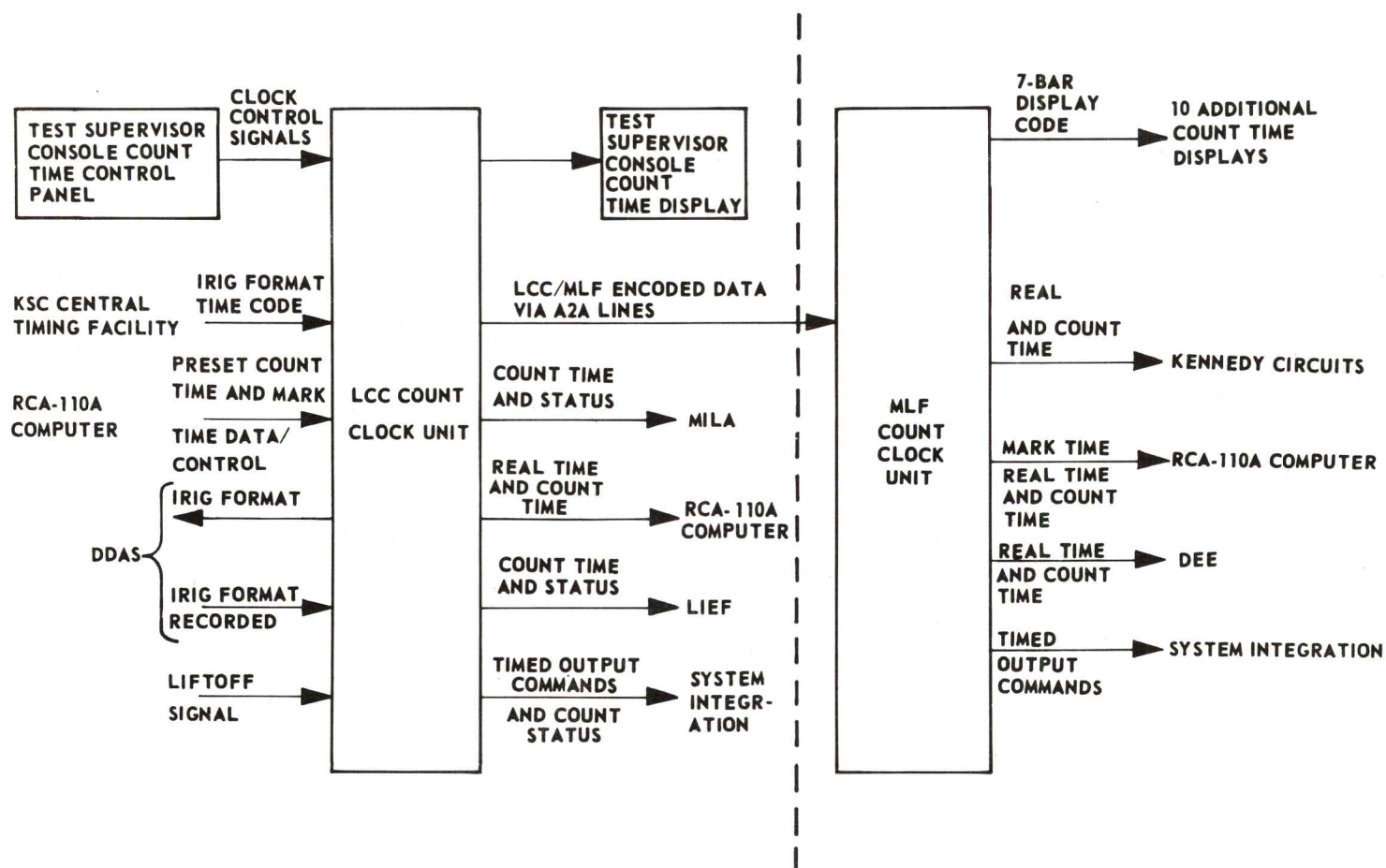


Figure 21. Count Clock System

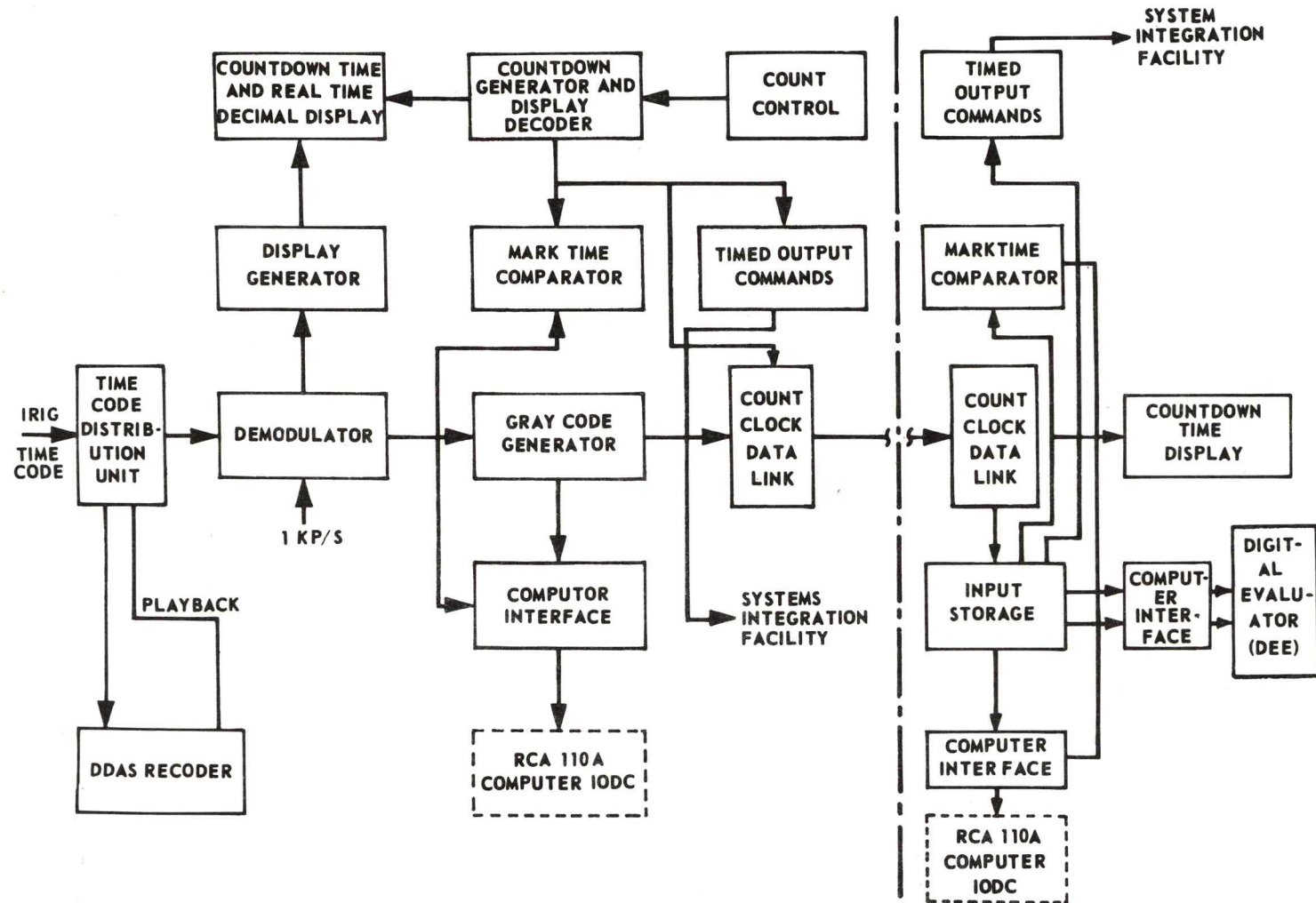


Figure 22. Count Clock Simplified Block Diagram

The Gray code generator converts the straight binary time of day into a Gray code parallel format for transmission to the MLF data link and for input time to the LCC RCA-110A computer. The computer uses the time code to aid in the generation of real-time subroutines and is input via computer interface circuits for logic level conversion. The straight binary time of day, converted to Gray code, results in a parallel format of 27 digits, which is compatible with computer input words.

Code Equivalents		
Decimal Number	Binary Number	Gray Code Number
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101
10	1010	1111
11	1011	1110
12	1100	1010
13	1101	1011
14	1110	1001
15	1111	1000

The real-time Gray code time of day is also transmitted via the count clock data link to the MLF remote clock system. In that area, the data is input to a storage location where it is made available to the MLF RCA-110A computer. This computer utilizes real-time for the same basic purpose as the LCC computer.

The real-time event storage unit provides a means of storing such events as liftoff, and displaying this function versus time via the real-time event display. This storage is a permanent device.

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The countdown generator provides a count up time based on the accumulation of one pulse per second signals synchronized with the IRIG time code from the KSC timing center and generates a countdown time based in the depletion of a preset time decremented at a one pulse per second rate. The generator output is as depicted in Figure 22. The countdown can be controlled from either the RCA-110A computer or test supervisor count time control panel. Under the test supervisor's control, the clock can be stopped manually at any point during the test at the discretion of the operator; however, under computer control, the clock is stopped as the result of a test failure or as a result of the coordinated effort between the RCA-110A computer program and the CDC 160G ACE-S/C computer program. Also, under computer control, the direction of the count and the preset count time can be controlled in accordance with a given program. Additionally, the liftoff signal initiates the count up function of the countdown generator.

The count time output is routed to four separate locations: (1) time displays, (2) timed output commands, (3) RCA-110A computer, and (4) the mark time generator. The time displays project countdown time in decimal and also depicts indications pertaining to direction and count/hold. The timed output command unit functions as a milestone counter in that preset discretely (up to eight) of any arbitrary time can be inserted and when these times become coherent with countdown time, a discrete signal occurs. These discretely are sent to systems integration distributors where they are utilized in program control. The RCA-110A computer inputs are in BCD and are available to the computer upon request to correlate the programs with progression of the countdown sequence. The mark time comparator is utilized by the computer under program control. The computer inputs a preset time into the comparator, and when preset time is coherent with count time, an interrupt is sent to the computer. This interrupt informs the computer that a specific point in the countdown has occurred, thus causing the computer to perform the function previously programmed. If another critical time to be noted, a preset time is again placed in the mark time comparator. The functions of the MLF units are basically identical to those of the LCC, however they perform operationally differently, because of different program philosophy.

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TIME CODE

IRIG B serial time code utilized with the Type I count clock has the following characteristics:

- a. Time: Universal Time (UT-2).
- b. Time frame: 1.0 second.
- c. Code digit weighting options: BDC, SB, or both.
 - (1) Binary Coded Decimal (BCD) time of year code word: 30 binary digits.
 - (a) Seconds, minutes, hours, and days.
 - (b) Recycles yearly.
 - (2) Straight Binary (SB) time of day code word: 17 binary digits.
 - (a) Seconds only.
 - (b) Recycles each 24 hours.
- d. Code word structure:
 - (1) BCD: word begins at index count 1. Binary coded elements occur between position identifier elements (7 for seconds, 7 for minutes, 6 for hours, 8 and 2 for days) until the code word is complete. An index marker occurs between decimal digits in each group to provide separation for visual resolution.
 - (2) SB: word begins at index count 80. Five decimal digits (17 binary coded elements) occur with a position identifier between the ninth and tenth binary coded elements.
- e. Least significant digit occurs first.

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f. Element rates available:

- (1) 100 per second (basic element rate).
- (2) 10 per second.
- (3) 1 per second.

g. Element identification:

- (1) "On time" reference point for all elements is the leading edge.
- (2) Index marker 2 milliseconds
(Binary zero or uncoded element).
- (3) Code digit 5 milliseconds
(Binary one).
- (4) Position identifier--10 per second . . 8 milliseconds
(Refers to the leading edge of the succeeding element).
- (5) Reference marker--1 per second . . Two consecutive
position identifiers.

(The "on time" point, to which the code word refers, is the leading edge of the second position identifier).

- h. Resolution: 10 milliseconds (unmodulated).
1 millisecond (modulated).
- i. Carrier frequency: 1 kc, when modulated.

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CHAPTER II

SECTION V

DISCRETE CONTROL EQUIPMENT

The Discrete Control Equipment (DCE) is a special purpose digital machine capable of performing the control interface function between the LUT computer and the Saturn V Launch Vehicle on the LCC Computer and the ESE control and display panels. At the LUT the DCE Computer scans its program and other available information, determines the operations or tests to be performed on the vehicle, and provides output signals to the output section of the DCE. At the LCC, a similar unit is used in the same manner to interface the LCC Computer output to the ESE panels.

Operating in the automatic mode the DCE receives instructions from the LUT or LCC computer, converts the instructions to discrete outputs, and energizes appropriate Network Relays. Manual control, both local and remote, is provided as a backup capability in case of a major failure in the Saturn V Operational Computer System.

The DCE is designed to accept inputs at a bit rate of approximately 500 KC with a minimum of 90 micro-seconds between each two 24 bit word transmissions. The DCE decodes the 48 bit instruction word from the Saturn V Operational Computer System to select and activate, or deactivate, up to 24 discrete outputs for a total of 2016 D.O.'s.

The DCE is composed of the following:

- a. Input/Output Logic
- b. Communications Registers
- c. Decoder
- d. Encoder
- e. Control Panel (Local or Remote)
- f. Power Sequencer

The I/O Logic gates information into and out of the DCE in the manual mode but performs no functions in the automatic (computer) mode.

The communications Register is a 48 bit serial/parallel register. Computer data is entered serially and manual data is entered in parallel. (Refer to Figure 23.)

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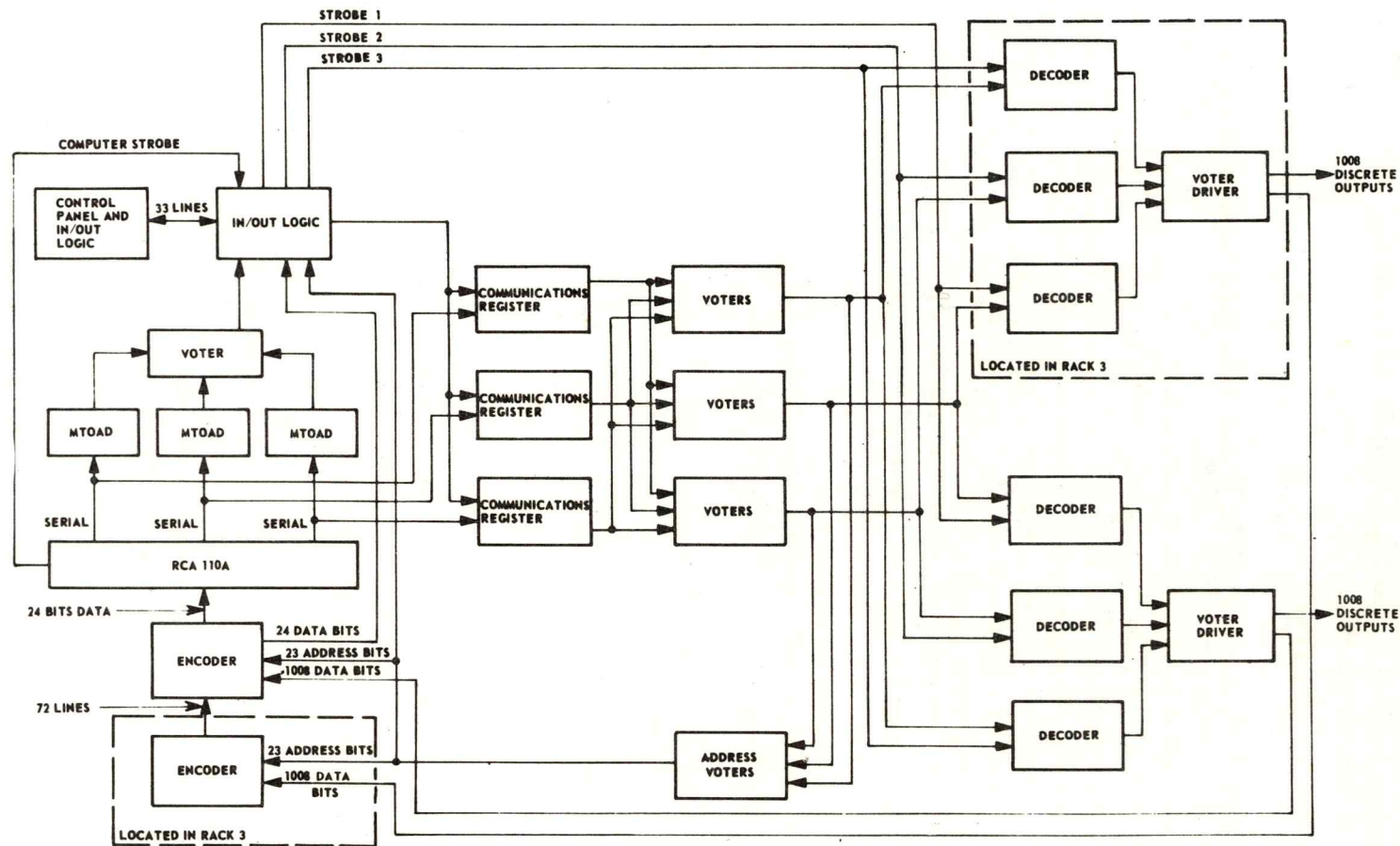


Figure 23. Block Diagram, Discrete Control Equipment

The Decoder accepts the voted information from the Communications Register, decodes the Address and Data Words and signals the selected discrete output or outputs.

The Decoder, a 2016 matrix of four multiplexed 504 matrices, is composed of NAND gates for decoding, amplifiers to provide logic driving power, and an output section. The NAND gates are arranged so that each bit of the Data Word drives the corresponding bit on 84 Address lines. These gates require a large number of drivers. Each of the first 21 bits of the Address Word drives an enable gate on 24 bits of Data information.

The address word is routed and applied directly to the 24 Data gates which each of its bits control. However, the Data word is gated to the assigned position in the decoding matrix and inhibited at the input gate until the Word Strobe signal allows the Data Word to pass to the output section of the Decoder.

The Decoder output section consists of a flip/flop, a voter/driver (called a "dvoter" to distinguish it from the Communications Register Voter), and a Level Converter in one of the two output lines of each discrete output. The flip/flops serve as a memory for the system while subsequent instructions are being processed.

The Encoder, utilizing the DO outputs, feeds back to the DCE Control Panel (manual mode) and to the Saturn V Operational Computer System (computer mode) the group address and the bit pattern for the selected group.

An encoder is provided for each 1008 block of Discrete Outputs to give the status of that block. Encoder operation will not be affected during the transfer to the other power source, provided the second power source is operative.

The Discrete Control Equipment is a Triple Redundant Majority Vote Logic System; voting is accomplished in two places by two different techniques. The Discrete Control Equipment is composed of three separate channels; each channel has its own set of power input cables and separate power supplies are used in each channel.

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The first voting technique is encountered at the interface between the Communications Register and the Decoder. The true side of each (48 total) flip/flop in the register is voted. To clarify the above statement: Consider that each bit output in each of three channels is routed to a total of three voters; the output of each of these voters is routed to the corresponding bit in the decoder. Therefore, the information is voted and regenerated on a best two-of-three basis. That is, each bit routed into the decoder is the result of a best two-of-three vote using the output of the Communications Register as the source.

The second voting technique is provided at the output driver which drives the controlled relay coil. The result of the vote is routed to the Saturn Vehicle, to the Discrete Output Equipment, where it is used to give word status to the Saturn V Operational Computer System and to the Manual Control Panel of the Discrete Control Equipment.

The DCE is a triple redundant system; however, each channel may be disabled for a TMR check by turning off the channel power supply (one channel check per diagnostic routine).

A "priority interrupt" signal is provided to the Saturn V Operational Computer System when one of the Discrete Control Equipment power supplies fails. The interrupt signal 28 ± 4 volt to 0 ± 0.5 volt. The opposite state should be available at the computer interface connector. If two out of three power supplies fail for the second 1008, the word strobes for the second 1008 will be inhibited. If two out of three power supplies fail for a particular 1008 the discrete outputs will go to the off state for that 1008 discrete outputs. Figure 24 is the DCE Simplex Block Diagram. Figures 25 and 26 are foldout pages 230 and 231 showing the overall ESE Signal Interface.

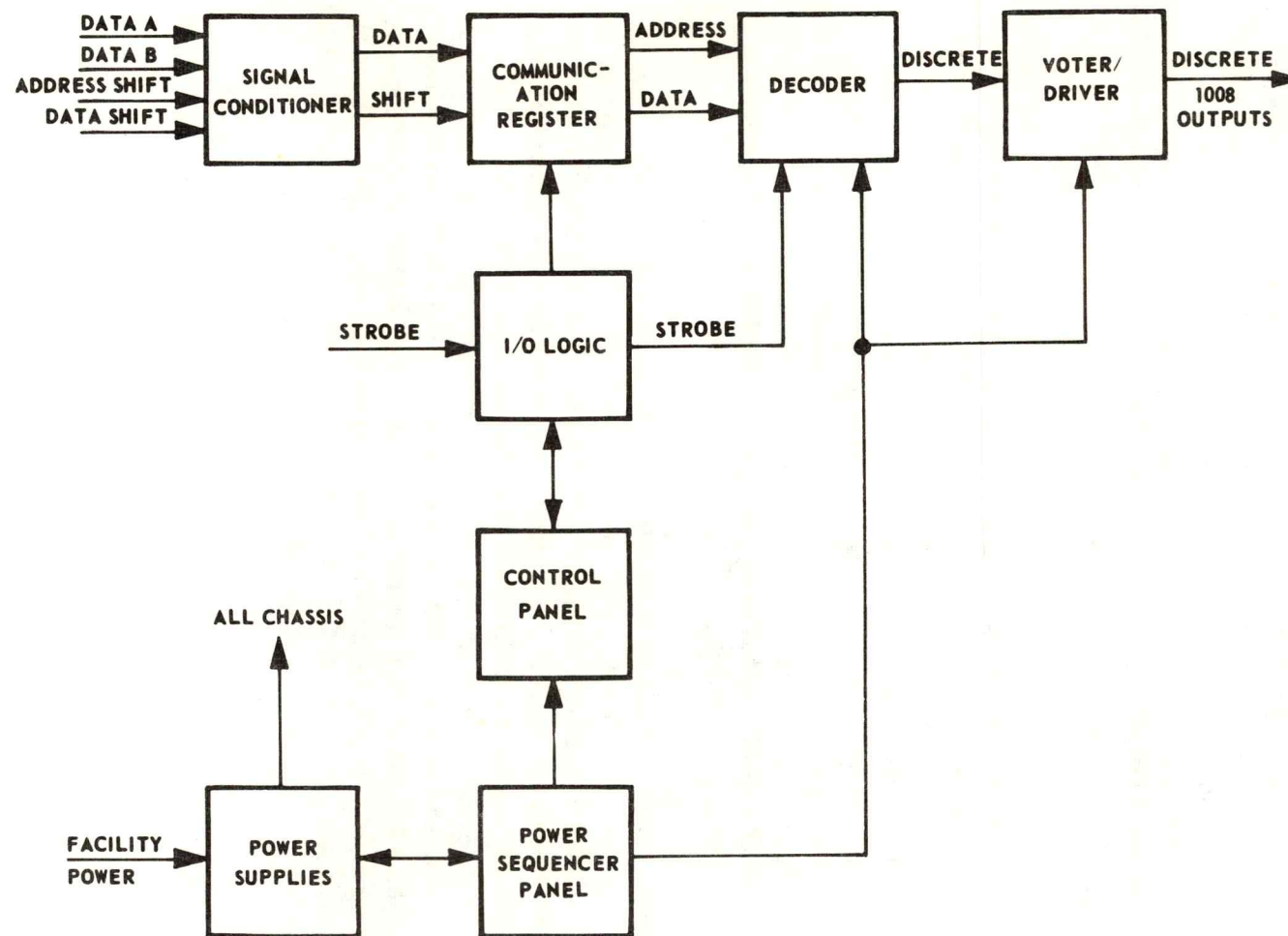


Figure 24. DCE Simplex Block Diagram

CHAPTER III

SECTION I

TELEMETRY

SATURN V TELEMETRY SYSTEM

Each stage of the Saturn V Vehicle carries an independent telemetry system. These systems modulate the signals from the measuring system onto RF carriers for transmission to ground stations. Three different modulation techniques are applied in the telemetry system of each stage:

1. FM/FM telemetry applies frequency modulation/frequency modulation with Pulse Amplitude Modulation (PAM) and triple Frequency Modulation (FM³) as auxiliary techniques
2. SS/FM telemetry uses single sideband modulation/frequency modulation
3. PCM/FM telemetry uses pulse code modulation

These different modulation techniques provide efficient transmission of the large number and variety of measuring data which has different requirements of bandwidth and accuracy (Table 1).

Low-response/low and medium-accuracy data may be sufficiently defined by sampling at a rate of 10 hertz, or less. In terms of frequency response this would be 2 or 3-hertz maximum variation. This category includes temperature, pressure, and other measurements where dynamic variations are not very likely or are not of particular interest.

Low-response/high-accuracy data requires accuracies of 1 percent or better. Examples are longitudinal acceleration and combustion chamber pressure measurements.

Medium-response/medium-accuracy data requires a 5 to 40-hertz response. Data of this category can be handled by sampling at 100 to 125 hertz per channel or less, or by FM/FM channels below the 3-kilohertz subcarrier using the standard deviation ratio of 5.

High-response/medium-accuracy data requires a 50 to 1000-hertz channel response. This type of data is readily handled by FM/FM subcarriers.

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TABLE 1. DATA CATEGORIES

Type	Frequency Response (hertz)	Accuracy Required (percent)
1. Low-response/low and medium-accuracy	2-3	2-5
2. Low-response/high-accuracy	2-3	1
3. Medium-response/medium-accuracy	5-40	2
4. High-response/medium-accuracy	50-1000	2
5. Wideband low-accuracy	50-3000	5
6. Event measurements	- - - -	- - - -
7. Digital measurements	- - - -	- - - -

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Wide-band data has a bandwidth of roughly 50 to 3000-hertz and normally no dc component of interest. Vibration data and sound intensity fall within this classification.

Event measurements constitute a special category. Interest in this data is limited to whether or not an event has occurred and, if so, the time of occurrence with respect to a specified time resolution.

In addition, much data originates in digital form, e.g., signals from the LVDC.

The wide-band data-carrying capability of standard FM/FM telemetry is very poor. The FM/FM system has one channel with a frequency response of 0 to 1050 hertz at a subcarrier deviation ratio of 5; the other channels have decreasing frequency responses down to 6 hertz. The sum of all the channel band-widths is only 4700 hertz. The bandwidth efficiency of a standard FM/FM system with subcarriers operating at a deviation ratio of 5 is about 1.6 percent. A corresponding figure for a PAM/FM system is about 3.5 percent; for a PCM/FM system, it is about 3.0 percent.

The necessity to transmit wide-band data (acoustic and vibration measurements) led to the use of SS/FM telemetry. An RF carrier is frequency modulated with single-sideband, amplitude-modulated carriers. The bandwidth efficiency of such a system is roughly 10 times greater than that of FM/FM. It is capable of transmitting 45 hertz of data over the same bandwidth used by the FM/FM link to transmit 4700 hertz of data.

A theoretical comparison of the signal/noise performance of the SS/FM with a standard FM/FM system is useful. Since single-sideband subcarriers do not possess wide-band gain, one would logically expect that SS/FM would perform less favorably in this respect than FM/FM, probably by a factor equal to 3 times the deviation ratio, which is the wideband gain of the FM subcarrier. However, if the modulating signal of such a system is to be vibration data, other factors can more than compensate for the lack of wide-band gain in the subcarrier.

These compensating factors result from a prior knowledge of the nature and characteristics of vibration data. A Gaussian or normal curve is a good approximation of amplitude distribution characteristics of such data. Since the summation of Gaussian functions is a Gaussian function

itself, the composite signal modulating the transmitter (in an SS/FM system carrying vibration data) could be expected to resemble a Gaussian function. The peak-to-peak amplitude of the data applied to an FM sub-carrier must be limited to the band edges of the subcarrier channels, the deviation being ± 7.5 percent of center frequency, to prevent adjacent channel interference. Thus, when data possesses a high peak-to-rms ratio, the signal capacity of the channel is reduced below its signal capacity for a sine wave modulating signal (1.41 peak-to-rms ratio). Correspondingly, Gaussian data with a peak-to-rms ratio of 4.0 reduces rms data capability to 2.83.

No such inherent peak data restriction exists in the SS/FM system. The data peaks of the individual channels add in a random manner, resulting in an amplitude distribution of the composite signal similar to that of the data at the channel inputs and having a peak factor of approximately the same magnitude. Thus, with Gaussian-type characteristics and an identical number of channels, the SS/FM system will accommodate two or more times as much peak carrier deviation per channel as an FM/FM system.

Data which originates in digital form and data requiring high accuracy are transmitted through the PCM/FM system. The digital data transmission link is relatively insensitive to imperfections in the transmission channel. Below a threshold noise level, the accuracy is not appreciably affected by noise in the channel. Nonlinearity in the transmission channel is of little consequence. By a relatively simple and reliable operation, the serial digital data which contains noise and deteriorated rise time can be regenerated into its original noise-free form.

Also, digital data transmission is compatible with real-time data processing by digital computers at ground stations. A separate digital data output of the PCM/FM system is used for automatic preflight checkout of the launch vehicle. This is called the digital data acquisition system. The Mod 301 PCM/DDAS Assembly is also connected with the LVDC for checkout of the S-IVB/IU Stage in orbit. During flight, all operational data is transmitted over the PCM/FM link.

To increase the data handling capacity of telemetry systems, several data channels are multiplexed. Two types of multiplexing are utilized: frequency-division multiplexing and time-division multiplexing.

Frequency-division multiplexing is the process of simultaneous frequency sharing of one RF carrier transmission link by dividing the available bandwidth into a number of channels, each with a separate center frequency.

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Spacing is provided between these channels to allow each channel to be frequency modulated or deviated about the center frequency. After modulation occurs, the subcarrier signals are combined linearly, and the resultant composite signal is used to frequency modulate an RF carrier. FM/FM and SS/FM are examples of this frequency division multiplexing.

Time-division multiplexing is the process of sequential sampling of two or more data sources and applying the data samples to a common output in a fixed sequence. The samples may or may not be separated by a "dead time" space. Usually some "marker" is made a part of the output signal to designate the beginning or end of a sampling cycle. This is for identification and synchronization purposes at the data reduction point.

The Saturn telemetry systems make use of several types of time-division multiplexers. The Mod 270 Multiplexer Assembly is a time-division multiplexer for analog data. It is used in conjunction with the FM/FM telemetry system and the PCM/FM system. The Mod 245 Multiplexer Assembly provides time-division multiplexing for wide-band data and is used for SS/FM telemetry and FM telemetry. The remote digital submultiplexers and digital multiplexers are used in connection with the Mod 301 PCM/DDAS Assembly. Remote analog submultiplexers are used for analog data connected to the Mod 270 Multiplexer Assembly.

The number of RF carriers allotted to each modulation technique is chosen to provide an appropriate balance of data originating on the stage. The telemetry equipment associated with each stage consists of a "building-block" arrangement, which may be connected in numerous combinations to satisfy specific measuring requirements. The number of carriers allocated to FM/FM, SS/FM, or PCM/FM and also the specific combination of building blocks vary from stage to stage and from vehicle to vehicle.

Typical S-IVB/IU Telemetry System

Flight (mission) control data will be sent in parallel to the IU PCM/FM and S-IVB PCM/FM systems. Therefore, in the event of a failure in one of the PCM systems (IU or S-IVB), the other PCM systems can be used to transmit the flight control data.

Table 2 lists the type and number of telemetry systems and multiplexers used in the stages of Saturn vehicles. Because of the smaller quantity of measurements required in operational vehicles, the

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Stage/ ESE	Telemetry System	Number of Systems		Number of Multiplexers		Transmitter	
		R&D	Oper	R & D	Oper	Frequency	Power
IU	FM/FM SS/FM PCM/FM	2 1 1	1 - 1	1x CIU 2x Mod 270 1x Mod 245 1x RDM Mod 410 1x RDSM	1x CIU 2x Mod 270 2x RDM Mod 410	Saturn V: 225-260 MHz and 2200-2300 MHz	20 W
S-IVB	FM/FM SS/FM PCM/FM	3 1 1	1 - 1	4x Mod 270 1x Mod 245	2x Mod 270	225-260 MHz	20 W
S-II	FM/FM SS/FM PCM/FM	3 2 1	2 - 1	5x Mod 270 1x Mod 245 7x RASM 2x RDSM	2x Mod 270 2x RDSM 2x RASM	225-260 MHz	20 W
S-IC	FM/FM SS/FM PCM/FM	3 2 1	1 - 1	4x Mod 270 2x Mod 245 1x RDSM	1x RDSM 2x Mod 270	225-260 MHz	20 W

Note: CIU = Computer Interface Unit RASM = Remote Analog Submultiplexer
RDSM = Remote Digital Submultiplexer RDM = Remote Digital Multiplexer
(Mod 410)

number of telemetry systems is also reduced. (Figures given for operational vehicles are "best guess" at the present time.)

From one to six time-division multiplexers are synchronized from a central timing source located in the PCM/DDAS Assembly. Each time-division multiplexer provides an output to the PCM/DDAS Assembly which combines the outputs into a single serial wave-train. The individual analog samples are digitized and combined into a digital format which is transmitted via coaxial cable to the ground checkout equipment. This data is also transmitted via a PCM/FM carrier for in-flight monitoring.

Each of the time-division multiplexers has a second data output which is identical to the output provided to the PCM/DDAS Assembly except that it is conditioned for PAM transmission. These outputs may modulate a 70-kilohertz, voltage-controlled oscillator in FM/FM telemeter assemblies. This arrangement provides redundant transmission of some multiplexer outputs using both PAM and PCM techniques.

FM/FM Telemetry System

The FM/FM telemetry system frequency multiplexes the input data. The conditioned signals derived from pressure, temperature, etc., modulate the frequency of the subcarrier oscillators. The combined output of several subcarrier oscillators is again frequency modulated on the RF carrier. Standard IRIG frequency channels are assigned. The data bandwidth capabilities of these channels are shown in Table 3. Slow-varying data is applied to the low-frequency channels; data with higher frequency variations, must be applied to the higher frequency channels. FM/FM systems are susceptible to various sources of noise and distortion (fluctuation noise, crosstalk, harmonic distortion of the individual subcarrier signals, subcarrier data feed-through, and distortion of individual subcarrier signals due to band-limiting filters), which affect the accuracy of the telemetered data.

Each of the subcarrier oscillators of an FM/FM system may be preceded by another subcarrier group. Each of these "Sub-subcarriers" would, in this case, be modulated by the actual measurement values. This technique is called FM/FM/FM, or FM³. The technique

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TABLE 3. IRIG SUBCARRIER CHANNELS ($\pm 7.5\%$ CHANNELS)

Channel	Center Frequencies (kHz/s)	Lower Limit (kHz/s)	Upper Limit (kHz/s)	Nominal Frequency Response (Hz/s)	Nominal Rise Time (ms)	Maximum Frequency Response (Hz/s)	Minimum Rise Time (ms)
1	0.40	0.370	0.430	6	58	30	11.7
2	0.56	0.518	0.602	8	42	42	8.33
3	0.73	0.675	0.785	11	32	55	6.40
4	0.96	0.888	1.032	14	24	72	4.86
5	1.30	1.202	1.398	20	18	98	3.60
6	1.70	1.572	1.828	25	14	128	2.74
7	2.30	2.127	2.473	35	10	173	2.03
8	3.00	2.775	3.225	45	7.8	225	1.56
9	3.90	3.607	4.193	59	6.0	293	1.20
10	5.40	4.995	5.805	81	4.3	405	0.864
11	7.35	6.799	7.901	110	3.2	551	0.635
12	10.50	9.712	11.288	160	2.2	788	0.444
13	14.50	13.412	15.588	220	1.6	1,088	0.322
14	22.00	20.350	23.650	330	1.1	1,650	0.212
15	30.00	27.750	32.250	450	0.78	2,250	0.156
16	40.00	37.000	43.000	600	0.58	3,000	0.117
17	52.50	48.562	56.438	790	0.44	3,938	0.089
18	70.00	64.750	75.250	1,050	0.33	5,250	0.067
19	93.00	86.025	99.975	1,400	0.25	6,975	0.050

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trades bandwidth for additional channels; therefore, the frequency response of the channels is much lower. Since another modulation stage is used, the technique is less accurate than FM/FM.

A time-multiplexed signal may be fed into a subcarrier oscillator of an FM/FM system to increase the channel capacity. Time multiplexing consists of sequentially sampling a number of data signals with an electronic or mechanical commutator. The commutator output appears as a train of pulses of varying amplitude. This technique is known as Pulse-Amplitude Modulation (PAM/FM/FM).

The basic modulation scheme and principal components used (subcarrier oscillators, mixer, power amplifier, and transmitter) are essentially the same for each stage of the FM/FM system. Each channel receives a signal from the Measuring Distributor. This input signal modulates a voltage-controlled subcarrier oscillator. The frequency-modulated signals from the various subcarrier oscillators are combined in the mixer amplifier. The composite signal is frequency modulated on a radio-frequency carrier in the VHF band (225 to 260 megahertz) for transmission to the ground stations. The transmitter provides a signal power level of approximately 20 watts.

The available standard IRIG channels may be utilized in different ways. The input signals from the Measuring Distributor are in the range of 0 to +5 volt dc (2 to 7 volts peak-to-peak ac when a band-pass filter is used in place of a channel or subchannel oscillator).

When used, triple FM (FM^3) is applied to the channels above channel 13. A subcarrier channel of 70 kilohertz (± 30 percent) is used for time-multiplexed signals from the Mod 270 Multiplexer Assembly. When this PAM technique is applied, all IRIG channels above 30 kilohertz will not be used. The Mod 270 solid-state, time-division multiplexer operates at a rate of 3600 samples per second. It consists of 30 primary channels which are sampled 120 times per second. In addition, 10 submultiplexers may be used on selected main channels; each sampled at a rate of 12 per second. The multiplexer accepts input signals in the range of 0 to 5 volts dc and provides two PAM wave train outputs. One wave train modulates the 70-kilohertz, voltage-controlled subcarrier oscillator with a frequency deviation of ± 30 percent (i. e., 49 to 91 kilohertz for an input signal from 0 to 5 volts dc). The second wave train is used for the PCM system.

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The RF Assembly accepts single sideband FM and FM analog signals from the telemetry assemblies and provides the highly-stable, close-tolerance carrier frequency (± 0.01 percent). It further provides the capability of varying the carrier frequency in a manner (± 1 percent of the best straight line approximation for 125-kilohertz deviation at modulation frequencies from 300 hertz to 100 kilohertz proportional to the input signal amplitude, thereby providing an RF link from the measurement systems in the flight vehicle to the ground receiving station.

SS/FM Telemetry System

The Saturn SS/FM telemetry system is designed specifically for transmission of the large volume of vibration data from the Saturn Vehicle. This system can transmit 15 channels, each having a response of 30 to 3000 hertz, for a total data bandwidth of approximately 45 kilohertz within the standard telemetry carrier bandwidth.

Each of the 15 data inputs is fed to a balanced modulator and heterodyned with a 455-kilohertz carrier. The output of the modulator is fed to a mechanical bandpass filter (455 to 458 kilohertz) which passes only the upper sideband. The output of the filter is fed to a second balanced modulator where it is translated to the proper baseband frequency. The baseband position is determined by the carrier supplied from the frequency synthesizer. The two balance modulators and the mechanical bandpass filter for each data channel make up the channel units. The channel units are identical for all channels.

The second modulator carriers are supplied to the channel unit from the frequency synthesizer and comb filters. These 15 subcarriers transpose the data of an assigned frequency between 4.74 and 72 kilohertz. These are the lower sideband outputs of the second modulators.

Both sidebands of the second modulators go to the summing amplifier No. 1 and the 200-kilohertz low-pass filter where all upper sidebands of the second modulator are filtered out. Here a 75.835-kilohertz pilot tone is summed into the channel unit outputs. The pilot tone provides a signal at the receiving station for demodulation of the 15 channels.

After leaving the 200-kilohertz low-pass filter, the composite signal is passed through a signal regulator. From the signal regulator,

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the composite signal is summed with the signal from the non-translated special service channel. The frequency response of this channel is 0 to 1200 hertz. Its normal use is to carry a 960-hertz signal provided by the Mod 245 Multiplexer Assembly for demultiplexing the signals at the receiver. The output of the summing amplifier No. 2 is used to frequency modulate an RF transmitter.

All the carrier signals and the pilot tone are generated internally in the airborne SS/FM assembly by a single 910.025-kilohertz crystal oscillator. This signal is used to drive a flip flop which provides the 455.012 kilohertz carrier signal and a frequency synthesizer provides all sub-carriers and the pilot tone from the comb filters.

To provide a 3-kilohertz information bandwidth and allow sufficient guardband, a channel spacing of 4.74 kilohertz is used. This spacing is convenient to generate in the synthesizer and allows an adequate guardband of 1.74 kilohertz. The 75.83-kilohertz pilot tone falls just above the highest baseband frequency. It is used as a reference in the ground demodulation equipment to regenerate the basic 455 and 4.74-kilohertz frequencies. Since the amplitude of the transmitted 75.83-kilohertz pilot tone is regulated, it is also used as an automatic gain control.

The SS/FM Assembly is used in conjunction with a vibration multiplexer (Mod 245) to expand its data-handling capability by time-sharing specific data channels. SS/FM telemetry is not carried in operational vehicles.

PCM/DDAS Telemetry System

The PCM/DDAS telemetry system serves a dual purpose in the Saturn Launch Vehicle. This system functions as a telemetry link for digital data (PCM/FM) and as a part of the DDAS. PCM/FM is required on the launch vehicle in order to obtain sufficient accuracy, with acceptable bandwidth efficiency, for digital data transmission from data sources such as the LVDC. The DDAS provides necessary measurement data to the LVDC. Before launch, it also provides measurements to the launch computer in the ground checkout stations (via coaxial cable).

To provide flexibility, the system is "built up" from several assemblies which may be combined as required in a particular stage application. The following assemblies may be used to "build up" a

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PCM/DDAS telemetry system:

1. Mod 301 PCM/DDAS Assembly
2. PCM RF Assembly
3. Mod RDSM-1D Remote Digital Submultiplexer
4. Mod 410 Remote Digital Multiplexer
5. Mod 270 Multiplexer Assembly
6. A remote analog submultiplexer which may be used with a Mod 270 Multiplexer assembly
7. Computer Interface Unit

MOD 301 PCM/DDAS Assembly

The Mod 301 PCM/DDAS Assembly is the central piece of equipment in both the telemetry link and the DDAS link. It provides the output signals for telemetry and automatic checkout.

The PCM/RF Assembly contains the signal conditioner, power amplifier, and RF transmitter for the telemetry link.

The Mod RDSM-1D Remote Digital Submultiplexer is used to connect digital data sources to the Mod 301 PCM/DDAS Assembly.

The Mod 410 Remote Digital Multiplexer is used in the IU to connect the LVDC to the Mod 301 PCM/DDAS Assembly.

The Mod 270 Multiplexer Assembly is used to connect analog data into the Mod 301 PCM/DDAS Assembly.

The remote analog submultiplexer may be used to submultiplex data being fed through the Mod 270 Multiplexer Assembly.

The Computer Interface Unit allows the LVDC, operating through the LVDA, to read selected measurement data which is being transmitted through the Mod 301 PCM/DDAS Assembly.

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A brief functional description of the Mod 301 PCM/DDAS Assembly and the PCM/RF Assembly is given on the following pages. The multiplexers and the computer Interface Unit are described in the following paragraphs.

The Mod 301 PCM/DDAS Assembly performs six major functions as follows:

1. Scans the PAM wavetrains of several (1 to 6) Mod 270 PAM Multiplexer Assemblies in a programmed sequence and combines these wavetrains into a single PAM wavetrain.
2. Encodes the PAM samples in this wavetrain into 10-bit digital form.
3. Accepts data in digital form and programs it into selected time slots in the output serial format.
4. Generates the required frame and master frame identification codes, combines these codes with the digital and encoded analog data, and arranges the desired serial format for output.
5. Provides a 600-kilohertz FM modulated carrier as the DDAS output, and an NRZ modulating output for the PCM RF Assembly.
6. Provides the synchronization outputs necessary to synchronize the Mod 270 Multiplexer Assemblies and remote digital submultiplexers.

The Mod 301 PCM/DDAS Assembly is composed of the six functional subsystems listed below:

1. PAM scanner (and associated program patch).
2. Analog-to-digital converter.
3. Digital multiplexing and formatting logic.
4. Clock programming and timing logic

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5. DDAS voltage controlled oscillator.

6. Power supplies.

PAM Scanner. The PAM scanner connects one or more Mod 270 Multiplexer Assemblies outputs in a programmed sequence to the ADC input for digitizing. By means of the scanner program patch, any multiplexer arrangement compatible with the system application can be accommodated. Up to three multiplexer arrangements (modes) may be programmed at the scanner patch, and the automatic switching between modes is accomplished by applying external 28-volt dc commands.

The scanner gates are 4-transistor, back-to-back, balanced configurations which switch both legs of the PAM circuit of each PAM multiplexer. The transformer coupling of the switching logic input of the gates provides a favorable impedance condition for the PAM signals.

The PAM scanner and program patch are packaged on printed circuit cards which plug into the Mod 301 PCM/DDAS Assembly.

Analog-to-Digital Converter. The analog-to-digital converter encodes the PAM signals received through the PAM scanner by the successive approximation method. The digital output is fed in parallel form to a parallel storage register according to commands received from the programming and timing logic. Its operation is non-synchronous (not synchronized with other parts of the system) and at a clock rate of approximately 250 kilohertz which is provided by a blocking oscillator.

Encoder command pulses at the system word rate are provided by the programming logic. When an encode command is received by the ADC, it begins an encode cycle at its own clock rate; this requires approximately 56 microseconds. At the end of the cycle, the ADC register switches have been set to the digital equivalent of the analog quantity present at the buffer input during the encode cycle. The logic levels from the register switches provide a parallel digital output until the next encode command arrives. The register switches are then reset and a new encode cycle follows.

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Digital Multiplexing and Formating Logic

The function of the digital multiplexing and formating logic is to combine the encoded data from the ADC, externally generated digital data, and frame (and master frame) identification words into the required output sequence. The specific time slot into which data is inserted is controlled by command pulses from the programming and timing logic. The 10-bit output of the ADC is transferred into the parallel storage register by each word rate clock pulse (so long as the encoder inhibit bus is unenergized). When the encoder inhibit bus is energized, the ten AND gates at the ADC output are disabled, and the ADC output is not transferred into the parallel storage register.

Up to ten 10-bit groups of digital data from external sources can be programmed into selected time slots at any of the four system sampling rates. The data is accepted in parallel. A zero-volt level represents a logical "0" and a positive level represents a logical "1". Inputs are buffered and then shifted into a magnetic core register before being transferred into the parallel storage register. The MCR provides temporary storage and dc isolation of the data source. Each MCR, along with its ten associated buffers and other circuits, is powered by an individual supply which is dc isolated. This permits monitoring of several digital data sources without interconnecting their dc commons.

A WRITE command to an MCR causes the 10 bits of data to be stored in the magnetic cores. The WRITE command is programmed (at the command program patch) to occur before the time for transfer of the data into the PSR. Typically, the command occurs during the previous word time, but it can be programmed to occur at any word time after the previous sample of the specific channel is read into the PSR. For example, several 10-bit data sets can be written into their MCR's simultaneously and then placed into specific time slots in the output format. This mode of operation is utilized in monitoring a 40-bit set of data from the LVDC.

The READ command to the MCR is timed to transfer the data into the output register during the least significant bit time of the previous word time. READ commands are also OR'd together to provide a function for inhibiting the transfer to ADC data through the encoder gate.

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The digital input section has 10 channels. Each channel will accept a 10-bit input in parallel form. To increase the data handling capacity, the input section may be fed from 10-channel remote digital submultiplexers.

The frame identification logic generates three unique code groups and inserts them consecutively during the last three word times of the PCM/DDAS frame. Once each 30th frame, the framed ID logic receives a signal from the frame ID reversal flip flop. This signal causes the frame ID logic to complement (reverse) all bits in the frame ID code of the 30th frame. This forms the master frame identification code. The code group is as follows:

Word 29B	1 0 1 1 0 1 1 1 1 0
Word 30A	1 0 1 0 0 0 1 0 0 1
Word 30B	1 1 0 0 0 0 0 1 1 0

The serializing logic shifts the contents of the PSR bit-by-bit into the NRZ flip flop thus forming the serial NRZ output. The states of the bits per word counter are decoded, combined with the PSR outputs, and clocked to provide set-reset pulses to the NRZ flip flop. The two complementray outputs of the NRZ flip flop are buffered and provided at an output connector for use as a modulating input to the PCM/RF Assembly. One side of the NRZ flip flop provides a modulating input to the DDAS/VCO.

Clock, Programming, and Timing Logic

The clock, programming, and timing logic provides the timing signals necessary for the MOD 301 PCM/DDAS Assembly as well as signals required to synchronize logic in other telemetry assemblies.

One phase of the 72-kilohertz clock provides bit rate pulses to the serializing logic while the other phase steps the B/W counter. The outputs from each trigger of the B/W counter are decoded in the serializing logic and used to select stages of the PSR to form the serial bit train which controls the NRZ flip flop.

Count "2" of the B/W counter is decoded and initiates a series of three successive timing pulses which are 1.75 microseconds apart.

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The first (clear) pulse occurs approximately 2 microseconds after the least significant bit is transferred to the NRZ flip flop and resets all 10 stages of the PSR. The second pulse (READ clock) provides the correct timing phase for the transfer of data into the PSR from the ADC, the frame ID logic, or an MCR. The third pulse (WRITE clock) provides the proper phasing for writing external digital words into the MCR's. This pulse also signals the ADC to proceed with digitizing the succeeding analog signal.

The reset pulse of the B/W counter steps the group counter. This pulse occurs during the 2^2 bit time because of offset in the serializing logic. This allows settling time for the analog data inputs, (which are gated by the scanner in synchronism with the group counter) before the ADC begins digitizing. The group counter is a divide-by-two counter (one flip flop).

The reset pulse of the group counter steps the channel counter at a rate of 3600 pps. This consists of a divide-by-five counter and a divide-by-six counter which together form a divide-by-thirty counter.

The reset of the channel counter steps the divide-by-ten frame counter and the divide-by-three multiplexer counter. Both of these counters are stepped at the PCM/DDAS frame repetition rate of 120 times per second.

The 4 counters define each time slot in the PCM/DDAS format. The divide-by-two group counter provides the timing for the interlacing of two multiplexer groups. Each group is comprised of up to three Mod 270 Multiplexers which are controlled by the divide-by-three multiplexer counter. The divide-by-three multiplexer counter provides timing for the sharing of specific mainframe time slots. The divide-by-thirty channel counter steps in synchronism with the sampling action of the 30 by 120-channel analog gates (each sampled 120 times per second) in the Mod 270 Multiplexer Assemblies. The divide-by-ten frame counter steps in synchronism with the 10 by 12 submultiplexers (10 gates samples 12 times per second).

The counts of each of the 4 counters are decoded and routed to the command program patch. A programming arrangement provides selection of READ and WRITE commands corresponding to specific time slots. These commands provide the timing signals to the MCR's necessary to place external digital data inputs into a specific format. Decoded outputs of the group counter and multiplexer counter are also

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routed to the scanner program patch, which provides selection of the multiplexer scanning sequence. Up to three multiplexer-scanning sequences may be programmed on the scanner program patch. A specific sequence is selectable by an externally generated mode command. The mode commands are 28-volt dc signals from GSE, the vehicle command, or other sources appropriate to the application. (Note: Mode 1 does not require application of an external mode command voltage.)

The control logic also generates 3 sets of wave-forms used for synchronizing logic in other assemblies to the clock and frame rates of the Mod 301 PCM/DDAS Assembly. Two sets of waveforms provide the correct waveform shape, frequency, and phase for synchronizing Mod 270 Time Division Multiplexers. The two waveform sets are identical except for the offset in phase necessary for interlacing group A and group B multiplexers. Each set consists of a 3600-hertz square wave and a 278-microsecond pulse with a repetition rate of 4 times per second.

The third waveform set consists of an output from each stage of the divide-by-ten frame counter and a 3600-hertz square wave. This set of waveforms is utilized to synchronize remote digital submultiplexer assemblies.

DDAS Voltage Controlled Oscillator

The DDAS/VCO provides an FM modulated carrier (600 kilohertz) for transmission of the PCM/DDAS signal (via coaxial cable) to DDAS receiving equipment.

A 600-hertz transistor multivibrator is bias modulated by the serial NRZ data. An amplifier preceding the multivibrator presents an impedance of approximately 50 kilohms to the NRZ data input and also provides a non-linear modulating characteristic which makes the frequency deviation relatively insensitive to variations in the input data logic levels. A frequency deviation of approximately + 35 kilohertz is used.

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A common-collector buffer stage drives a filter which is designed to remove harmonics from the multi-vibrator output. This output stage delivers a nominal 75 milliwatts to a 100-ohm load.

Power Supplies. There are six separate power supplies used in the Mod 301 PCM/DDAS Assembly.

A 28 Vdc-to-28 Vdc converter regulates the primary 28 Vdc power to the assembly and isolates the digital return in the Mod 301 PCM/DDAS Assembly from the vehicle 28 Vdc return line. It supplies 28 Vdc ± 1 percent at a nominal 25 watts output to the remaining power supplies in the system.

The 6 Vdc card accepts + 28 volts from the converter and provides + 6 Vdc at 250 ma, and -6 Vdc at 50 ma. The +6 Vdc output provides collector voltage to the programming, timing, and scanning portions of the Mod 301 PCM/DDAS Assembly. The -6 Vdc output provides base bias voltage to the same circuits.

The +18 Vdc and +5 Vdc card accepts, regulates, and converts 28 Vdc to +18 Vdc and +5 Vdc. All circuit returns on this card are common. These voltages are used in the non-critical and digital circuits in the ADC (encoder) section of the assembly.

The -9 Vdc supply card provides bias voltage for the encoder section of the Mod 301 PCM/DDAS Assembly.

The +15 Vdc regulated supply obtains its input voltage from the +18 Vdc supply. The +15 Vdc is used as the reference voltage from which the comparison voltage is derived for the ladder network in the encoder.

The +12 Vdc supply is a simple Zener-resistor divider. It is used to provide bias voltage for the circuits on command program patch B.

PCM/RF ASSEMBLY

The PCM/RF Assembly contains the modulator and the RF transmitter for the PCM/FM telemetry link.

The assembly consists of a frequency-shift keyer, a premodulation filter, a hybrid 3-watt FM transmitter, and a single-stage RF power amplifier. These components are powered by a solid-state regulated power supply. They are mounted to system chassis.

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The input signal applied to the assembly is a 72,000 bits per second-NRZ digital signal from the Mod 301 PCM/DDAS assembly. The signal amplitude ranges from 6 to 10 volts peak to peak: rise and fall times are from 0.5 to 3.0 microseconds. Input sine wave signals of 4 volts peak to peak and zero to 100 kilohertz will not modulate the transmitter.

Premodulation filtering of the digital signal restricts sideband components outside a band of plus or minus 250 kilohertz around the carrier center frequency to 68 db below the level of the unmodulated carrier. The RF power output is 15 watts. The center frequency of the RF carrier is selectable to any frequency between 225 and 260 megahertz with center frequency stability and accuracy within 0.01 percent. A positive voltage excursion of the PCM/RF Assembly input signal produces an increase in carrier frequency.

TELEMETRY CHECKOUT EQUIPMENT (TCE) (Refer to Figures 27 and 28)

Telemetry checkout equipment, located in room 2P10 of the LCC, is used to check out the RF transmitter outputs of the Saturn V vehicle telemetry systems, the ML ground DDAS medium frequency (MF) transmitter, and to route vehicle outputs to the Information Systems Building for their automated checks of the stage telemetry systems. These telemetry checks are performed during vehicle high bay checkout (in VAB) via coaxial cables (VHF and MF for stages and VHF, UHF, and MF for IU). The TCE also supports telemetry troubleshooting when the vehicle is on the pad via the RF-VHF-UHF air link and hardware coaxial cables (MF - 600kc - PCM/DDAS). All TCE measurements are manually controlled at the TCE station and include the following:

- a. RF power levels.
- b. Carrier frequency and deviation.
- c. Subcarrier oscillator frequency and pre-emphasis levels.
- d. SS/FM channel frequency and amplitude.
- e. PCM format.
- f. Telemetry data continuity.

Figure 27 is a foldout-page 232 that depicts the Instrumentation and RF Ground Checkout Station.

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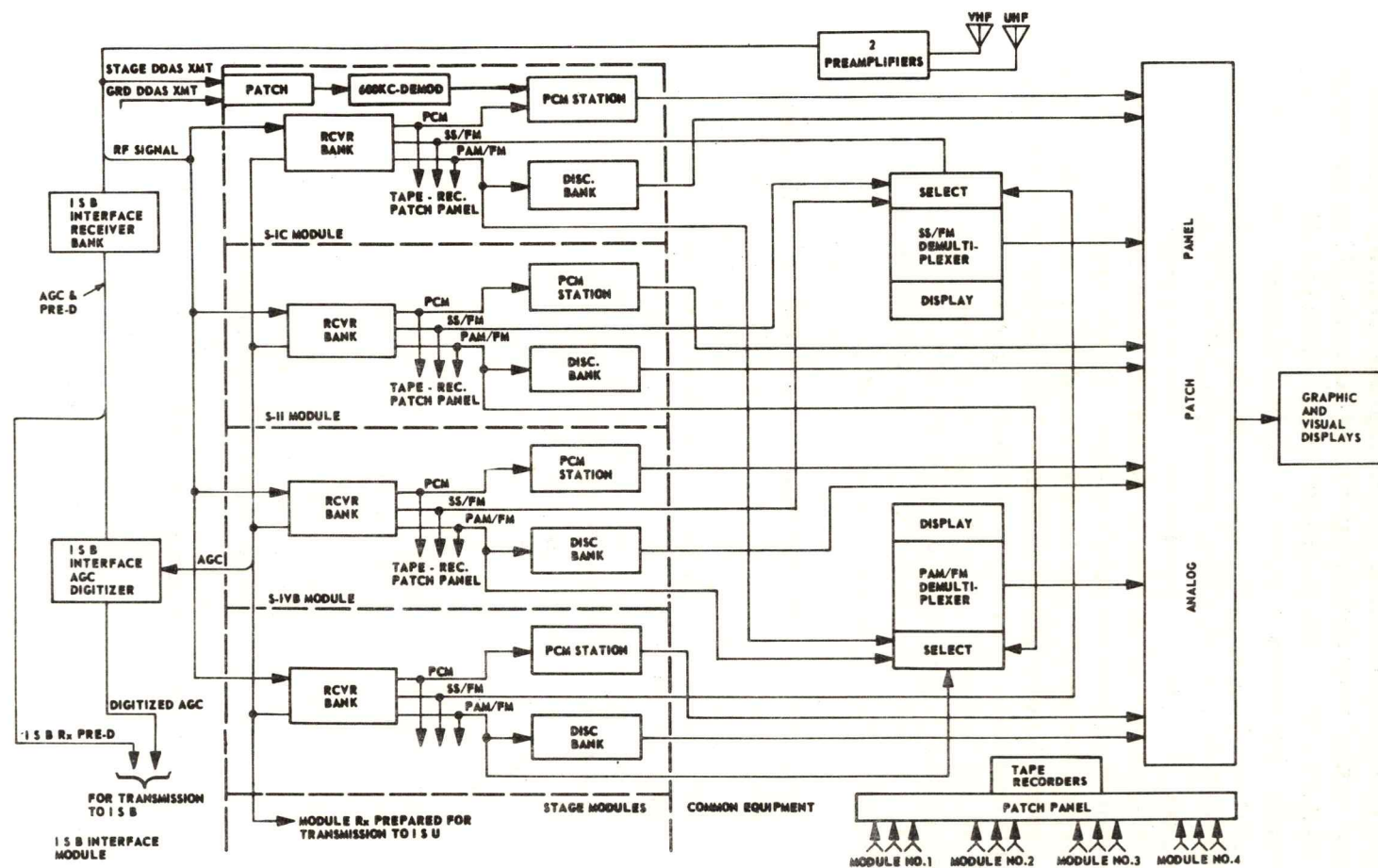


Figure 28. General Block Diagram T/M C/O Equipment

The TCE consists of stage-oriented receiving equipment, common support equipment, and Information Systems Building (ISB) interface equipment (see Figure 27). This equipment is capable of monitoring two Saturn V vehicle checkouts simultaneously. Stage-oriented equipment (one set for each stage and the IU) consists of a bank of RF receivers, a bank of FM/FM discriminators, a PCM/DDAS station (TRS-1), and related peripheral display and test equipment. Common support equipment consists of magnetic tape and strip chart recorders, PAM and single sideband (SS) demultiplexers, digital recorders, roof antennas and preamplifiers, and control and display equipment. The ISB interface equipment consists of a bank of RF receivers with related equipment and an automatic gain control (AGC) digitizer.

Each of the four vehicle telemetry systems (S-IC, S-II, S-IVB, and IU) has three VHF outputs and one medium frequency output (PCM on 600 kc carrier for DDAS). The IU also has an additional UHF telemetry output. The three vehicle VHF telemetry outputs are PAM/FM/FM, SS/FM, and PCM/FM, which are transmitted via the RF link when the vehicle is on the pad.

During VAB checkout, the TCE interfaces with the Information Systems Building and with the following:

- a. Each vehicle stage - (1) Via VHF (and UHF for IU) coaxial cable through coaxial switch in vehicle stage, and (2) via MF coaxial cable (PCM/DDAS 600-kc carrier).
- b. The ground ML-DDAS transmitter - via MF coaxial cable (PCM/DDAS 600-kc carrier). This input can be patched in at the TCE-PCM station patch panel.

During checkout when the vehicle is on the pad, the TCE interfaces are as indicated above, except that the stage VHF and UHF signals are transmitted via the air link to TCE antennas located on the LCC roof. The medium frequency coaxial cable signals (PCM/DDAS - 600 kc) are available at the DDAS line receivers (Unit 1451) located in the LCC firing rooms.

Figure 28 is a general Block Diagram of the Telemetry Checkout Station.

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MEASUREMENTS SYSTEM (Refer to Figure 29)

The measurements system is made up of the LCC measuring station and four VAB calibration test stations. This system is used primarily while the launch vehicle is undergoing checkout in the VAB, but will also support re-testing operations performed at the launch area.

The VAB measurements system facilitates the data conversion, display, monitoring, and control functions required to:

- a. Identify each data channel and verify that the sensors are operational.
- b. Conduct calibration tests to assure that all signal conditioner characteristics are correct within specified tolerances.
- c. Direct the calibration readjustment of those signal conditioners that are not within the specified tolerances.
- d. Verify and document the calibration status of signal conditioners.
- e. Support and monitor the functional testing conducted by other groups.
- f. Support calibration of signal conditioners in conjunction with the LCC firing room measuring station while the launch vehicle is on the launch pad during prelaunch checkout.

The LCC measuring station provides the capabilities required for:

- a. Continuous, real-time display of critical red-line launch vehicle stage (S-IC, S-II, S-IVB, and IU) and ground support equipment measurements.
- b. Post-launch, quick-look, system performance evaluation.
- c. Display and recording of data for special tests performed on the launch vehicle in the VAB and on the launch pad.

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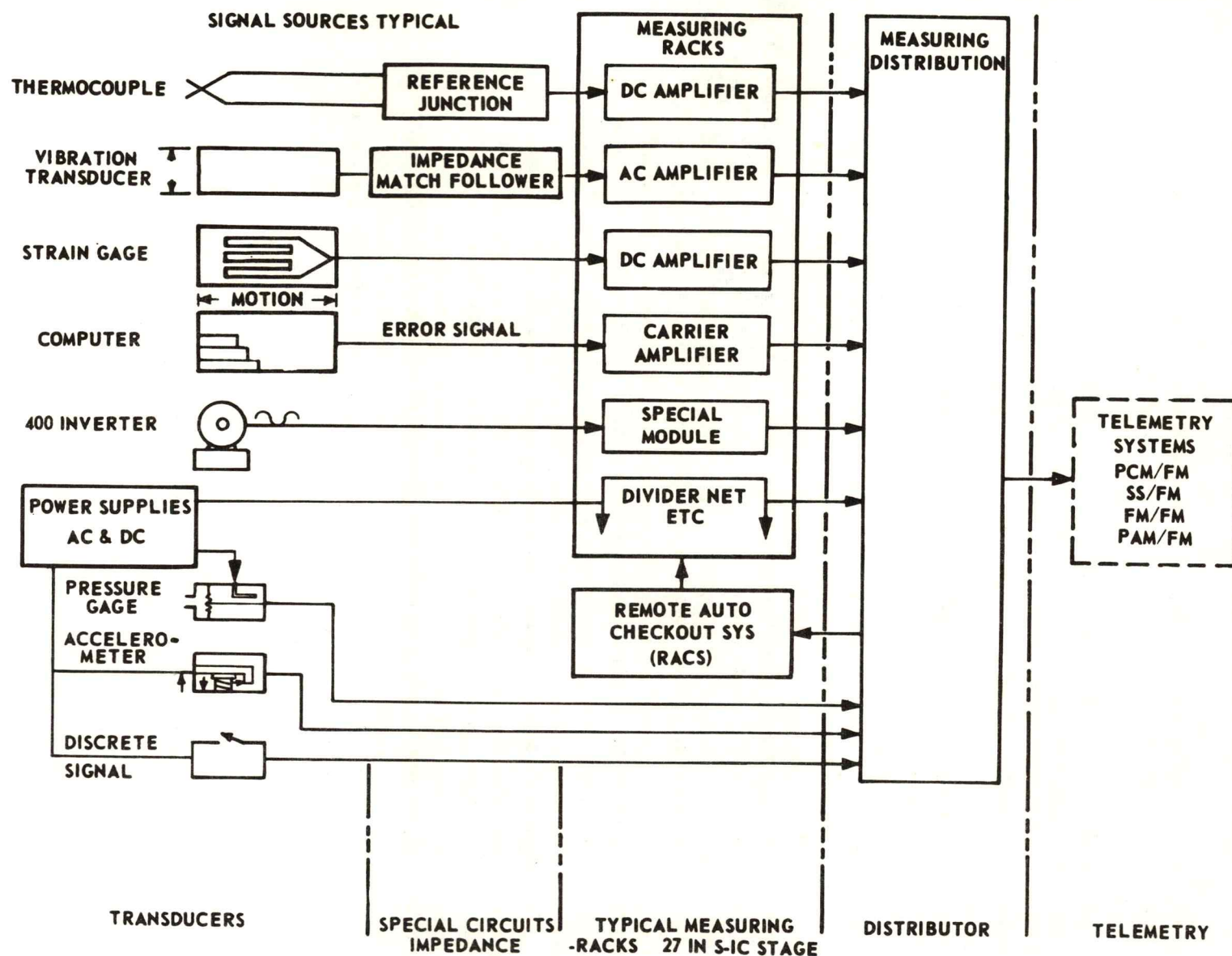


Figure 29. Block Diagram Airborne Measuring System

The measurements system functions through interfaces with other systems, including the vehicle measuring system, telemetry system, RACS, DDAS, hardwire data network, intercommunications systems, and the MILA timing system. Some of these interfaces are included on the signal interface block diagram. The launch vehicle stage measuring system provides measurements to the telemetry system for inflight performance monitoring and to the ground support equipment for prelaunch readiness determinations. Some measurements are used for both prelaunch and inflight monitoring. The launch vehicle measuring system is comprised of sensors, measuring racks, and measuring distributors. Two systems built into the launch vehicle stage facilitate the verification of the signal conditioner modules calibration from the ground. These are the Remote Automatic Calibrate System (RACS) and the Digital Data Acquisition System (DDAS). The RACS provides for the selection of a particular signal conditioner in a measuring rack and the energizing of the calibrate relays. The output signal from the signal conditioner module is returned to the ground equipment via the DDAS or the hardwire data network.

The VAB measuring system, located in the VAB high bay areas, provides the necessary functions to verify the calibration, and proper operation of the launch vehicle stages measuring systems, and to direct the recalibration of the launch vehicle measuring system signal conditioner modules. The VAB measuring system consists of four identical calibration test positions capable of operating independently. Each VAB calibration test station (one for each stage) consists of a DDAS receiving station (Refer to Figure 30), an analog recorder unit, five calibration test positions, and a digital control interface unit. (Each calibration test position contains manual control equipment for operation of the vehicle RACS, which selects the desired vehicle signal to be calibrated.) The calibration test positions are located on the following VAB equipment levels and are used in conjunction with the specific stage shown:

- a. Third - for test and checkout of the S-IC measuring system.
- b. Fifteenth - for test and checkout of the S-II measuring system.
- c. Twenty-second - for test and checkout of the S-IVB measuring system.
- d. Twenty-seventh - for test and checkout of the IU measuring system.

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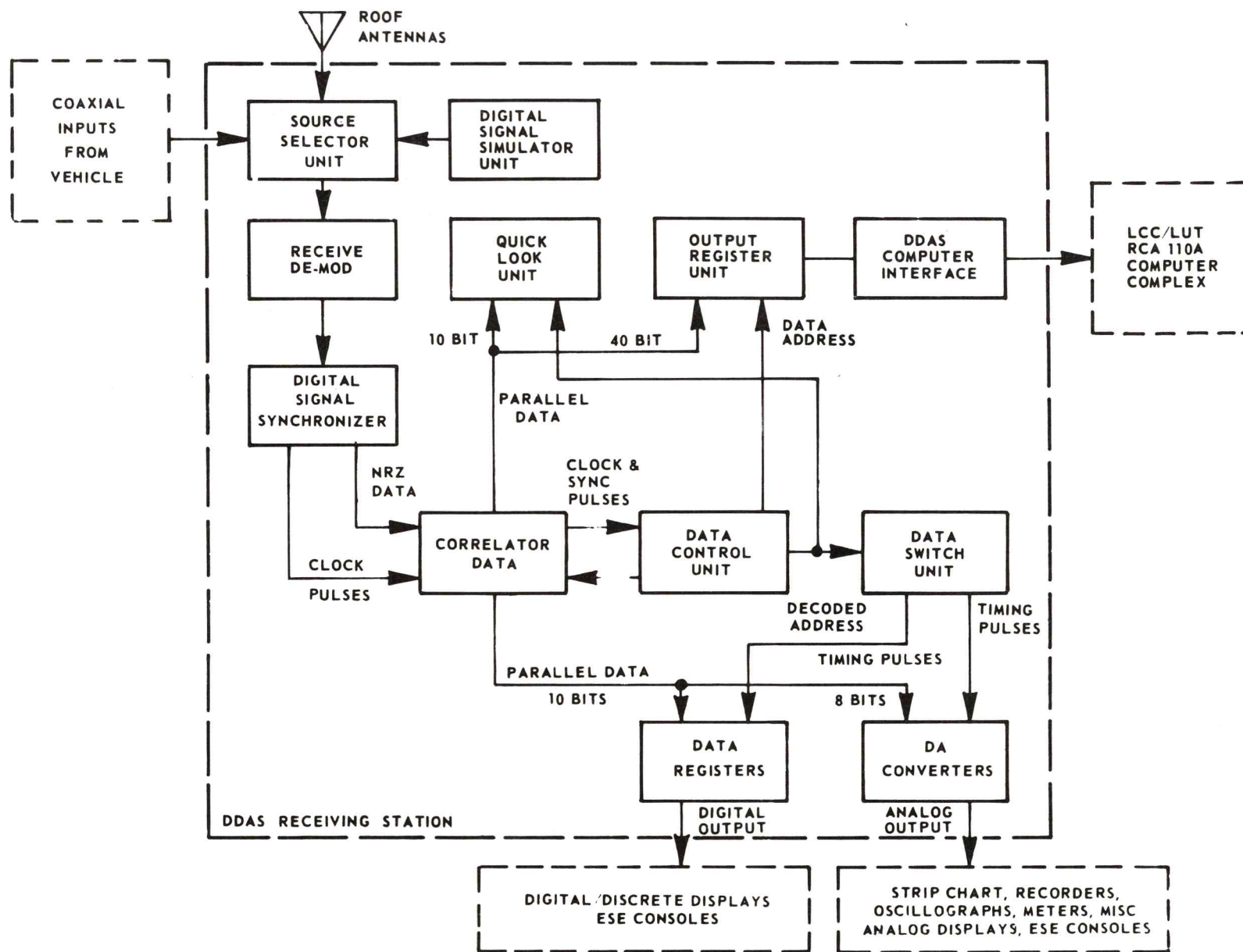


Figure 30. General Block Diagram DDAS Receiving Station

The VAB measurements system performs the following operations for each stage of the launch vehicles:

- a. Select, by controlling the launch vehicle stage RACS, a signal conditioning module and place that module in a calibrate condition.
- b. Obtain from the DDAS the response data from the signal conditioner.
- c. Select, display, and record the measurement available from the DDAS.
- d. Normalize data by scaling and removing offset.
- e. Record hardwire data.

The LCC measuring station will be utilized to support test and check-out operations of the launch vehicle in the VAB and during countdown at the launch pad. The data to be recorded will be transmitted through the DDAS or by other systems directly and indirectly from the launch vehicle and launch ground support equipment.

The LCC measuring station equipment consists of strip chart recorders, oscillograph recorders, calibrator panels, distributors, control and monitor panels, and associated equipment. Patching capability via program boards in row distributors will permit routing incoming measurements and calibration signals to any recording device located in that row of racks. This equipment is located in Firing Room No. 1 Area C, Rows A through F, cabinets 1-11 of each row except row F, which has ten cabinets.

During the launch countdown, certain parameters of the launch vehicle system performance and status are evaluated to determine if these systems are functioning properly and safely. During automated check-out, the LCC measuring station (Refer to Figure 31) provides a continuous recording capability of measurements considered too critical to be observed periodically. These measurements are monitored continuously in real time for trends, short-term disturbances, and other discrepancies. Examples of critical measurements are the fuel and LOX tank pressures, gear case temperatures, etc.

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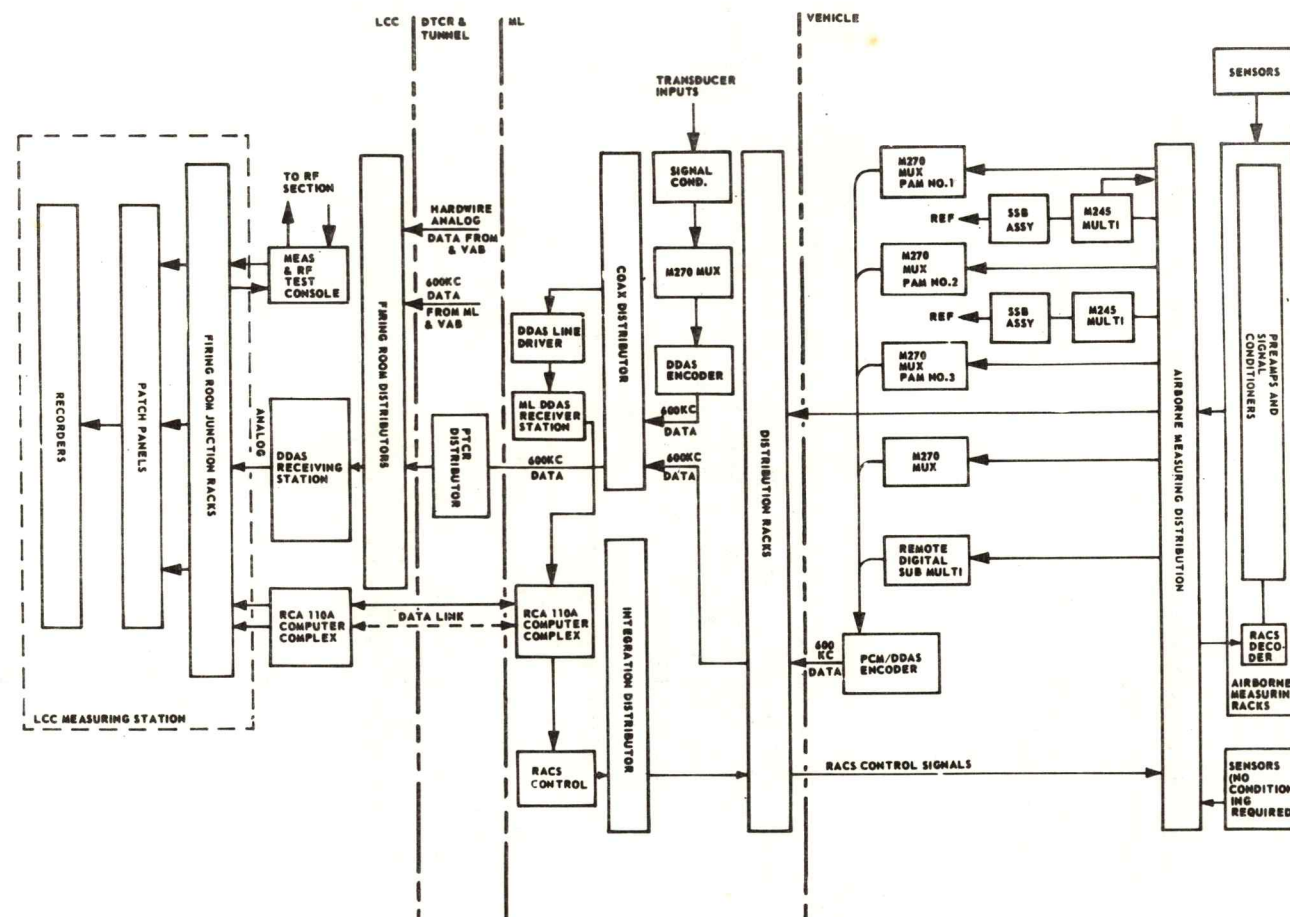


Figure 31. General Block Diagram LCC Measuring Station

LCC measuring station has interfaces with other systems (Refer to Figure 32) to:

- a. Receive analog input signals from five DDAS (S-IC, S-II, S-IVB, IU, and ground support DDAS). A minimum of 100 analog signals from each DDAS will be accepted.
- b. Receive signals from the launch vehicle and ground support equipment on hardwire lines for monitoring and recording data. This includes data to determine the safe operation of the equipment during countdown, and launch, and that which requires a bandwidth greater than the sampling rate of the DDAS.
- c. Receive time code signals from the MILA timing system.
- d. Include an intercommunications network for adequate support.

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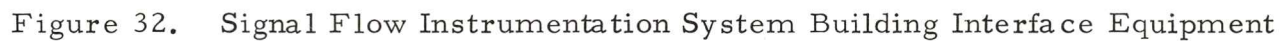


Figure 32. Signal Flow Instrumentation System Building Interface Equipment

CHAPTER III

SECTION II

REMOTE AUTOMATIC CALIBRATION SYSTEM

INTRODUCTION

Vehicle measurements are to be made prior to launch of the Saturn V by computer controlled equipment. It is mandatory that remote automatic means be provided to check all of the measurement sources. This is accomplished by the Remote Automatic Calibration System (RACS).

FUNCTIONAL DESCRIPTION: (Refer to Figure 33)

The remote automatic calibration system permits a remote calibration of the measuring system prior to launch. During vehicle checkout, calibration of measurements is accomplished through the RACS and various corrections can be made by adjusting potentiometers on the modules. Prior to launch time, the RACS may be operated if the system drifts or deviates from the final adjustments. The data obtained is used to correct the flight data for more accurate measurements.

Each signal conditioning module contains 2 relays, the necessary circuit to simulate the transducer as well as the upper (HI) end and the lower (LO) end of the signal range for that particular measurement. The transducer is connected to the module in the RUN mode.

A binary-coded signal is sent from the GSE through the umbilical cable to the Measuring Rack Selector in the vehicle to select a particular measurement for calibration. Figure 34 shows the RACS of the IU (each stage has a separate RACS). The signals are generated in the GSE either by a manual keyboard or from a computer program. These signals are decoded on the vehicle and distributed to the various Measuring Racks to operate the checkout relays.

The calibration signal consists of 13 bits in parallel. There are 6 bits for rack selection, 5 bits for channel selection, and 2 bits for mode selection. (One checkout relay is for the HI mode, or checkpoint, and the other is for the LO mode, or checkpoint.) The same code is used on all stages to provide a 31-rack capacity. The IU RACS is designed for 14 racks.

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CDS		
I.U. RACS DISPLAY PNL 8630-1710A1A2 15.75	S-IVB RACS DISPLAY PNL 8630-1710A2A1 15.75	BLANK 8.75
I.U. RACS CONT PNL 8630-1710A1A2 10.50	S-IVB RACS CONT PNL 8630-1710A2A2 10.50	BLANK 3.50
INTERCOM PNL 3.50	BLANK 3.50	BLANK 3.50
S-II RACS CONT PNL 8630-1710A1A3 10.50	S-IC RACS CONT PNL 8630-1710A2A3 10.50	BLANK 8.75
S-II RACS DISPLAY PNL 8630-1710A1A4 15.75	S-IC RACS DISPLAY PNL 8630-1710A2A4 15.75	BLANK 17.50
BLANK (FRONT) RACS DIST BOX NO. 1 (CENTER) 8630-1710A1C1 22.75	BLANK (FRONT) RACS DIST BOX NO. 2 (CENTER) 8630-1710A2C1 22.75	RACS PWR SUP. 28V, 100A 8630-1710A3A1 31.50
		AIR FILTER 8630-1710A3A2 5.25
RACS MEAS		

Figure 33. RACS Measurement Station
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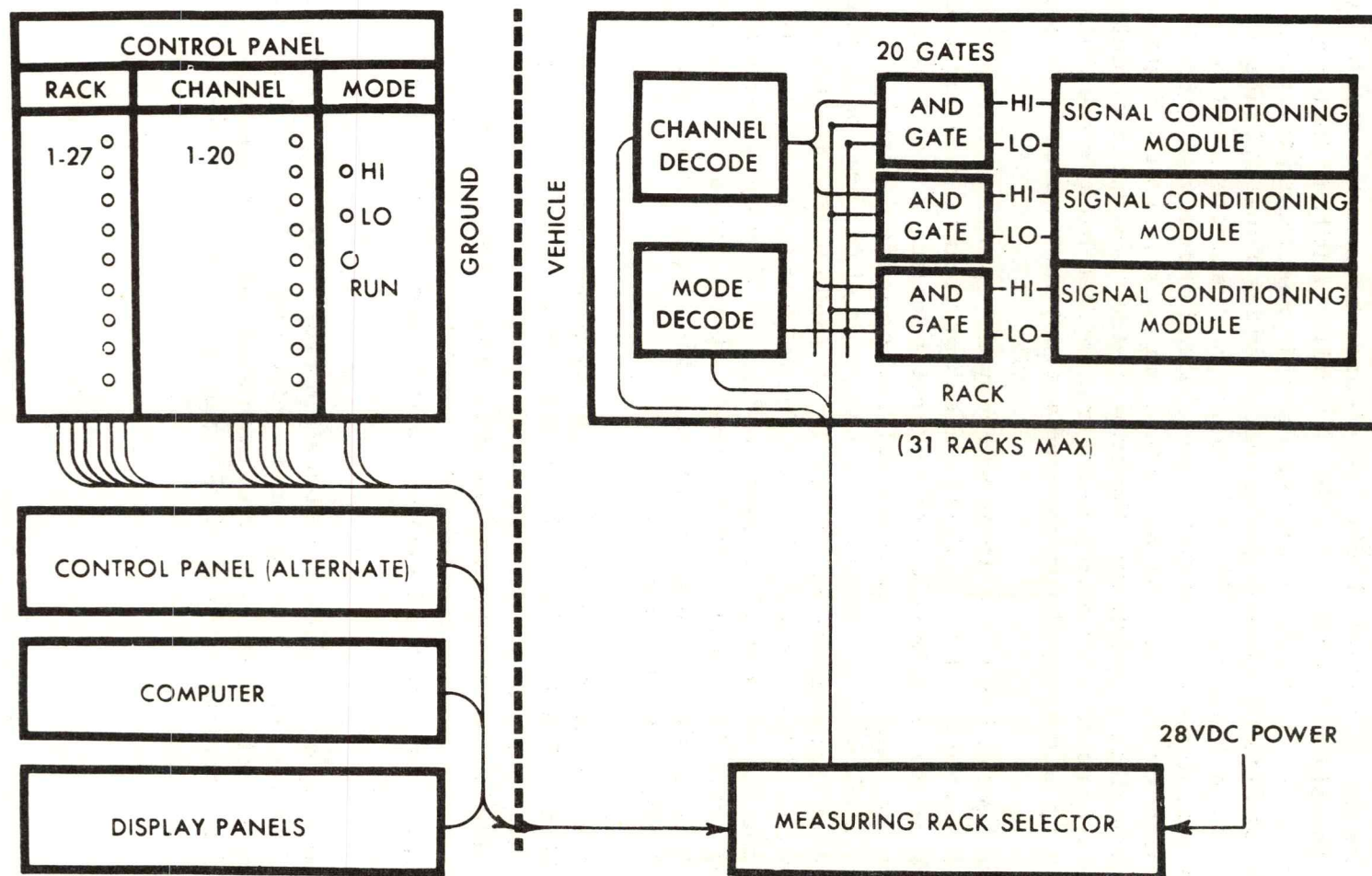


Figure 34. RACS System Block Diagram

OPERATION

Any remote measurement checkout system must have the capability of choosing one signal source, applying a known quantity to that signal source, and comparing the response against preselected tolerances. Figure 34 depicts the control panel that provides a manual means of choosing a signal source. The measuring rack selector routes the control signal to the correct rack, the channel decode and gate circuitry switches the control signal within the racks, and the Signal Conditioning Modules perform a function on the transducer circuitry which should result in an output being transmitted back to the GSE where it may be displayed and checked against known proper values.

The control panel has pushbuttons whereby the operator can select the signal source which he wishes to check or verify the calibration. The operator makes this selection by first selecting a rack, then a channel in that rack and finally the calibration mode desired (HI, LO, RUN). HI mode will result in the verification of calibration at the high end of the transducer range, while LO mode verifies calibration at the low end of the range. The RUN mode button returns the circuitry to the run or normal operate condition. With the selection of the mode, a parallel binary coded signal is transmitted to the vehicle through the umbilical connector, while on the display panel a lamp is energized indicating the selection.

There can be any number of control display panels connected in parallel in the system. Electrical interlocks are arranged so that once a selection sequence is started on one panel, all other panels are locked out. In addition, a warning light notifies other operators that the system is in use. Each control panel controls the calibration at only one stage; multiple parallel systems will be required for the multi-stage vehicles.

The measuring rack selector decodes the rack select signal and directs the signal to the rack which has been addressed. There will be one measuring selector rack located in each step and connected directly through the umbilical to the control panel associated with that stage.

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The signal conditioning modules, where used, bridge the interface between the measuring transducers and the data transmission system. A signal conditioning module is associated with each vehicle transducer which is checked by RACS. These signal conditioning modules are grouped together and mounted in Measuring Racks. A Measuring Rack contains up to 20 modules. These racks are located in various parts of the vehicle to minimize cable lengths and provide accessibility for servicing if required.

A typical signal conditioning module is simply a dc amplifier. Each amplifier module contains an isolated regulated power supply of limited capacity for transducer excitation. This might be used to excite a strain gage pressure transducer, for example. Most important in the modular concept is the plug-in printed circuit board which allows the amplifier to be adapted to several different types of measurements or to change the range of measurement by simply replacing the card. The card also contains circuitry to allow verification of the calibration of the measurements, such as bridge unbalancing resistors, or a voltage divider to substitute for the transducer.

Within each measuring rack, packaged in a configuration identical to the signal conditioning modules, are the electronic circuits necessary to complete the system. These consist of channel decode circuitry and 20 gates, one for each channel as indicated in Figure 34.

When the proper three signals are presented at any one or more "and" gates, the "and" gates will deliver an output to either the HI or the LO relay in the associated Signal Conditioning Module. The energizing of the relay makes the appropriate circuit changes in the signal conditioning module such that the output of the module should correspond to the correct one of the predetermined HI and LO transducer outputs. The absence of either of the HI and LO mode signals removes the gate signal from the relay returning the amplifier or conditioning module to the RUN condition.

It should be noted that the verification of the calibration requires the correct voltage application or other operation by the relay. The voltage sources delivering these voltages are not planned to be automatically or continuously monitored, however, they will be checked prior to a vehicle checkout and the probability is low that the calibrate voltage and the measuring module will be proportionately in error so that an unacceptable value could erroneously indicate satisfactory measuring system calibration.

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SUMMARY

The RACS is a system that is used when the launch vehicle is in the Vehicle Assembly Building (VAB) to check the calibration of the instrumentation sensors on the vehicle. The system may be operated either manually or automatically through the RCA-110A programming. The RACS is used in conjunction with the measurements system when the vehicle is in the VAB and any time prior launch at the pad.

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CHAPTER III

SECTION III

R.F. GROUND CHECKOUT STATION

INTRODUCTION

The R.F. Checkout Station interrogates and monitors the performance of the R.F. systems. With the launch vehicle in the VAB High Bay, connections between the Offset Doppler (ODOP) tracking system and the airborne television, and the R.F. Checkout Station is by antenna coupler and coaxial cable. With the launch vehicle on the launch pad, the checkout of the R.F. systems is open loop through antennas mounted on the roof of the VAB. After the Arming Tower is in place at the launch pad, antenna couplers and passive antenna repeaters are used to insure a reliable R.F. link with the R.F. Checkout Station in the VAB. The results of all tests obtained by the R.F. Checkout Station are correlated with or supplemented by DDAS data.

DESCRIPTION AND LOCATION (Refer to Figures 35 and 36)

The R.F. Ground Checkout Station is located in the VAB at the 318 foot level. It has the capability to interrogate and monitor the performance of the individual R.F. systems. Bench test checkout of the R.F. systems is performed with the systems removed from the vehicle and connected via coax cable directly to the R.F. test set in the Checkout Station. Bench test checkout is performed only when the R.F. test results indicate that checks or adjustments must be made requiring removal of the airborne system from the launch vehicle.

The R.F. Checkout Station can be used to perform checks ranging from simple frequency and power output measurements to the more complex calibration checks of phase shift, etc.

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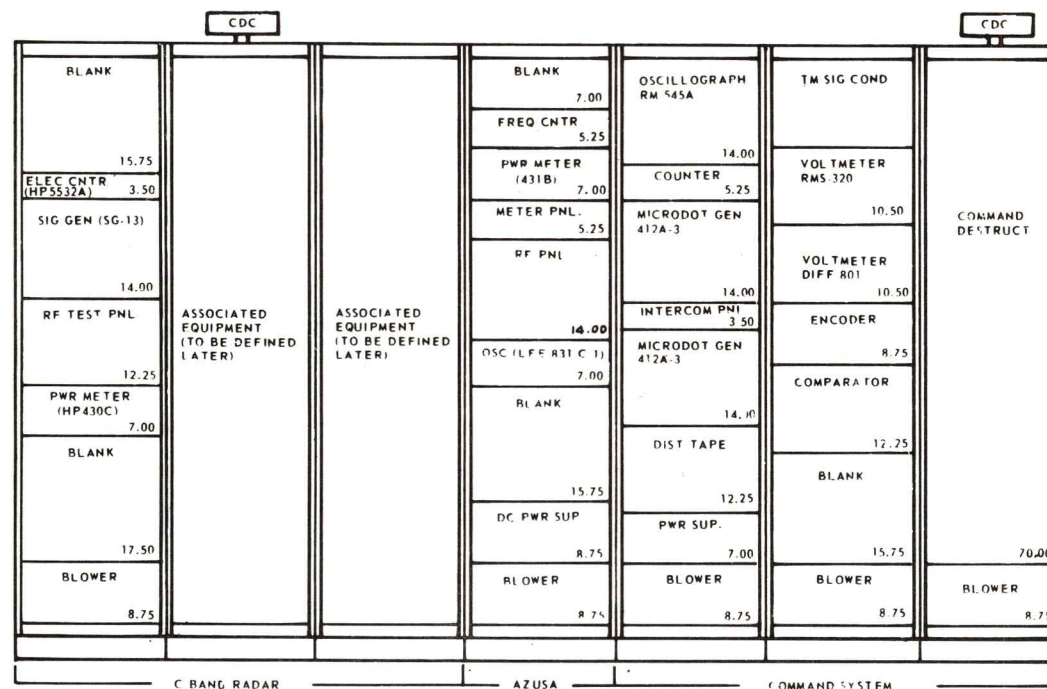


Figure 35. RF Ground Checkout Station

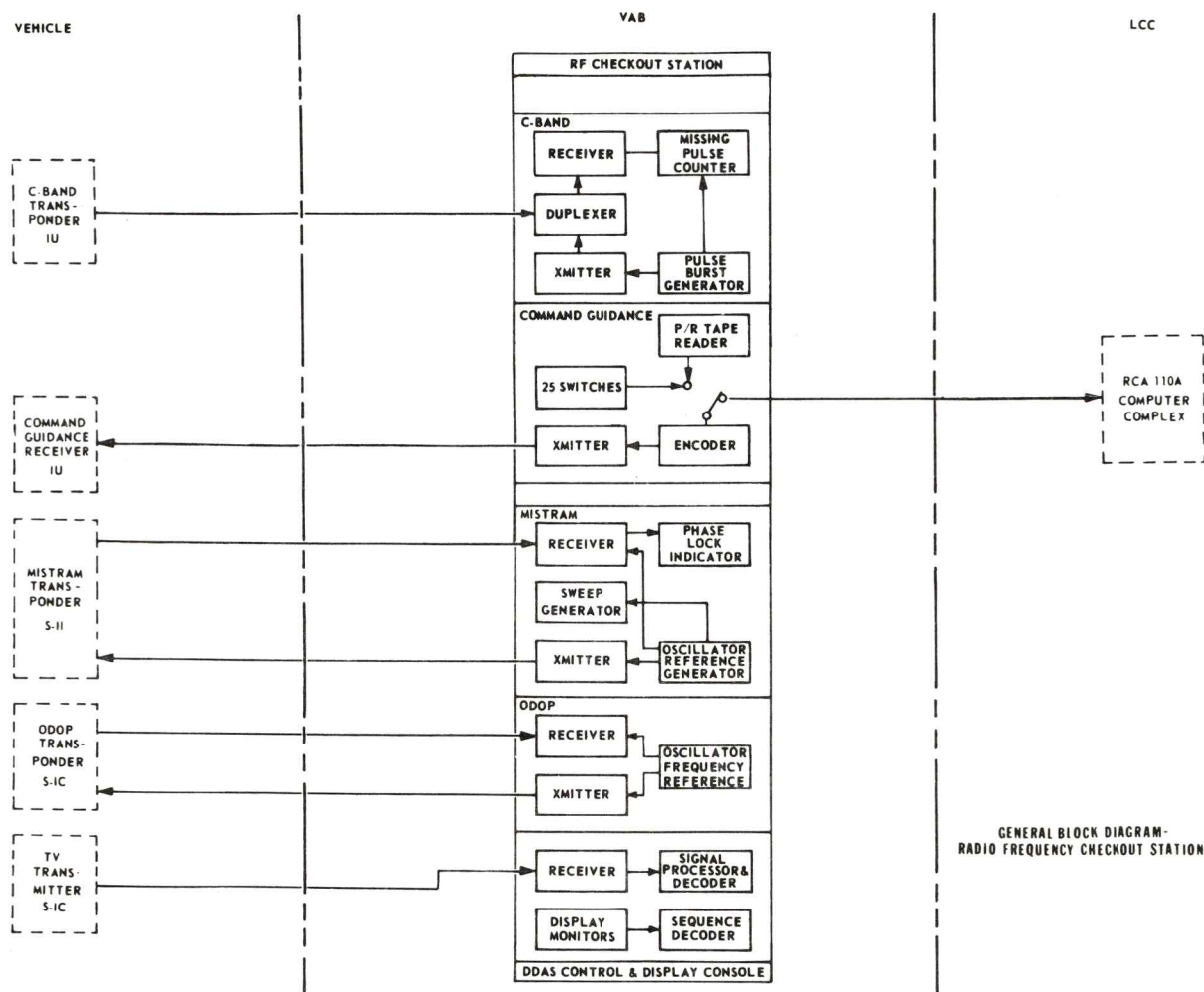


Figure 36. General Block Diagram RF Checkout Station

The R. F. Ground Checkout Station is composed of the following checkout systems:

- a. Azusa Transponder Checkout System
- b. C-Band Radar Beacon Checkout System
- c. Command Guidance (S-Band) Checkout System
- d. Offset Doppler (ODOP) Tracking Checkout System
- e. Television Checkout System
- f. Range Safety Checkout System
- g. DDAS Display and Control Console and certain common test equipment such as a spectrum analyzer, frequency counter, oscilloscope, etc.

The major checkout systems that comprise the R. F. Ground Checkout Station are discussed individually in the following paragraphs.

AZUSA TRANSPONDER CHECKOUT SYSTEM (Refer to Figure 37)

AZUSA is an automatic, high precision electronic trajectory measuring system consisting of a single ground station and an airborne transponder. The system determines space vehicle position by measuring slant range and direction cosine values from the ground station to the transponder. These values are measured by continuous phase comparison between signals transmitted to and received from the space vehicle. The ground station beams a microwave signal to the transponder, where the received signal is offset in frequency and retransmitted to the ground station. Ground station receiving antennas are arranged along two mutually perpendicular baselines. Since the path lengths from the transponder to each receiving antenna differ, replay signals arrive at separate antennas slightly out of phase. These phase differences are a measure of two direction cosines, L_m and M , with respect to the antenna baselines. By modulating the carriers and measuring total phase delay of the modulation frequencies over the propagation path length, the system determines slant range, R . This range and direction cosine data is fed to an IBM 709 computer, which supplies predicted impact information to range safety display plotters.

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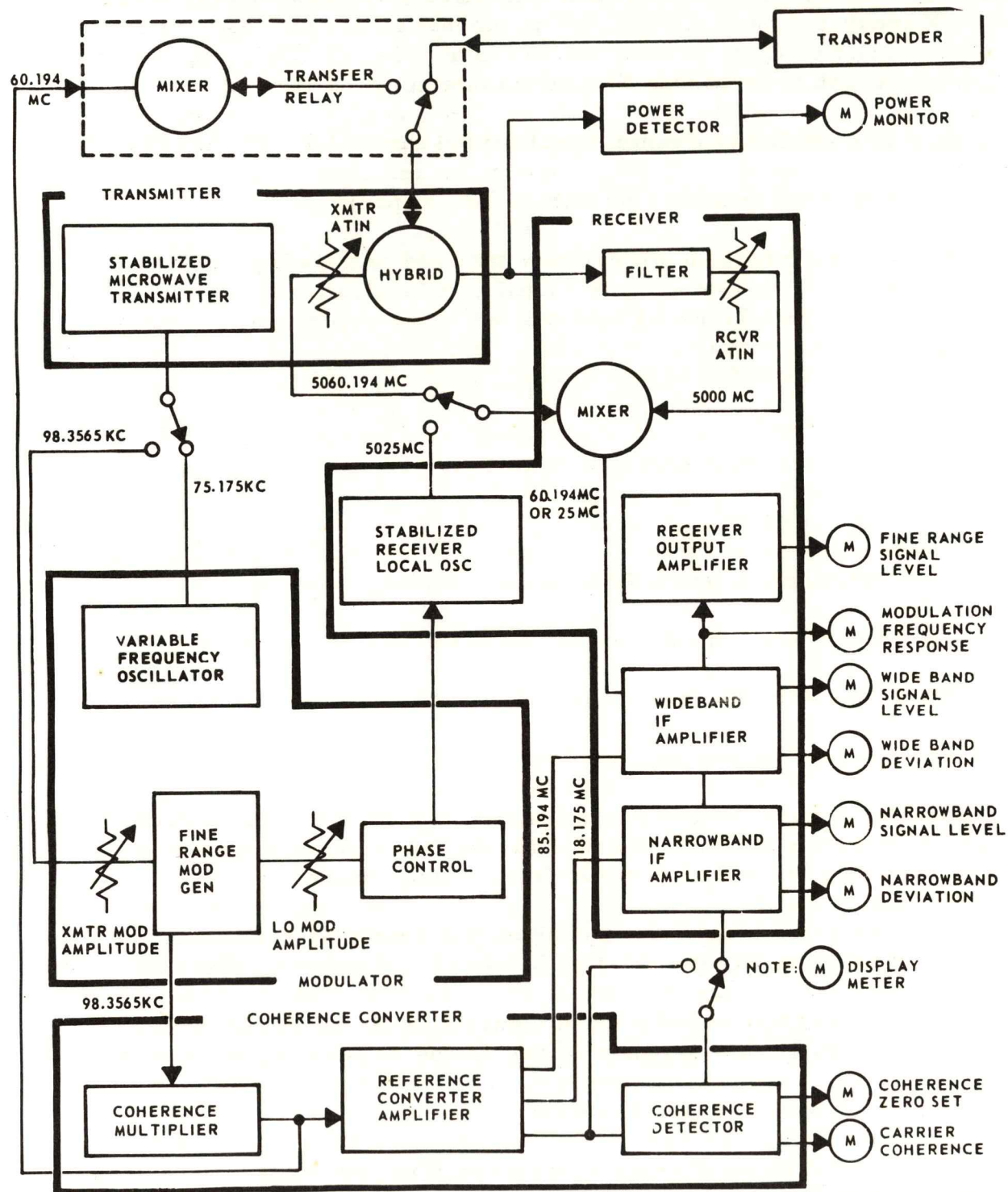


Figure 37. Azusa Transponder Block Diagram
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The AZUSA Transponder Checkout System consists of a Checkout Set, a Relay Assembly, a Transponder Simulator, and associated cabling. The Checkout Set and its related equipment are used to test critical characteristics of the AZUSA transponder either on the bench or after installation in the vehicle. For bench testing, a calibrated coaxial cable is used to couple directly to the checkout unit. When the transponder is installed in a vehicle, calibrated cables (Heliax), waveguide, and antenna couplers or direct connections are employed according to location of the installation (VAB or launch pad).

In analogy, the checkout set can be compared to the r-f portion of a ground tracking station with additional capabilities for measuring transponder parameters. The Checkout Set is capable of measuring the following transponder characteristics:

- a. Locked power output
- b. Lock-on bandwidth and sensitivity
- c. Offset frequency error
- d. Closed loop 98-kc FM noise
- e. Static and dynamic 98-kc phase shift
- f. Modulation frequency response ("M" rise)
- g. Phase coherence

Basically, the checkout set contains a transmitter section, a receiver section, and a modulation and display section (refer to Figure 37). It contains equipment to perform the following functions:

- a. Generate frequency stabilized microwave signal acceptable to the transponder.
- b. Modulate the transmitted signal with the 98-kc fine range modulation frequency as used in the Azusa tracking system.
- c. Receive reply signals from the transponder.
- d. Measure the characteristics of the returned microwave signals and the associated modulation.

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- e. Display the test results for operator analysis by means of meter readings.

TRANSMITTER SECTION

The transmitter section consists of a frequency modulated reflex klystron having an Automatic Frequency Control (AFC) loop for stabilization. The klystron generates a 5060.2-mc carrier that may be modulated at the fine range rate, 98.3565 kc. The AFC loop consists of a transmitter reference generator, a crystal mixer, a wideband AFC i-f amplifier (coarse AFC detector), a narrowband AFC i-f amplifier (fine AFC detector), and a d-c amplifier.

TRANSMITTER REFERENCE GENERATOR

The transmitter reference generator provides a crystal controlled output frequency of 458.245 mc for AFC control of the klystron oscillator. A crystal controlled oscillator in the reference generator operates at a frequency of 57.280616 mc. This frequency is multiplied by a factor of eight (to 458.245 mc) and the eleventh harmonic of 458 mc (5040.594 mc) is mixed with the 5060.194-mc signal in a coaxial-type crystal mixer to produce an intermediate frequency of 19.5 mc. The 19.5 mc signal is fed to the wideband AFC i-f amplifier.

WIDEBAND AFC I-F AMPLIFIER

The wideband AFC i-f amplifier acts as a wideband discriminator to assist in locking the transmitter klystron frequency to the crystal reference frequency. The wideband amplifier is composed of 4 stages of r-f amplification, a limiter, and a discriminator. The discriminator bandpass is from 18.7 mc to 20.3 mc. Discriminator output is a d-c voltage which is fed to the AFC d-c amplifier (sometimes referred to as the microwave modulator). From a point between the last r-f amplification stage and the limiter stage, the amplified i-f signal is also applied to the narrowband AFC i-f amplifier.

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NARROWBAND AFC I-F AMPLIFIER

The narrow band AFC i-f amplifier provides a fine, stabilizing loop to lock the klystron frequency to the crystal reference. In this narrow-band amplifier, the 19.5 mc signal is converted to 4.5 mc and then to 500 kc. The 500-kc signal is limited, then applied to the narrowband AFC i-f amplifier discriminator. This discriminator bandpass is from 488 kc to 512 kc. The narrowband discriminator curve has a steeper slope than the wideband discriminator, and is therefore more sensitive.

The output of the narrowband discriminator is a d-c voltage which is added to the input of the wideband discriminator. Effectively this places the wideband and narrowband discriminators in series, the equivalent of two voltage generators in series, and provides a wider frequency range of capture with narrowband control of the klystron reflector voltage.

AUTOMATIC GAIN CONTROL

AGC is provided for the first three r-f amplifier stages in the wideband AFC i-f amplifier and a single 4.5-mc i-f stage in the narrowband amplifier by controlling limiter grid current. AGC from the narrowband amplifier is also used to activate the lock-on indicator. The outputs of the wideband and narrowband discriminators are also applied, respectively, to the WIDEBAND and NARROWBAND DEVIATION meters located on the front panel of the checkout set.

TRANSMITTER D-C AMPLIFIER

The transmitter d-c amplifier adjusts the klystron center frequency by relaying the discriminator d-c voltage from the wideband and narrowband AFC i-f amplifiers to the klystron repeller. This unit also frequently modulates the klystron with signals from the modulation signal generator.

Approximately -1850 vdc is applied to the voltage regulator section in the d-c amplifier. Controls in the d-c amplifier determine the static potentials applied to the klystron repeller. The coarse tuning control has sufficient range to allow adjustment over several klystron modes and sufficient selectivity to allow setting the klystron on frequency. The TRANSMITTER TUNE control provides an external control for varying the klystron frequency over a small portion of its mode. The TRANSMITTER TUNE control is the load resistor of the cathode follower which drives the d-c amplifier. D-C voltage from

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the Transmitter COARSE and FINE AFC detectors is fed directly to the grid of the d-c amplifier tube. Modulation signals are developed in the modulation signal generator and applied across the cathode of the same d-c amplifier tube. The unit is designed to have approximately 30 db gain from dc to 120 cps and at 98 kc.

AUTOMATIC FREQUENCY CONTROL

The reference generator, wideband and narrowband amplifiers, and the d-c amplifier comprise the transmitter AFC loop. If the klystron is oscillating at 5060.2 mc, the output of the crystal mixer will be 19.5 mc. This 19.5 mc signal is fed to the wideband and narrow band discriminators which will supply a d-c error voltage if the intermediate frequency is not exactly 19.5 mc. The d-c voltage will be positive or negative, depending on whether the intermediate frequency is above or below 19.5 mc. If the intermediate frequency is exactly 19.5 mc, the error voltage will be zero. The error voltage is applied through the d-c amplifier to the klystron repeller, thereby maintaining a 5060.2-mc output frequency.

KLYSTRON

The transmitter reflex klystron has a frequency range of 4900 mc to 5200 mc and an average rated power output of 1 watt. With the proper voltages, the klystron oscillates at a center frequency of 5060.2 mc, modulated or unmodulated.

The 5060.2-mc signal from the klystron is fed through the transmitter attenuator to the hybrid ring. From the hybrid ring the 5060.2-mc signal passes through cabling and a relay assembly into either the transponder simulator or transponder. The transponder, or the simulator, will return a 5000-mc signal through the relay assembly, cabling, and hybrid ring to the receiver section.

RECEIVER SECTION

The receiver section is composed of the local oscillator and its AFC loop, a coaxial mixer, a wideband i-f amplifier and its discriminator, a narrowband i-f amplifier and its discriminator, a 98-kc output amplifier, and the coherence detector.

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LOCAL OSCILLATOR AND AFC LOOP

The local oscillator generates a 5025-mc signal which also may be modulated. The local oscillator (LO) can be modulated only when the TEST SWITCH is set to 98-KC PHASE SHIFT. The LO AFC loop is almost identical with the transmitter AFC loop except for the reference generator output frequency (5005.5 mc) and the crystal controlled oscillator operating at a frequency of 56.880682 mc.

WIDEBAND I-F AMPLIFIER

The 5025-mc signal from the LO is mixed with the returning 5000-mc transponder (or simulator) signal to produce an intermediate frequency of 25 mc. This 25-mc signal is fed to the wideband i-f amplifier. The wideband i-f amplifier discriminator provides signal strength and frequency deviation indications on front panel meters, and provides an input to the narrowband i-f amplifier. The wideband discriminator has a bandpass of from 23.7 mc to 26.3 mc. Discriminator output operates the WIDEBAND DEVIATION meter to give a coarse indication of how far the i-f signal is off frequency. AGC is provided for two of the amplifier stages; the AGC voltage also operates the WIDEBAND SIGNAL LEVEL meter which indicates received signal strength.

NARROWBAND I-F AMPLIFIER

The input to the narrowband i-f amplifier discriminator is obtained from the grid of the limiter preceding the wideband discriminator. In the narrowband chassis, the signal is amplified and double-converted to an intermediate frequency of 500 kc. The signal is then applied to a narrowband discriminator and an AM detector. The narrowband discriminator has a bandpass of from 475 kc to 525 kc, and operates in the same manner as the wideband discriminator. Narrowband discriminator output operates the NARROWBAND DEVIATION meter to give a precise indication of how far the i-f signal is off frequency. The NARROWBAND SIGNAL LEVEL meter operates on the AGC signal.

TEST SWITCH

Some channels in the receiver section are not in operation at certain TEST SWITCH positions. The TEST SWITCH is located in the modulation signal generator in the modulation and display section.

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The switch has six positions:

- a. CARRIER COHERENCE
- b. FINE RANGE NOISE
- c. MODULATION FREQUENCY RESPONSE
- d. FREQUENCY AND POWER
- e. 98-KC PHASE SHIFT
- f. DC LOOP GAIN

98-KC OUTPUT AMPLIFIER

The 98-kc output amplifier receives its input from the wideband discriminator. The amplifier agc operates the 98-kc SIGNAL LEVEL meter to indicate the 98-kc signal strength. This meter is also used to indicate noise levels in the checkout set and the transponder.

MODULATION AND DISPLAY SECTION

The modulation and display section consists of a modulation signal generator, a phase control chassis, and a receiver output amplifier. This section produces the modulation signals and delivers them to various parts of the checkout set through the TEST SWITCH. This switch automatically sets up the circuits required to perform the tests.

The modulation signal generator produces a fixed frequency 98.3565-kc signal and a variable frequency 50-kc to 205-kc signal. The 98-kc signals can be used to modulate both the transmitter and local oscillator klystrons; the variable frequency output modulates only the transmitter klystron. The selection of these signals depends upon the position of the TEST SWITCH.

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PHASE CONTROL

The phase control chassis receives a 98-kc input signal from the modulation signal generator. Its purpose is to shift the phase of the 98-kc signal being fed to the local oscillator during the 98-kc phase shift test. The adjustable phase shifting network consists of a semi-fixed delay line (1.75 microseconds total) and two variable calibrated delay lines in series. One variable delay line provides a 1.0 microsecond (coarse) delay and the other provides a 0.2 microsecond (fine) delay.

RECEIVER OUTPUT AMPLIFIER

This unit amplifies the 98-kc fine range modulation level for display in closed loop 98-kc noise and phase shift tests. Modulation response from the wideband i-f receiver also is detected and displayed on a front-panel meter.

COHERENCE DETECTOR

The 60.194-mc transponder offset frequency, after being heterodyned in the wideband and narrowband i-f amplifiers to 6.625 mc, is phase-compared with the 60.194-mc reference signal from the coherence multipliers which also has been heterodyned to 6.625 mc. The phase jitter between the two signals, which is read on the CARRIER COHERENCE meter, indicates whether the response signal from the transponder under test is phase locked (coherent) with the interrogation signal. Both channels make use of common oscillators in the heterodyning process to eliminate internal phase jitter.

TRANSPONDER SIMULATION

Calibration of the checkout set is accomplished by simulating a perfect transponder at the end of the r-f interrogation path. The simulated signal is used to calibrate interrogation path phase delay, checkout set noise level, internal frequency deviations, and coherence detection circuits. The simulator signal is derived from the coherence multiplier chassis in the checkout set.

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COHERENCE MULTIPLIER

The 98.3565-kc signal from the modulation signal generator is frequency multiplied 612 times. The resultant 60.194-mc output is fed to the relay assembly, where it is mixed with the 5060.194-mc output of the transmitter to simulate a transponder response signal. This 60.194-mc reference signal is also fed to the reference converter amplifier as part of the phase control loop. After heterodyning with a common oscillator, the transponder offset frequency is phase-compared with this reference frequency in the coherence detector to check phase coherence.

RELAY ASSEMBLY

The relay assembly switches the r-f signal generated in the checkout set either to the transponder or to a crystal mixer mounted in the relay assembly. The checkout set signal is heterodyned in the mixer with the signal from the transponder simulator signal generator, and the difference frequency (transponder simulation) is fed back into the checkout set.

DISPLAY AND CONTROLS

Meters and indicator lamps are used to read out data and to monitor operation of the checkout set. Attenuators and switches are used to set up test conditions and to apply power to the proper circuits.

SUMMARY OF THE CHECKOUT SET FUNCTIONS

The transmitter generates a stable carrier frequency and the modulation generator impresses on this carrier a fine range signal identical with that produced by the AZUSA ground transmitter. Transmitter output can be attenuated to simulate signal levels at typical operating ranges. The composite frequency-modulated signal is applied to an AZUSA transponder, which retransmits the composite signal at a center frequency 60.194178 mc below the received carrier. The retransmitted composite signal is fed back into the checkout set receiver, where it is amplified and detected. The receiver local oscillator can be modulated at the fine range frequency and the modulation phase can be adjusted to null with the modulation returned from the transponder. This procedure measures the phase shift within the transponder, which must be constant and as small as possible. The checkout set measures the phase shift at the fine range modulation frequency to an accuracy of 0.1°.

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The checkout set monitors carrier coherence by comparing the frequency and phase of the returned carrier with a multiple of the fine range modulation frequency. This assures that the transponder maintains the correct offset frequency without introducing distortion or phase jitter. Power monitors and attenuators are used to measure power output and receiver sensitivity of the transponder. Operation of the transponder AFC loops is checked by measuring loop lock-on bandwidth and sensitivity. AFC action is checked by varying the checkout set transmitter frequency and observing that the transponder follows the variation. Doppler effect is simulated by introducing a fixed increment of artificial phase shift.

Checkout set operation is monitored by crystal oven indicators, klystron power indicators, and power supply meters. These devices indicate proper operation of the checkout set.

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C-BAND RADAR TRACKING SYSTEM

The AN/FPS-16 Radar Set is a high accuracy, amplitude comparison monopulse radar capable of manual or automatic acquisition and tracking of objects in flight. The radar provides highly accurate trajectory data for evaluating performance and for maintaining range safety. The radar system installed as one of a chain of radars along the flight path to insure sufficient tracking throughout the entire missile flight.

The AN/FPS-16 Radar operates in two different modes: the skin mode, in which a pulse of electromagnetic energy from the ground radar antenna is reflected back from the target, and received by the ground antenna; and the beacon mode, in which the same pulse triggers a beacon or transponder carried by the target, which in turn sends back a pulse of energy that is received by the ground radar antenna. The advantage of the latter method is that the energy sent back by the transponder is stronger than the reflected energy, and targets can be tracked at tremendous slant ranges depending on the power output of the transponder.

C-BAND RADAR TRANSPONDER

The SST-102A C-Band Radar Transponder is used as part of the complete tracking systems for the Saturn vehicles. Its function is to extend the tracking range of the C-Band tracking and instrumentation radar. To accomplish this function, the transponder receives either coded or single pulse interrogations and transmits a single pulse reply in the same frequency band.

The following paragraphs are a functional description of the C-Band radar system.

DUPLEXER

An interrogating RF signal is fed to the transponder through a TNC connector J₂ to a ferrite circulator. The circulator, a four-branch, three-port ferro-magnetic duplexer is used to isolate the received signal from the transmitted signal, to permit the use of a common antenna for the transponder. In addition, and of more importance, it isolates the magnetron from energy reflected by antenna mismatch. This results in a matched load being presented to the magnetron, independent of antenna voltage standing wave ratio (VSWR) variations. The circulator consists of a short piece of circular wave-guide which contains a ferrite rod mounted along its longitudinal axis and a resistor card mounted at one end. On the outside of the duplexer are mounted permanent magnets magnetized along the longitudinal axis of the waveguide. The circulator also couples the signal to the preselector with very little insertion loss.

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PRESELECTOR, MIXER, AND LOCAL OSCILLATOR

The function of the preselector is to de-sensitize the receiver to all signals but those having the desired frequency of the interrogating signal. In addition, it prevents damage of the mixer crystal by antenna reflected transmitter energy.

The output of the preselector is fed to the mixer which serves to mix the local oscillator and interrogating signal frequencies, the different frequency of 60 mc is further amplified by the IF amplifier.

The local oscillator employed in the transponder is a reentrant cavity type oscillator employing a ceramic planar triode. A single adjustment is used for tuning the local oscillator over its tuning range of 5400 to 5900 mc in order to supply a signal of the proper frequency to the mixer and obtain the desired 60-mc IF output.

IF AMPLIFIER

The IF amplifier employed in the SST-102A Transponder is an all-transistorized unit containing six mesa germanium transistors as the basic IF amplifier followed by a transistor detector and pulse amplifier. Emitter detection is employed in each IF amplifier stage to produce a secondary output for each stage when it becomes saturated at high signal levels. These emitter outputs are coupled together through a tapped delay line and amplified in a separate transistor summing amplifier, which adds this amplified output to that of the original IF output signal.

The video amplifier inverts and amplifies the signal from the IF amplifier with a voltage gain of approximately two. The output of the amplifier is coupled into the pulse subtractor, the delay stabilizer. Since the output of the IF amplifier is approximately logarithmic, its output voltage will be proportional to the decibel RF input. A point at a constant voltage down from the top of the output voltage pulse will then correspond to a point that is a fixed number of db down from the peak of the RF input signal. For IF output video pulses that exceed 0.5 volt, the pulse subtractor allows only their tops, a fixed number of volts from the peak, to be coupled into the following stage. The pulse subtractor is inoperative for pulses less than 0.5 volt. For these signal levels, both IF and decoder operate in a linear manner.

The output of the pulse subtractor is coupled into a pulse amplifier where it is amplified and inverted. The output of the pulse amplifier is coupled into the blocking oscillator circuit. If the signal exceeds the triggering threshold the blocking oscillator is triggered and will develop a standard amplitude pulse to operate the decoder circuitry.

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The decoder's function is to operate on the output pulse of the pulse form restorer, and determine whether or not the signal occurs with a specified (selected) pulse. The decoder will produce one of two possible output pulses for one of the four possible codes depending on the position of the code selector switch.

The decoder employs a passive delay line and coincidence "AND" gates to perform the decoding action between the first two pulses. Operation of the two pulse decoder is conventional, a passive delay line having been chosen rather than an active circuit, in order to obtain good stability and freedom from susceptibility to interference by noise triggering.

The third pulse decoding is accomplished by coincidence between the delayed two pulse decoder output and a gate pulse. The action is similar to that of the two pulse decoder, with the exception that an active delay circuit is used in lieu of a delay line, since the tolerance for the third pulse position is quite broad, and a considerable degree of protection from noise firing has already been achieved by the two pulse decoder.

The transponder delay generator produced a pulse delayed in time, relative to the decoder output. The magnitude of the delay is adjusted to produce an overall system delay of 2.0 ± 0.9 or 4.3 ± 0.2 microseconds, depending on the position of the delay switch.

The modulator control circuit furnishes the trigger and "turn-off pulse" for the modulator as well as limiting the pulse repetition frequency to a duty factor of $2.2 (\pm 2) \times 10^{-3}$. Unless the inhibit multivibrator has been triggered, pulses out of the delay generator are coupled through an inhibit gate to trigger a blocking oscillator. The blocking oscillator output is coupled to an emitter-follower, which is coupled to the modulator driver, which in turn provides the power gain required to trigger the modulator reliably.

When the modulator is triggered, a positive pulse referred to as the "modulator control trigger," is coupled from the modulation transformer to a d. c. amplifier circuit and into the inhibit multivibrator circuit. This triggers the inhibit MVB, which generates a 47.5 ± 2.5 microsecond negative pulse. This pulse is applied to the inhibit gate, preventing any further triggering of the modulation for its duration. The same pulse is coupled into the modulator to aid modulator turn-off. The modulator control trigger, coupled into the d. c. amplifier circuit, is stretched and filtered to provide a d. c. voltage proportional to the transmitter duty factor. If this voltage becomes great enough, the pulses from the pulse form restorer output are allowed to trigger the inhibit multivibrator. These pulses, and thus the inhibit pulse, occur before the output of the delay generator.

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Therefore, the modulator cannot be triggered again until the voltage has decreased below the threshold value. The output pulse from the modulator is used to trigger the magnetron of the transmitter.

TRANSMITTER

The magnetron employed in the SST-102A transmitter section is a pulse cross field microwave vacuum tube device with a permanent magnet. It is continuously tunable from 5400 mc to 5900 mc and has a TNC output connector. The magnetron has a minimum peak power output of 900 watts on any duty cycle up to 0.0024 which is fed through the duplexer to the antenna.

POWER SUPPLY

The power supply used in the SST-102A Transponder operates from a 28-volt d. c. power source supplied from batteries on board the vehicle.

The function of the power supply is to convert the unregulated primary power source d. c. voltage to the regulated voltages of various magnitudes required to operate the transponder circuitry. It also provides d. c. isolation between the power source ground and the transponder ground. The power supply consists of two basic circuits; a series regulator which supplies a constant output voltage and a d. c. to d. c. converter having various d. c. output voltages.

The series input regulator is designed to hold its output voltage constant at 21 volts d. c. for input voltage changes from 24 to 30 volts d. c. and for all load variations corresponding to transmitter duty cycles from 0 to 0.002. Isolation is provided between input and output voltages, allowing remote grounding of the negative output of the power source. An LC filter is provided in each input line to block line transients generated by the transponder.

The d. c. to d. c. converter circuit is a conventional RL coupled multivibrator in which switching transients are minimized by the use of a separate feedback transformer with the output power transformer operating in a nonsaturating condition.

C-BAND ANTENNA

The C-Band Radar Transponder utilizes one antenna for both receiving and transmitting, which is located on the outside skin of the instrument unit.

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C-BAND GROUND CHECKOUT SYSTEM (Refer to Figure 38)

The basic purpose of the checkout equipment is to generate a prescribed interrogation signal, vary this interrogation within limits and analyze the transponder reply pulses. The generation of the prescribed interrogation coding format will be accomplished with the Pulse Burst Generator. This generates a one, two, or three pulse burst having the required pulse spacing. This pulse burst is then utilized to modulate the RF Signal Generator. An additional output is sent to the Missing-Pulse Detector. The output of the signal generator is properly coded pulsed RF signal. This signal burst is used directly for VAB checkout. For pad checkout, signal amplification is necessary, and the 10-watt TWT Amplifier is utilized. The inclusion of the TWT amplifier is accomplished with RF Patch No. 1.

A portion of the pulsed signal is coupled to the power meter selector by means of a 20 db directional coupler.

Attenuator No. 1 is utilized to vary the peak RF power out for sensitivity measurements. The pulsed energy is then sent to the circulator. The function of the circulator is to allow the use of common transmission lines for both transmitting and receiving.

The pulsed RF energy is switched to the desired checkout area by means of switch No. 1. The transponder's relay utilizes the same transmission path back to the circulator. The action of the circulator causes the returned signal pulse to be directed down the receiver arm. Directional coupler No. 2 couples a portion of this energy to the power meter selector switch for measuring return peak power. Attenuator No. 2 is utilized in the signal path prior to limit input signal levels.

The RF Receiver then amplifies and demodulates the return pulse. The video output is sent to a Missing-Pulse Detector and to an oscilloscope for pulse parameter measurements. The oscilloscope is also utilized to measure the interrogation burst pulse parameters.

The purpose of the Missing-Pulse Detector is to detect the absence of a reply pulse. It is reset for every interrogation sequence; if a reply is not received, the Missing-Pulse Detector generates an output which is sent to the Frequency Counter.

The Frequency Counter counts the pulses missed in any desired time base. This missing pulse count is utilized as the criterion for sensitivity and bandwidth measurements.

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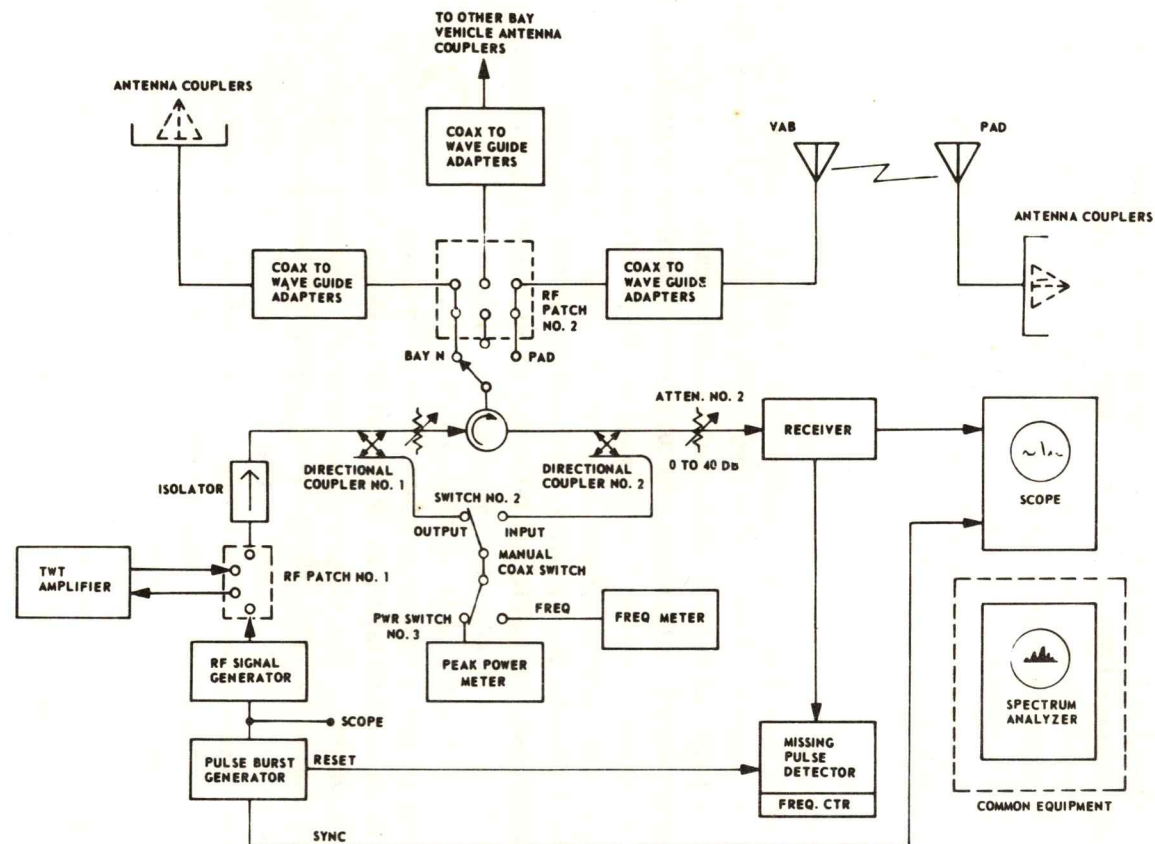


Figure 38. Block Diagram C-Band Radar Beacon C/O System

The spectrum Analyzer is used for pulse spectrum analysis of both interrogation and reply pulses. It is necessary to determine spectral purity which would not be otherwise discernible on detected video pulses.

The checkout equipment can be utilized in a self-check mode by loosely coupling the interrogation signal to the receiver and eliminating any return pulses. The video output of the receiver can then be viewed on the oscilloscope, and the frequency counter will read the basic PRF.

COMMAND COMMUNICATIONS (GUIDANCE) SYSTEM

The command communications system is used to transmit digital information from ground stations to the Launch Vehicle Digital Computer in the Instrument Unit.

The command message is transmitted in the S-band using a carrier frequency of 2101.8 MHz. The command message is modulated on a 70 kHz subcarrier, which in turn is modulated on the 2101.8 MHz carrier. The signal from the ground station is received through the S-band transponder of the Saturn communication and command system in the IU. The receiver separates the transmitted message from the carrier and feeds the resulting signal to the IU Command Decoder where decoding is accomplished. From the decoder, the command message is sent through the LVDA to the LVDC. Verification of the message received is achieved by transmitting a signal over the IU-PCM telemetry system back to the ground station.

The Saturn IU command system is closely related to the Apollo Spacecraft up-data link. Both systems use essentially the same ground station equipment of the manned space-flight network. The Saturn IU command system is designed to assure a high probability that the LVDC receives the correct message.

The commands and data to be transmitted to the vehicle will originate in the Mission Control Center in Houston, Texas, and are sent to the remote stations of the Manned Space Flight Network where they are transmitted to the vehicle.

The Command Guidance Checkout system located in the R.F. Ground Checkout Station transmits data to the I. U. receivers to check out the airborne portion of the system.

The checkout system can supply data direct from the RCA-110A Computer in the LCC, from a prepunched tape in the checkout station, or from manual inputs via switches at the checkout station.

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ODOP CHECKOUT SYSTEM

AIRBORNE EQUIPMENT

The ODOP Tracking System (Offset Doppler Velocity and Position) now being developed is designed to replace the Ultra High Frequency Doppler Velocity and Position (UDOP) Tracking System. It is expected to reduce the loop range error from 60 meters to approximately 16 meters.

The ODOP system is an elliptical tracking system that measures the range sum between ground stations and the vehicle. This range sum is determined by utilizing the total doppler shift in the frequency of a continuous wave radio carrier. The continuous wave carrier is transmitted from a ground transmitter and received at the vehicle by the transponder. The transponder offsets the carrier by 70 mc. The new carrier frequency is then transmitted to various ground receiving stations. The ODOP is a phase-coherent system; consequently, the doppler shift depends primarily on the wavelength of the transmitted signal and the radial velocity of the vehicle.

GROUND EQUIPMENT AND TRANSPONDER OPERATION (Refer to Figure 39)

Baselines from the ground transmitter station to the receiving stations and between the receiving stations are approximately 20 miles long. The ground transmitter contains a highly stable and accurate crystal-controlled oscillator the output of which is amplified and multiplied to 890 mc, and 960 mc. The 960-mc output frequency is used as a reference frequency for the signal received from the vehicle.

The ODOP transponder is a modified version of that used by Jet Propulsion Laboratories in the Ranger vehicles. The operating frequency has been shifted slightly and the receiver bandwidth increased to provide better acquisition and tracking characteristics.

The RF power amplifier is a 4-watt cavity amplifier. It has its own dc-to-dc converter which operates from a 28-vdc source.

ODOP CHECKOUT SYSTEM (Refer to Figure 40)

The ODOP System checkout equipment is located in Room 26E7 of the VAB at the 318-foot level. The ODOP transponder is a frequency offsetting device receiving 890 megacycles and delivering 960 megacycles at a power level of one watt.

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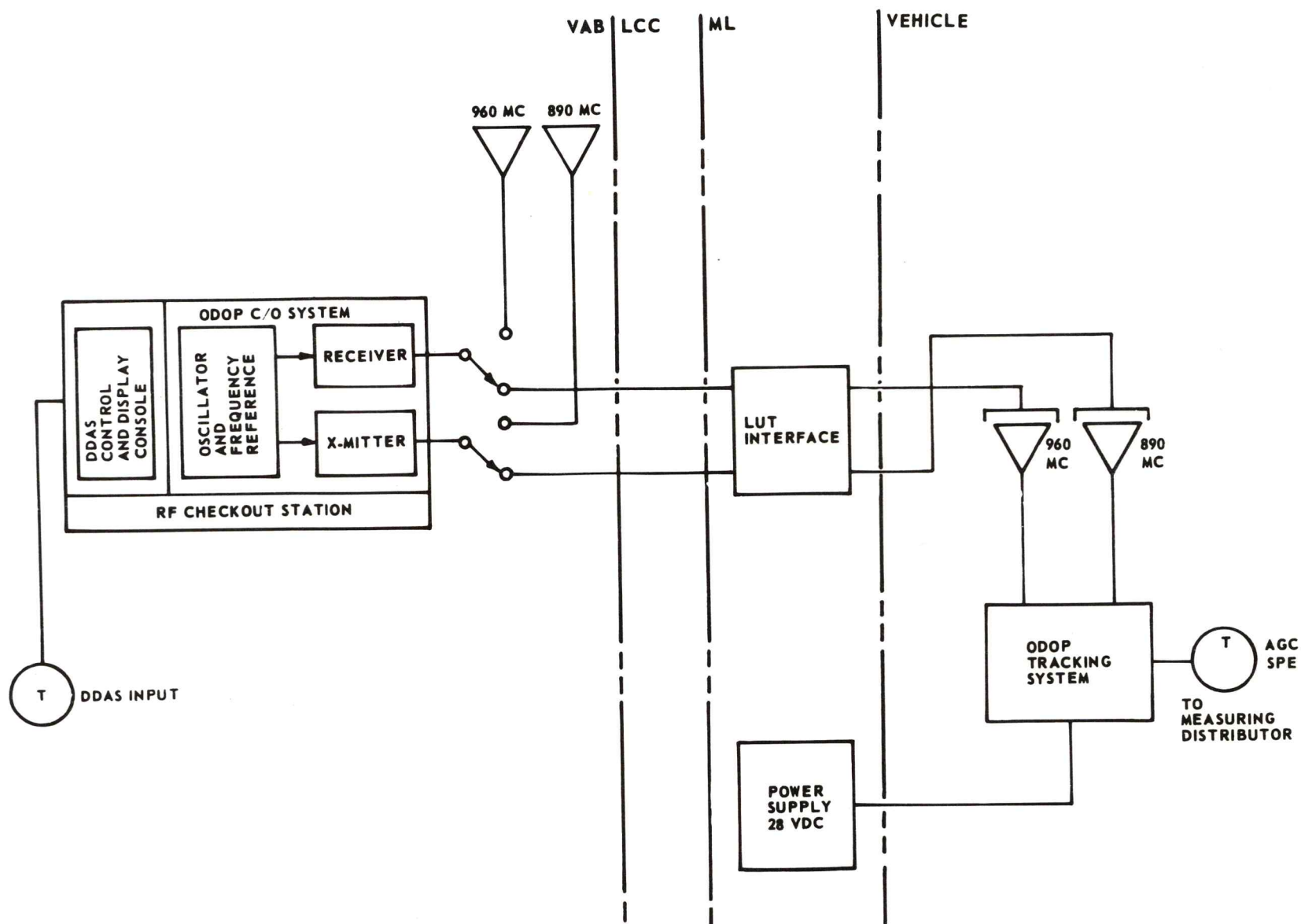


Figure 39. General Block Diagram - ODOP

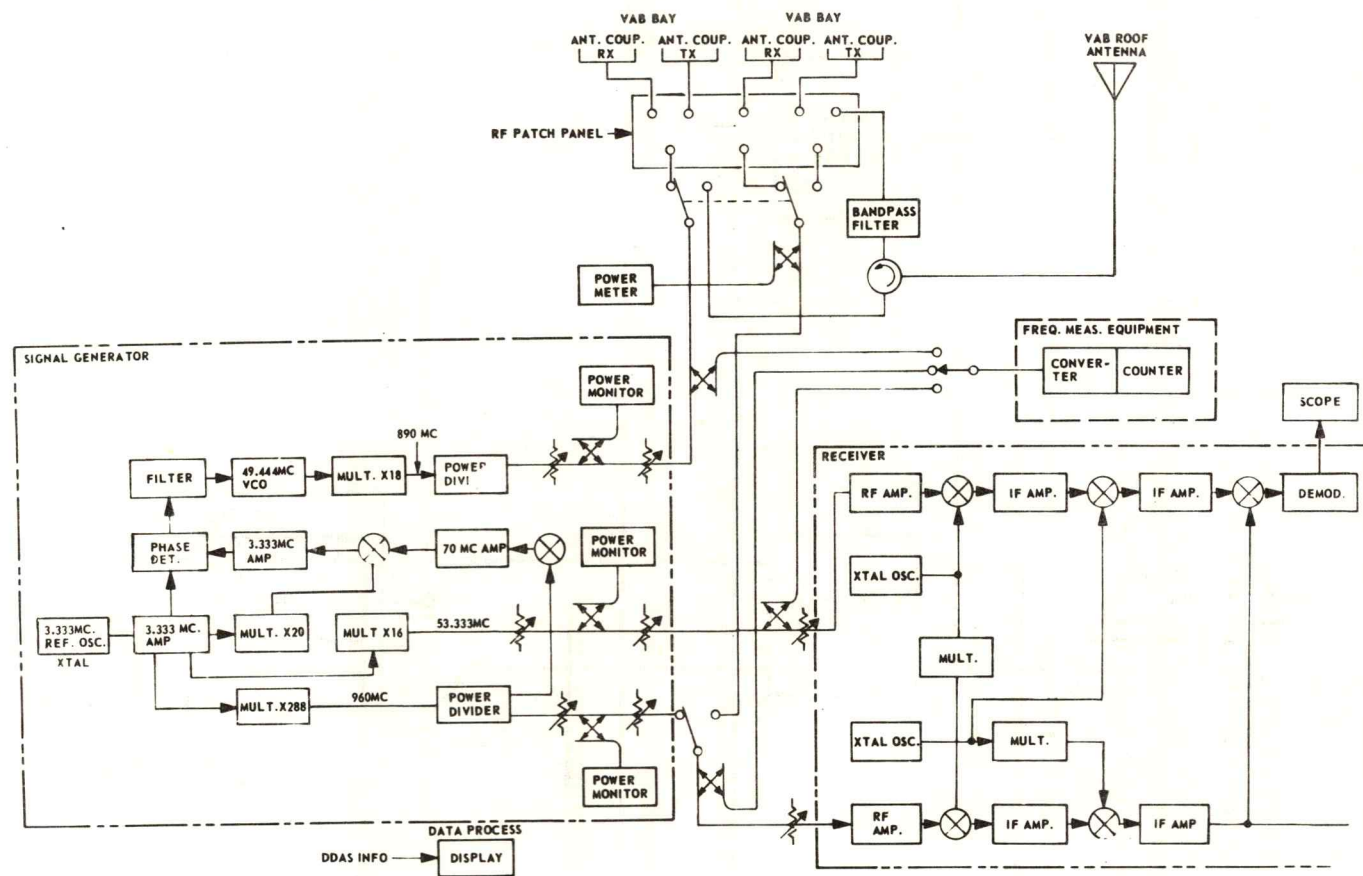


Figure 40. Block Diagram ODOP Checkout Station

The equipment services two high bays and any of the three pads by means of the roof antenna. Connection to the vehicle while in the VAB is by means of hat couplers.

The checkout equipment contains a signal generator and receiver which duplicate the basic functions of the ODOP ground station equipment.

The signal generator provides three basic output signals for interrogation of the transponder and operation of the receiver.

The three signals are the transponder interrogation frequency (890 megacycles), the receiver reference frequency (53.333 megacycles), and the simulated transponder reply frequency (960 megacycles). CW interrogation and reference frequencies are for checking transponder coherence at both nominal frequency and shifted frequency to simulate the doppler effect; simulated transponder reply is for self-checking of checkout equipment.

The receiver provides necessary functions for processing the transponder reply signal and the simulated transponder reply. Phase shift and phase jitter are evaluated and the presence and amount doppler shift determined.

Equipment required in addition to the receiver and signal generator includes.

- a. RF Switching Panel
- b. Power Meter
- c. Frequency Converter (Common Equipment)
- d. Counter (Common Equipment)
- e. Oscilloscope
- f. Tunable Bandpass Filter
- g. Control Circuitry

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TELEVISION SYSTEM

AIRBORNE TELEVISION SYSTEM

The Airborne Television System provides real time, visual vehicle performance information as well as permanent storage of pictures televised from the vehicle during flight. The combined images from all the cameras are recorded on video tape at the TV checkout system within the RF Checkout Station. A separate monitor provides a real-time image from each of the cameras. A kinescope record is made of the received video images as a permanent record backup to the video tape recordings.

The transmitter or exciter and RF power amplifier are installed in an environmentally-controlled equipment container located between positions I and IV of Unit 120. The remaining hardware, consisting of two TV cameras, associated optics, camera control units, and the video register are located in Unit 115.

Each camera has its own control unit to provide scanning signals and to amplify video signals. The video register contains a synchronizing generator which provides a timing pulse to keep the cameras synchronized to prevent loss of image continuity in switching. A sequencer switch, also located within the video register, controls the input of video information to the transmitter.

The two TV cameras are turned on by a GSE-supplied TV System on command thru the main power distributor at the start of LOX loading. Upon power transfer, the TV system receives its power from +1D20 (bus energized upon power transfer). At 3 seconds before engine ignition, a TV Lens Wiper Motor ON command is supplied by the GSE. Power is then supplied from +1D11 thru the closed contacts of 2K28 to the Lens Wiper Motors. During flight, 24 seconds after the retrorockets are fired, the TV RF amplifier is turned off.

TELEVISION CHECKOUT SYSTEM (Refer to Figure 41)

The TV System checkout equipment is shown in Figure 41. The checkout equipment is suitable for servicing two high bay areas and the three pad areas, by means of the VAB roof antenna. Connection to the vehicle while in the VAB is by means of antenna couplers.

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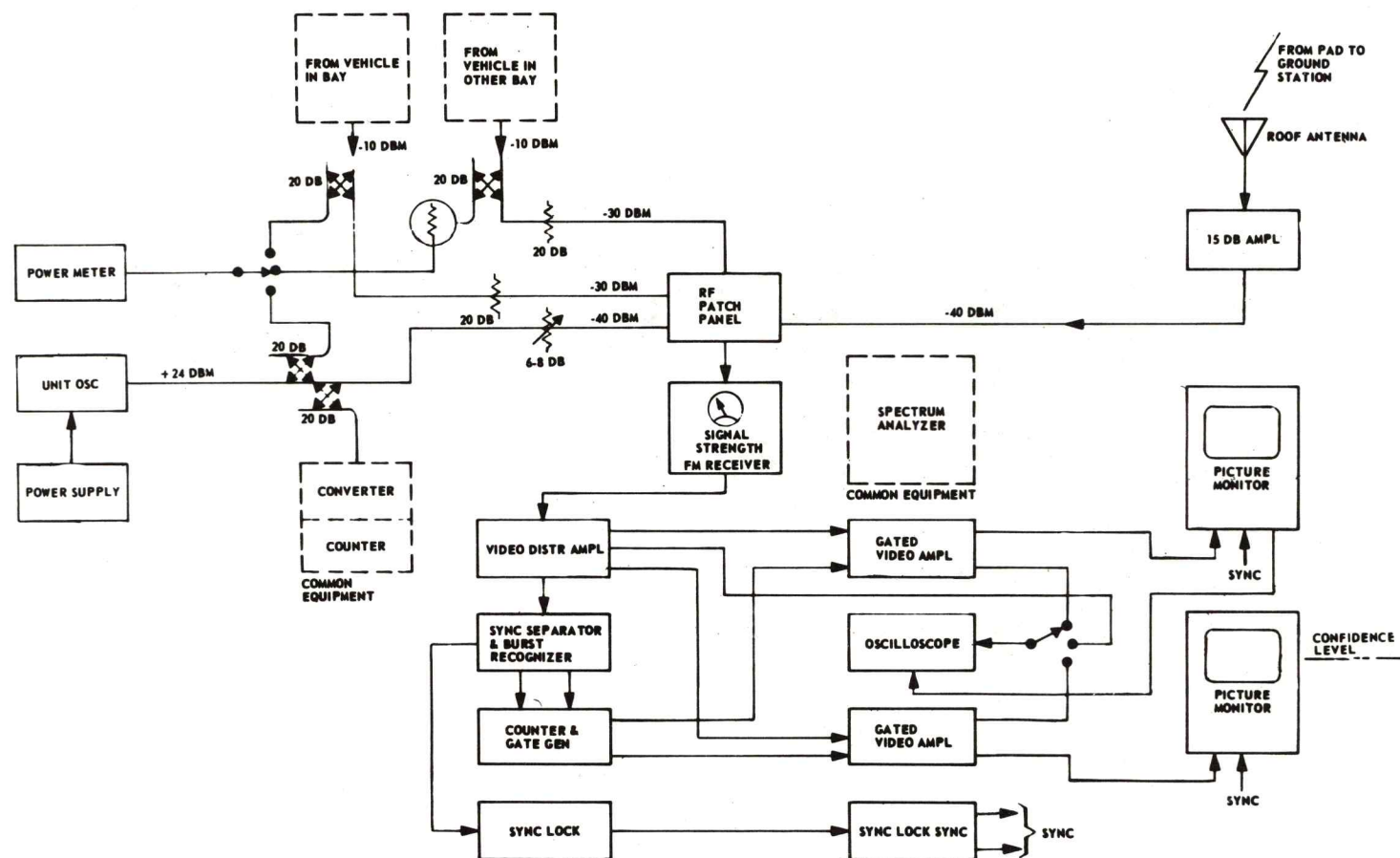


Figure 41. Block Diagram TV Checkout Station

A manual mode of operation is used in checking out the TV system. The signal is tuned in on the FM Receiver using the Picture Monitor and Oscilloscope as tuning indicators. Centering of the FM frequency range on the discriminator characteristics is judged by observing compression at either the black or the white peak of the signal when the tuning is either too low or too high in frequency.

After optimum tuning is established, the carrier average power is measured by means of the RF Power Meter, when the vehicle is in the VAB, or by means of the previously calibrated signal strength meter on the FM Receiver when the vehicle is on the pad. Previously determined calibrations of the RF path losses are used in making the RF power measurements.

The RF carrier frequency at sync peak is measured by obtaining a visible zero beat at the top of the sync pulse using the calibration unit oscillator. The oscillator frequency is determined by counting or by use of the oscillator dial which has been previously calibrated using the counter.

Observations and measurements of waveform parameters are made on the oscilloscope, and picture parameters are judged by means of the picture monitors. Correct operation of the decommutating circuitry is determined by observing the proper separation of the camera signals in the two gated Video Amplifier outputs.

The spectrum analyzer is used as desired for additional checks on the frequency content of the RF signal.

All of the equipment in the TV checkout system can be checked by using other items of the equipment. The RF receiver, power meters and the frequency measuring equipment can be checked by means of the Unit Oscillator. Playback of a previously recorded tape by means of the Video Tape Recorder checks out the operation of all other items in the system.

RANGE SAFETY SYSTEM

The new system provides a high degree of protection against intentional interrogation by unfriendly intruders and against unintentional interrogation (false alarms) by noise. The security against intentional interrogation is measured by the fraction of the total code combinations that an intelligent unfriendly interrogator, having unlimited technical resources, would be able to transmit during equipment access time. It is assumed that all system parameters are known to him except the code-of-the-mission. The security against unintentional or randomly generated false alarms is, as it should be, much greater than against intentional, intelligent

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interrogation. Operational difficulties of handling the security aspects of the system are minimized by using a removable, inexpensive, easily stored code plug to change the code-of-the-mission. All hardware is unclassified except the actual flight code plugs.

In contrast to a binary system, which utilizes a language consisting of only two distinct characters, the secure range safety command system uses a language consisting of 21 characters. Each character of the 21-character alphabet is formed from a sub-alphabet of seven symbols taken two at a time. Each symbol is a burst of an audio-frequency tone. A pair of tones transmitted simultaneously comprise a character. This high-alphabet technique provides the necessary high security without sacrificing essential performance characteristics of the present system. Further, the new high-alphabet system is, by design, tolerant of relatively wide radar or pulse interference.

The security is realized mainly by the message format, which consists of a nine character address word followed by a two character function (command) word. The limited time of access to the equipment is the final factor in the security.

Each character of the nine-character address word is unique within a given address, and therefore the system can operate without the necessity of a transmitted clock or reference synchronizing information. The symbols are, however, synchronous with the character interval period (and with each other) and are spaced and phased to minimize intersymbol interference, which could create unwanted characters.

The main RF carrier is frequency modulated by a subcarrier system which in turn employs a multiple frequency-shift (MFS) technique. The term frequency-shift keying (FSK) is also used to describe the technique. The portion of the baseband occupied by the subcarrier system is approximately the same as that now reserved and used for range safety purposes. The nominal tone frequencies, however, are not the same as the Inter-Range Instrumentation Group (IRIG) tone channel frequencies. The tone-frequency spacing is, by design, an integral multiple of the character repetition rate. This makes possible a simple phase-coherent tone keying scheme.

The two main vehicular components of the secure range safety command system (receiver and decoder) are presently being manufactured.

The range safety command system comprises all of the elements shown in Figure For purposes of this explanation however, the definition is narrowed to include primarily the uplink portion, which begins with the ground encoder and ends with the decoder in the vehicle.

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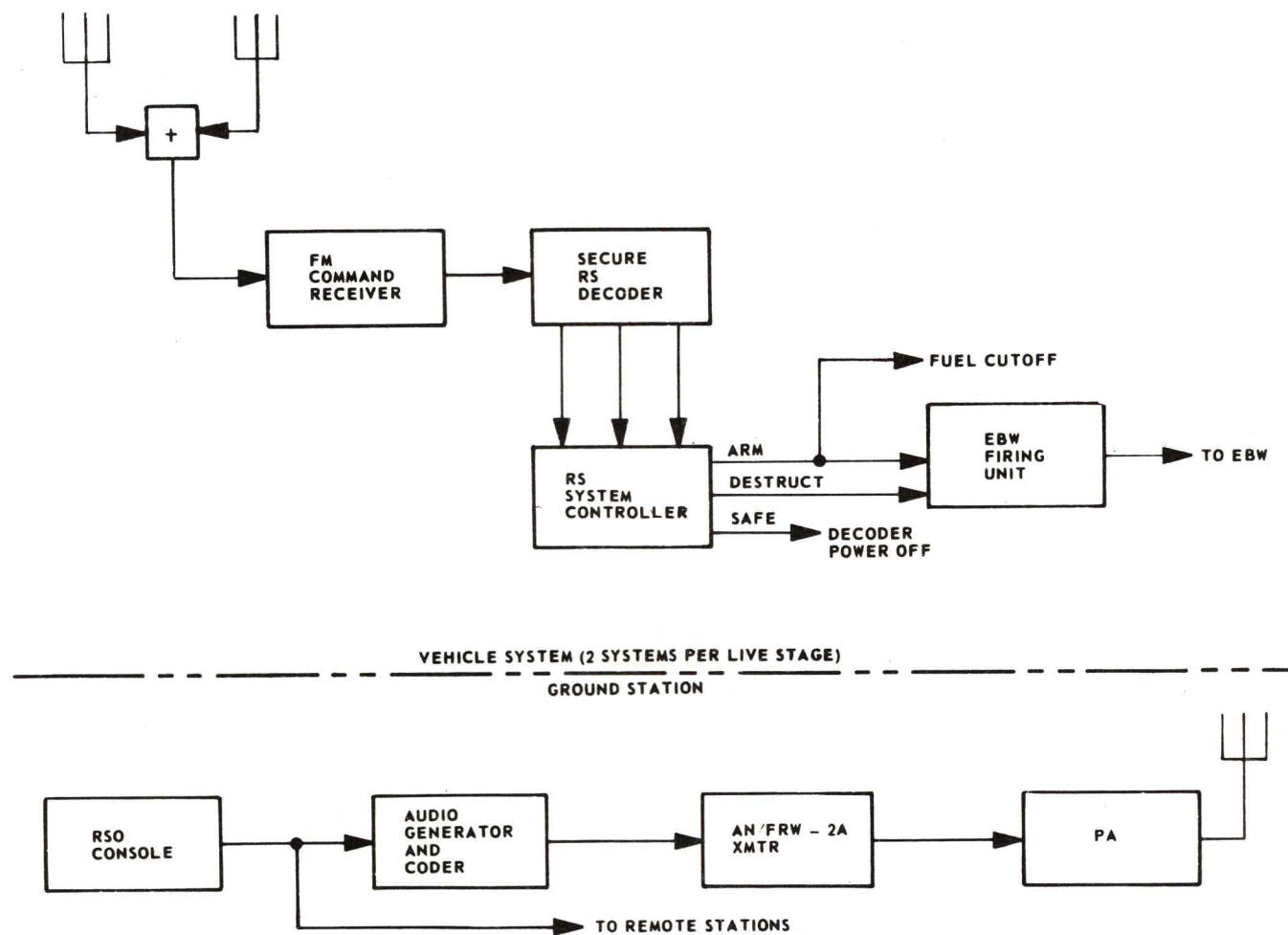


Figure 42. Typical Range Safety Command System Block Diagram

CAPE KENNEDY COMMAND - DESTRUCT FACILITY

In its simplest form, the ground facility at Cape Kennedy Missile Test Activity consists of the elements shown in block diagram form in Figure 43. Since a range safety command may have to be sent to the vehicle at any time prior to insertion, and since the range safety network must accommodate many different launch angles and many types of vehicles, it is necessary to provide a means of transmitting the desired command from remote sites as well as from the Cape. Although the block diagram does not show it, the RSO has available a remote site address and switching system that routes the command to all downrange stations.

When the RSO decides to initiate a command from his console, he actuates a hooded toggle switch. The output of the encoder is then routed in parallel form to a tone remoting transmitter which processes the message for transmission over the 8 km distance to the transmitter site. A tone remoting receiver at the transmitter site demodulates the message and feeds it to a modulator that converts the parallel information to the high-alphabet 11-character format. The 11 dual-tone bursts are then fed to the AN/FRW-2A transmitter system and to the vehicle. For reliability, a completely redundant backup system is provided, with a continuously monitoring error detector that provides automatic transfer to the backup system in case of a failure in the primary chain. To maintain simplicity in the block diagram, their error detection and switching circuitry is not shown.

The range safety equipment incorporates a priority-interrupt scheme that will interrupt any command being transmitted and transmit any higher-priority command selected by the RSO or originated by the computer. After completion of the transmission of the higher-priority command, the transmission of the interrupted command will resume.

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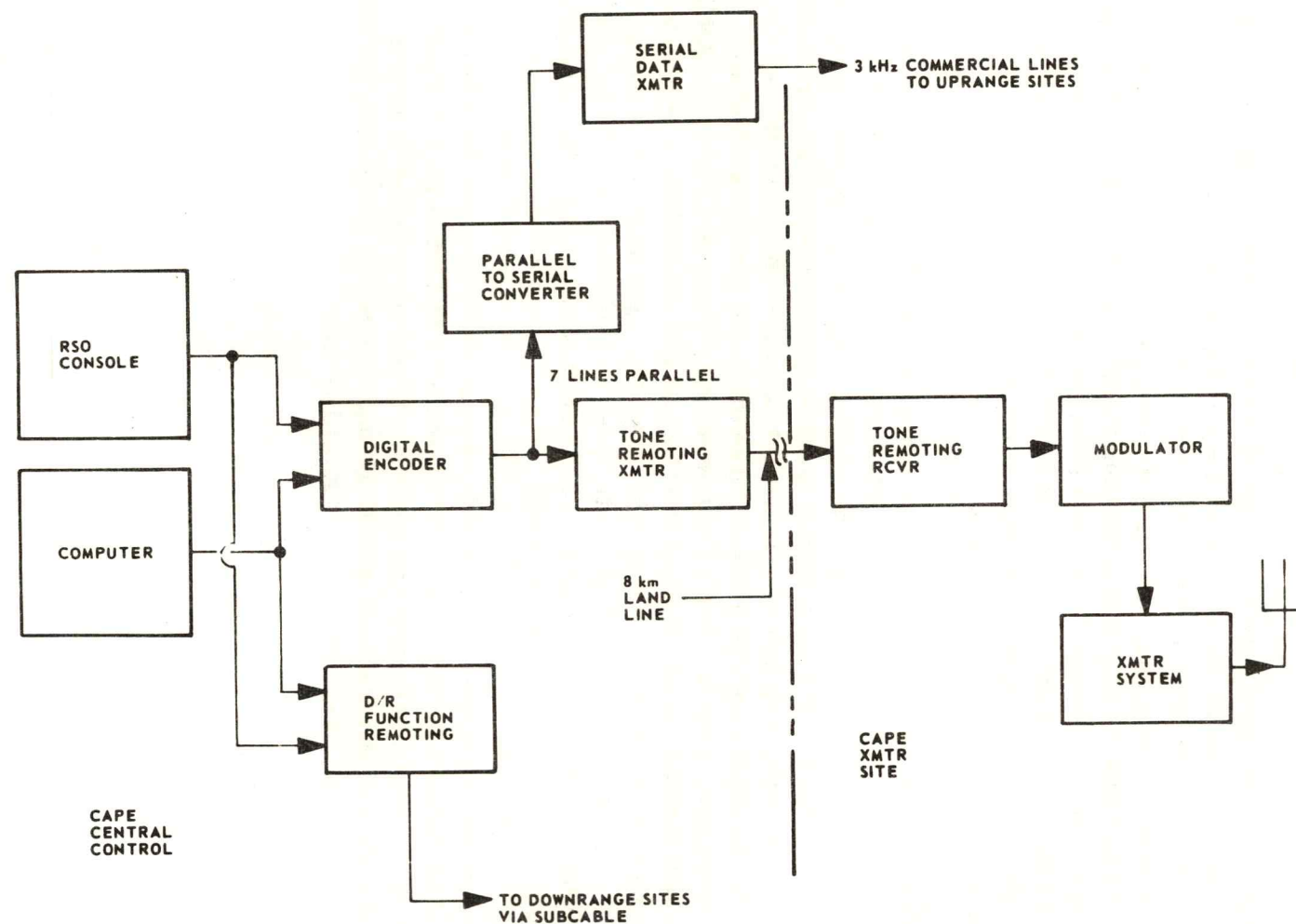


Figure 43. Cape Kennedy Range Safety Facility Block Diagram

DOWNRANGE REMOTE SITES .

When the vehicle is below the radio horizon of Cape Kennedy, the RF transmission will be made from one of the downrange sites. All downrange sites are connected by cable and when the RSO presses a command switch on his console, the command pulse will be transmitted over the cable via the supervisory control system (this system will be replaced by a digital remoting system in the near future). All sites will receive the command, and the transmitter on the air at the moment the command is received transmits the message to the vehicle (to keep the onboard receiver captured, one transmitter is always on the air).

UPRANGE REMOTE SITES (AS REQUIRED FOR 72 DEGREE LAUNCHES).

When the vehicle must be interrogated from an uprange site, the signal processing and routing is slightly different. As the parallel data leave the encoder at the Cape central control, they are changed to serial form by a parallel-to-serial converter and then applied to a serial data remoting transmitter. After being checked for errors, the serial message will be received at the proper uprange site, converted to parallel form, and fed to the modulator. The modulator will convert the binary-coded message to the high-alphabet 11-character format. This message is then transmitted to the vehicle.

PERFORMANCE MONITORING .

In addition to the equipment already described, each site will have a monitor receiver and test decoder connected to a display device and to a recorder to provide both a real time performance indication and a permanent record for later evaluation. A circuit will also be provided to bypass the AN/FRW-2A transmitter system and the monitor receiver so that the equipment can be checked without an actual RF transmission.

The Range Safety Command System is provided to satisfy range safety requirements for a ground controlled method of flight termination in the event the vehicle's flight path deviates from a pre-established corridor. Flight termination consists of engine cutoff and propellant dispersion.

The Range Safety System consists of two identical and redundant channels as indicated in Figure 44 for the S-IC Range Safety System. The two channels are electrically independent and explosively interconnected to ensure flight termination in the event of a malfunction of either channel. Each channel consists of the following:

1. Command Receiver
2. Decoder

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3. Range Safety System Controller
4. EBW Firing Unit
5. EBW Detonators

Two antennas, the Hybrid Ring and the ordnance train, consisting of the Safe and Arm (S&A) Device, the Confined Detonating Fuse, and the Linear Shaped Charge are common to the two systems.

To terminate the flight of the vehicle (refer to Figure 44) the antennas receive an RF signal modulated with one of several combinations of coded digital signals. The Hybrid Ring distributes this RF signal to both Range Safety Command Receivers (RSCR), where it is demodulated. A proper combination of these coded digital signals will cause the RSCR to issue a command to the Range Safety System Controller, which will arm (charge) the Exploding Bridgewire (EBW) Firing Units and cut off all engines. A second combination of digital signals will fire the EBW firing units. The EBW Firing Units discharge their stored-up energy into the EBW Detonator, which starts the explosive chain through the Safe and Arm Device, down the Confined Detonating Fuse and into the Linear Shaped Charge (LSC). The LSC ruptures the propellant tanks, thus causing propellant dispersion.

The following paragraphs describe the major components of the vehicle Range Safety System.

COMMAND ANTENNAS

The S-IC DRSCS receives Range Safety Officer (RSO) - initiated RF commands on either of the Range Safety Command Antennas. The two antennas are located 180° apart, both feeding a common hybrid ring. This hybrid ring provides equal RF signals to the MCR503 command receivers.

COMMAND RECEIVERS

Each of the two MCR503 command receiver systems (on the S-IC stage) consists of an ultra-high-frequency (UHF) receiver and digital decoder. The receiver demodulates the RF signals fed to it by the command antennas to recover the digital signals modulated onto the carrier at the Range Safety Command Transmitter Ground Station. The signals are fed to the digital decoders and are separated according to code. A proper combination of these coded signals will cause the decoder to issue a command to the Range Safety System Controller.

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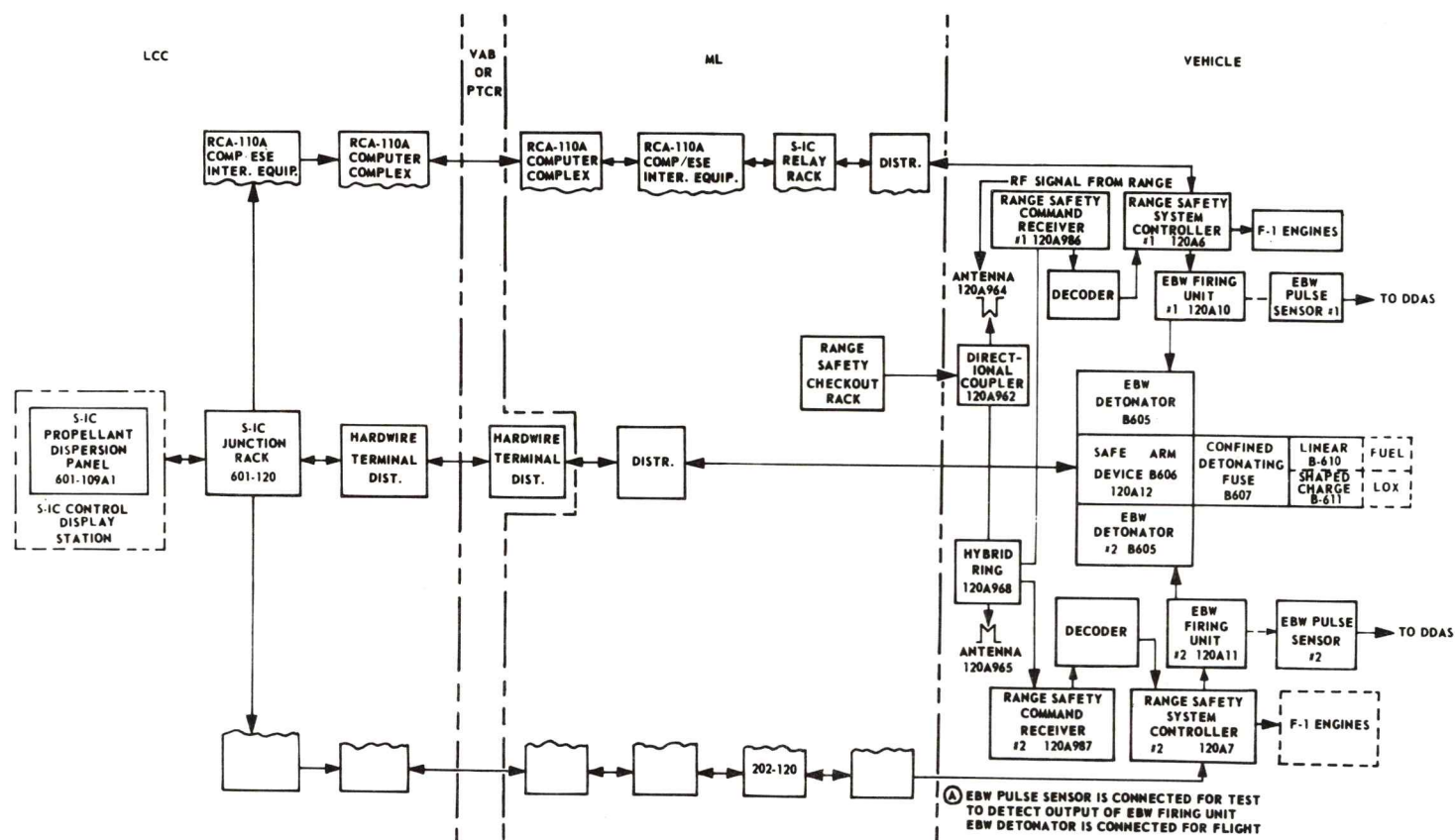


Figure 44. General Block Diagram S-IC Digital Range Safety Command System

RANGE SAFETY SYSTEM CONTROLLER

Ground control and monitoring of the Range Safety Command System is accomplished from the S-IC Propellant Dispersion Panel in the LCC, via the RCA-110A computer and hardware. Those signals required for emergency operation are hardwired. These consist of S&A Safe Command, S&A Safe Indication, Propellant Dispersion System Safe Command and EBW Firing Unit charging voltage. If in-flight conditions develop such that the vehicle cannot be permitted to continue under power, the Range Safety Officer causes the first of two commands to be transmitted to the vehicle. This command, when processed through the Command Receiver and Digital Decoders to the Range Safety System Controller, signals the appropriate relays in the controller to initiate Engine Cutoff and to charge the high-voltage storage capacitor in the Exploding Bridgewire Firing Unit.

EBW FIRING UNIT

The Exploding Bridgewire (EBW) Firing Unit consists of a high-voltage power supply, an energy storage unit, a trigger circuit and a switching device. Simultaneous with the Engine Cutoff signal, the high-voltage power supply (using vehicle 28BDC) charges the storage capacitor to approximately 2300 volts.

PROPELLANT DISPERSION

The second command transmitted by the RSO consists of the proper combination of digital codes to initiate Propellant Dispersion. Processing of this command through the vehicle Range Safety System, down to the Range Safety System Controller, is similar to the Engine Cutoff Command.

Receipt of the Propellant Dispersion Command in the Controller actuates appropriate relays to cause the charged EBW Firing Unit capacitor to discharge into the EBW Detonator.

EBW DETONATOR

The EBW Detonator is an electrically-activated device used for initiation of high-explosive trains. When the high-voltage, high-energy pulse is applied to a small wire resistance element (Bridgewire), the wire explodes and releases a small amount of energy. This energy initiates a small quantity of chemical explosive which in turn detonates a larger and more powerful output charge. This final charge detonates through a Safety and Arming (S/A) device into the explosive train.

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SAFETY AND ARMING DEVICE

A Safety and Arming Device is incorporated into the Range Safety System to prevent inadvertent system operation during ground checkout. The device is switched to the ARMED position just prior to liftoff.

The S/A device is basically a rotary solenoid with two explosive-filled holes in the shaft. In the armed position, the shaft is oriented so that the detonation can propagate through the two explosive charges in the S/A device to the Confined Detonating Fuse assemblies.

CONFINED DETONATING FUSE ASSEMBLIES

Confined Detonating Fuse assemblies consist of low-energy detonating cords encased with a multilayer protective sheath. The sheath is so designed that all explosive effects are self-contained, resulting in transmitting a detonation from the S/A device to the Linear Shaped Charges.

Ordnance tees are used to connect one Confined Detonating Fuse (CDF) assembly to two other CDF assemblies.

Quick-disconnect Ordnance Fittings are provided in the CDF assembly at the S-IC/S-II stage separation plane. These disconnects allow safe separation of the CDF assemblies during staging or ensure reliable propagation of a detonation. A propellant dispersion signal originating in the S-II stage or above, will propagate through this ordnance disconnect as backup to the S-IC system.

LINEAR SHAPED CHARGES

Linear Shaped Charges rupture the fuel and LOX tanks, in the event propellant dispersion is commanded from the ground. The explosive, detonated by the CDF, is so shaped that the force of the explosive is focused along a line to provide the required tankcutting action.

RANGE SAFETY GROUND CHECKOUT SYSTEM

For ground test, the EBW Firing Units are connected to the EBW Pulse Sensors instead of the EBW Detonators. A Pulse Sensor detects the presence of an adequate propellant dispersion signal and provides talkback to the ESE via DDAS. For ground test, an RF signal can be supplied to the RSCR's either closed loop from

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the Range Safety Checkout Racks via the airborne Directional Coupler or open loop from the range. In addition, the Range Safety Decoder can be functionally checked through a 75 ohm coaxial cable brought in through the upper umbilical. This cable can also be used to monitor the receiver video output directly, if desired.

The entire Range Safety Command System down through the EBW Firing Unit is functionally tested during ground checkout. An EBW Pulse Sensor is connected to the Firing Unit in place of the EBW detonator during ground tests. Also, the S/A device is rotated to the SAFE position, providing a physical block in the detonation train.

EBW Pulse Sensors receive the output of the EBW Firing Unit during ground tests. If voltage received from the Firing Unit is sufficient to have detonated the EBW detonator, a signal is provided by the Pulse Sensor to DDAS for display on the S-IC Propellant Dispersion Panel.

Ground checks of the RSCS are performed from the Range Safety Checkout Rack located on the LUT and the S-IC Propellant Dispersion Panel located in the LCC. The former provides a simulated range input to the Command Receivers via the Directional Coupler i.e., the RF signal modulated with the various combinations of digital codes. The latter provides the means to operate and monitor the action of the Command Receivers and EBW Firing Units as well as safing or arming the S/A device and safing the entire Range Safety (Propellant Dispersion) System.

DDAS CONTROL AND DISPLAY CONSOLE (REFER TO FIGURE 45)

The digital acquisition system (DDAS) display unit accepts inputs from an external DDAS receiving station and displays in analog format and manually preselected RF measurement and/or a binary word display confirming an event. The DDAS display unit is used on conjunction with the RF-GSE to cross-check measurements made with the RF-GSE during the RF checkout.

The "decoded address" for any desired DDAS channel is set up manually by selector switches. In order to setup the decoded address, four selector switches are provided as follows:

1. Channel selector
2. Frame selector
3. Group selector
4. Multiplexer selector

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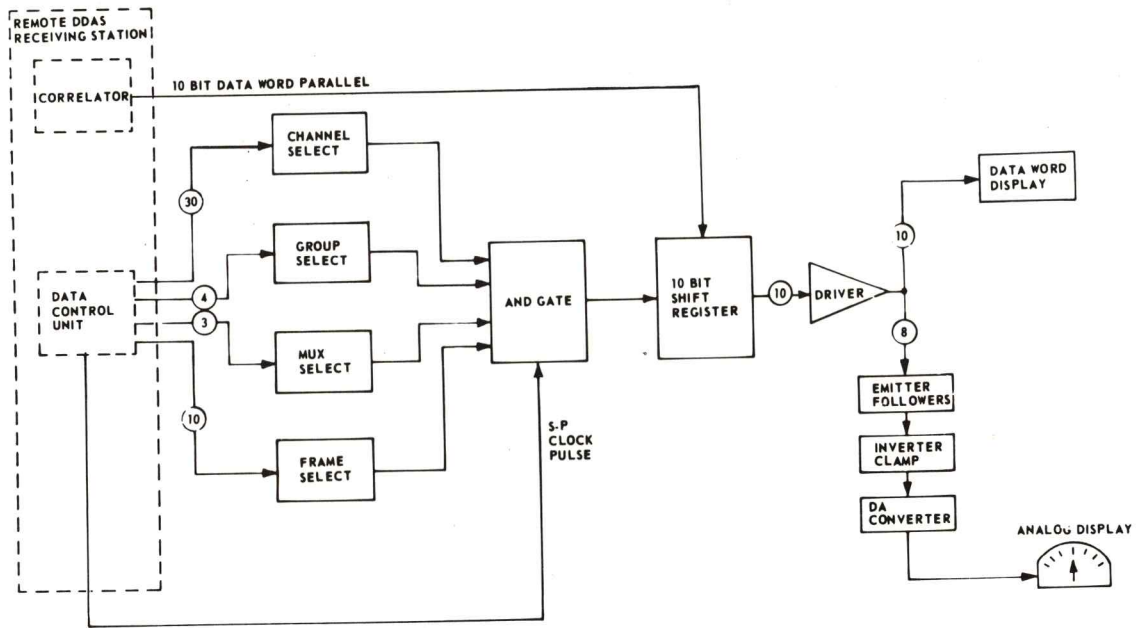


Figure 45. Block Diagram DDAS Control and Display Console

With the "decoded address" set, the DDAS display unit displays the following lights for the selected channel:

1. DDAS data word in binary format
2. Analog reading of data word (0 to 5 volts dc.)

The DDAS display unit displays both the DDAS data and the analog reading of the data word for measurements and events. Under normal circumstances, the operator reads the analog display. When event information is being monitored, the operator will read the data word display.

The DDAS display unit receives the decoded address, data word, and clock-pulse inputs from a remote DDAS receiving station in binary RZ format via hardware. The decoded address inputs are in parallel as follows:

Decoded channel count	30 lines
Decoded group count	4 lines
Decoded multiplexer count	4 lines
Decoded frame count	11 lines

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The data word is a 10-bit binary word received in parallel over 10 lines. The clock pulse has the same characteristics as the address and word pulses, and occurs coincidental with the receipt of a complete word data.

The electrical characteristics of all input signals are as follows:

Bit rate	72 or 144 kc
Duty cycle	50 per cent
Logical one	-3 volts \pm 1 volt
Logical zero	-11 volts \pm 1 volt
Format	RZ

The DDAS continuously commutates through its program of measurements. The DDAS display panel is capable of setting up the address for a given measurement desired and continuously displaying the data word and the analog equivalent of the data word.

The data word input is to a 10-bit shift register. The shift register obtains shift pulses for a four-input pulsed AND gate. The four control inputs of the AND gate are obtained from the four address selector switches. The four address selector switches receive decoded count from a remote DDAS receiving station. When all of the selector switches transfer a logic voltage simultaneously, the AND gate has a coincidence condition and generates a pulse upon receiving a clock pulse into its pulse input. The clock pulse is fed via hardwire from the remote DDAS receiving station to the AND gate.

The inputs of each stage of the DDAS display unit shift register are obtained from the remote DDAS receiving station. When the shift register receives a shift pulse, the 10 bits of data that are in the remote DDAS display unit shift register.

The 10-bit data in the shift register are fed through suitable drivers to the data word display and through emitter followers to a digital-to-analog converter and then to a meter for analog display.

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CHAPTER III

SECTION IV

SATURN V OPERATIONAL DISPLAY SYSTEM

INTRODUCTION

The Operational Display System provides a communications link between the system test engineer and the launch vehicle. It is used during the prelaunch checkout and launch sequence of the Saturn V launch vehicle, to monitor and analyze data going to and coming from the vehicle and various ground support systems. (Refer to Figure 46)

FUNCTION AND DESCRIPTION

The Operational Display System provides a means of monitoring, analyzing and controlling test data during prelaunch checkout. Real time digital information from the RCA-110A Computer system (vector and alphanumeric characters), closed circuit television (CCTV) from various points in the launch complex, or fixed data permanently stored on slides may be selected and displayed on any of up to twenty (20) display consoles. A composite presentation of fixed slide data and variable digital data may also be displayed on any of the consoles. When several consoles are being used concurrently, it may be necessary to assign specific functions to individual consoles to ensure that each assigned console does not duplicate or interfere with the operation of another console. A card key system is designed into the system to permit the operation of each console to be limited to specific functions. In such cases it may be necessary to appoint a master console to monitor and control the other consoles. Any console may be designated as the master by providing a master card key to the operator of that console. Each console operator may operate independently. Data may be monitored, updated, edited, or entered into the system by each console operator, hence, the display system provides a means of completely controlling all phases of vehicle prelaunch testing.

In addition to the above mentioned capabilities of the system, hard copies of displayed data may be made if desired and the data being displayed on any console may be transmitted over closed circuit T. V. links.

The Operational Display System consists of nine separate units interconnected to perform their related functions. The various units comprising the system and a brief description of each are presented in the following paragraphs. Figure 47 is a general block diagram of the display system showing relationships of the system, the RCA-110A computer and the launch vehicle.

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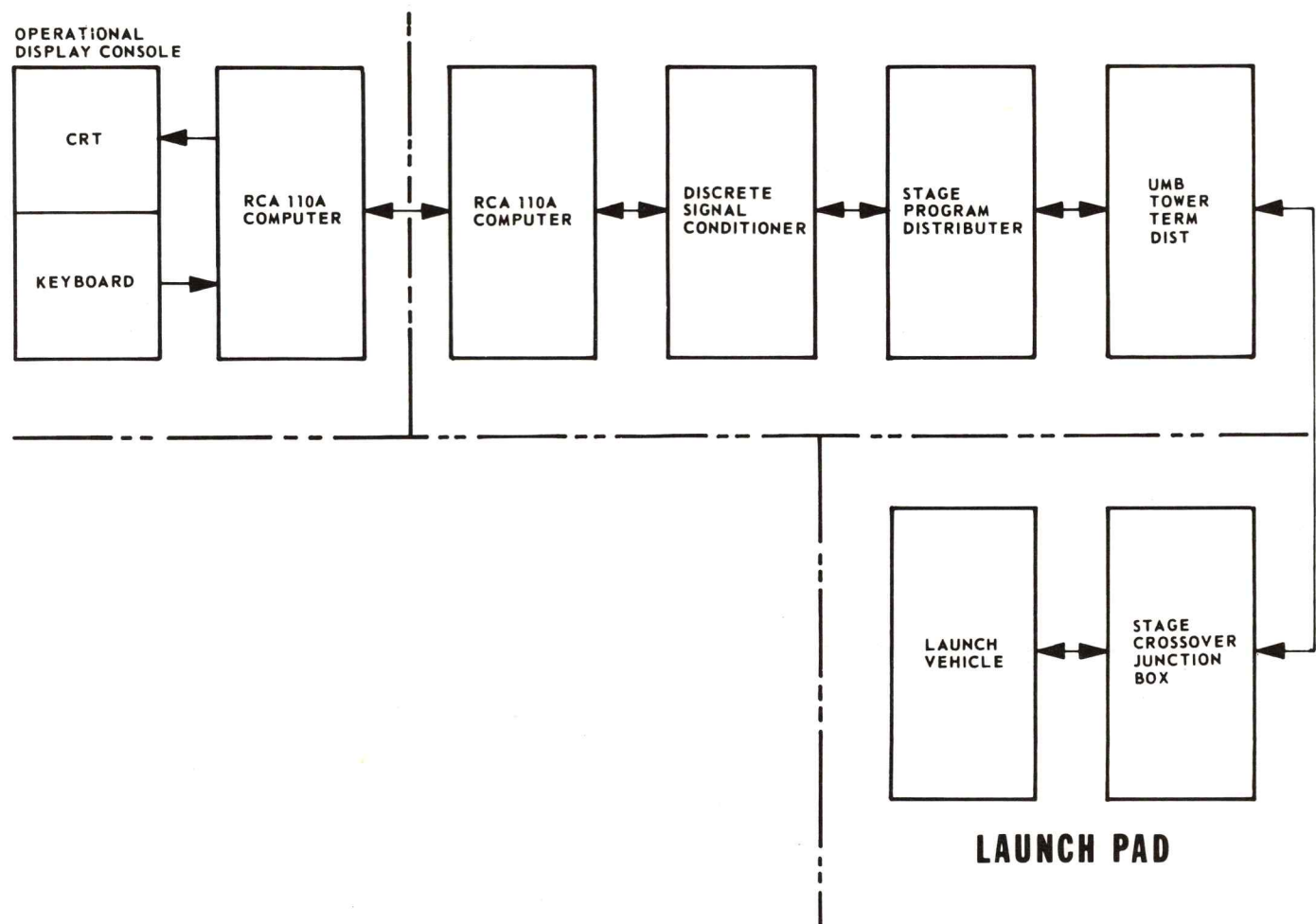


Figure 46. Typical Signal Flow for Display System

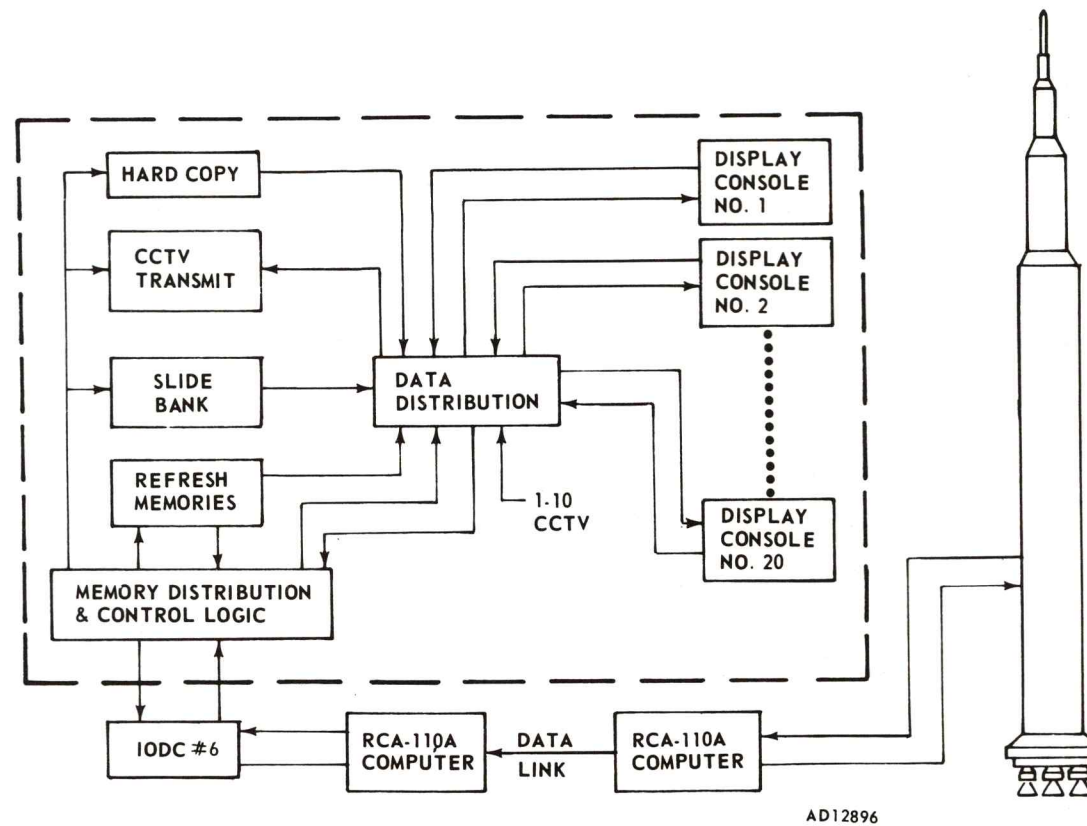


Figure 47. System General Block Diagram (Operational Display System)

CENTRAL LOGIC UNIT

The central logic provides buffering between the Display Processor Unit (DDP-224 computer) and other units of the display system. It reformates and processes incoming data and supplies it out to other system units. This process includes data storage in the refresh memories, control and status functions, and appropriate data distribution.

The unit consists of a two bay cabinet for rack mounting of the various assemblies comprising the central logic. Doors in the front and rear of the cabinets provide access to the assemblies. One bay of the racks house seventeen modular memory units and utilizes draw-type mounting for access to the card racks. The other bay mounts the various chassis that provide the active central logic functions. Four of these chassis, Digital Data Distribution, Data Exchange Control, Interrupt Control, and Peripheral Distribution, are also mounted on draw-type carriages to provide rapid access to the cards within the units.

DISPLAY CONSOLE UNIT

This unit converts digital data from the Central Logic Unit into a visual display on a CRT screen. Figure 48 depicts the Console. A control deck is incorporated into the unit for command and edit functions. The operator can select desired tests for display, request slide material as required, and command hard copy to be made of any display. With use of edit functions, the operator can add notations and vectoral lines to the display, as well as make erasures. The operator can select any of ten-closed-circuit television channels for viewing.

The Display Console Unit mounts a 21-inch cathode ray display tube in the top portion of the console. Operator controls and indicators are provided at a convenient height on a slightly sloping control deck. An alpha numeric keyboard is included for performing special editing functions (refer to Figure 49). A photo pen, mounted on the right side of the control desk, provides additional editing capabilities. A card cage rack, housing the display buffer circuitry is located below the control deck and is accessible via a hinged door. In the console rear, a hinged door provides access to the back portion of the cathode ray tube assembly as well as the various other equipment housed in the rack area.

DISPLAY PROCESSOR UNIT

The display processor unit is a DDP-224 general purpose digital computer that processes all command and edit functions requested by the display consoles. The processor also handles all communications to the RCA-110A computer and processes all input data received from the RCA-110 computer for use with the display system.

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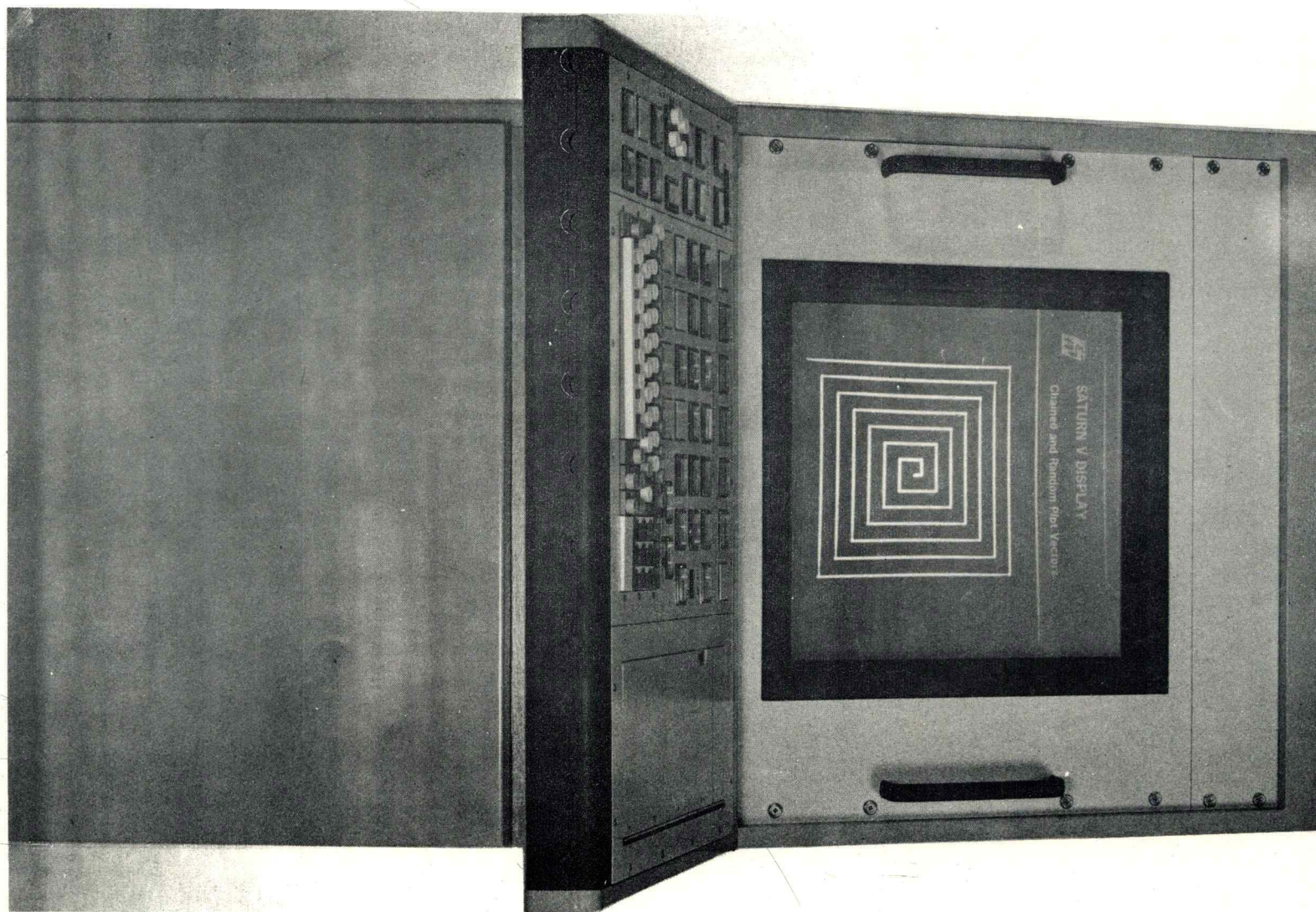


Figure 48. Saturn V Display Console

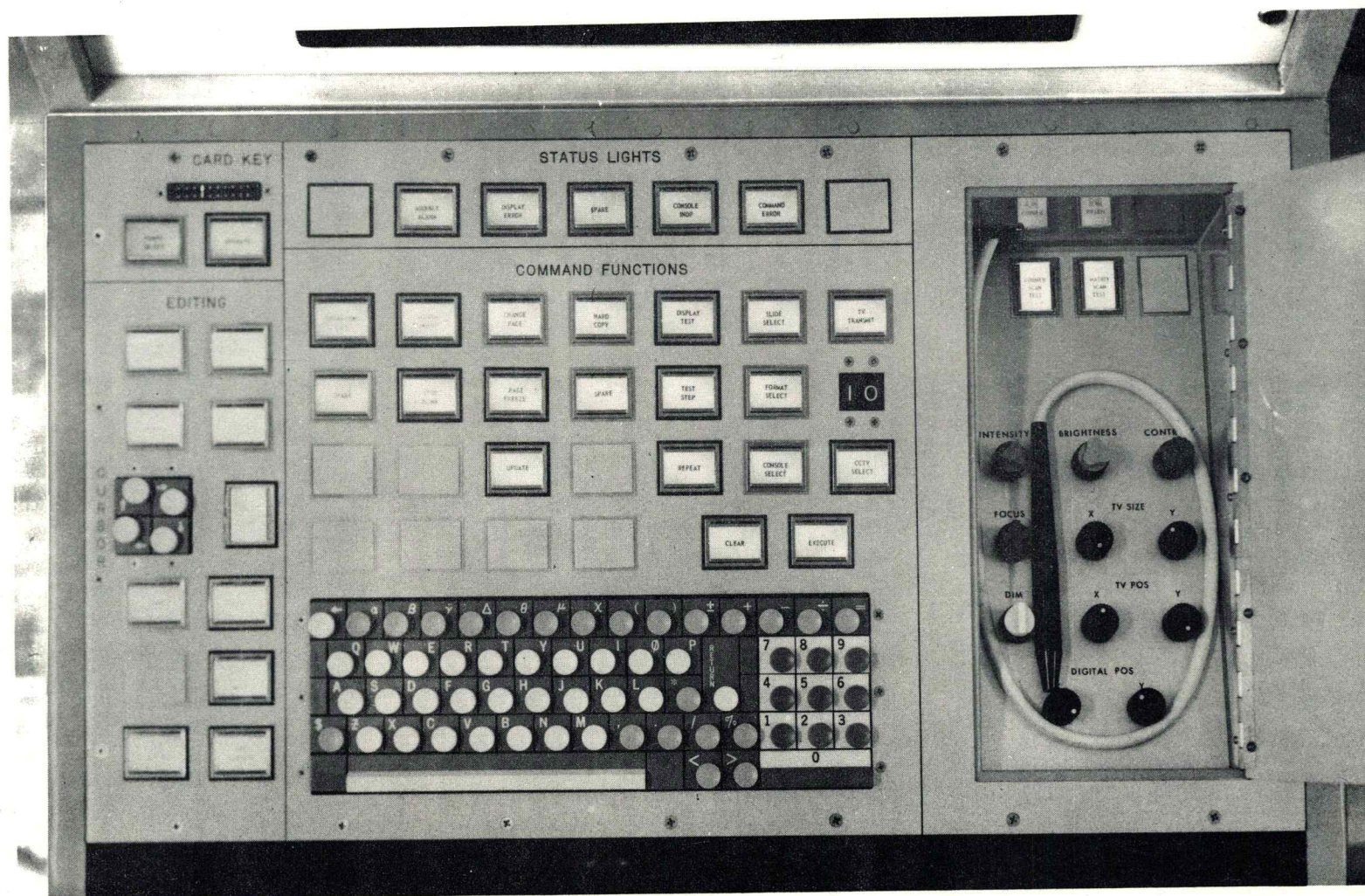


Figure 49. Console Keyboard Control Panel

TYPEWRITER UNIT

This is an IBM typewriter used to communicate with the Display Processor computer. As an output device, the typewriter functions as a printer to provide printout of computer supplied data. Conversely, when used as an input actuator, the typewriter converts the manually selected characters to binary coded-decimal equivalents for use by the computer. The typewriter also operates in conjunction with the paper tape unit as either an input or an output device.

PAPER TAPE UNIT

The Paper Tape Unit is another device used to communicate with the computer. When used to read a preprogrammed paper tape, the paper tape unit transfers the binary-coded-decimal data supplied by the computer to paper tape. The paper tape unit also operates in conjunction with the typewriter as either an input or an output device.

SLIDE TRANSMISSION UNIT

The Slide Transmission Unit generates video from projected 35 mm slide material for use by other units within the system. A Slide Bank provides storage for up to 256 slides which may be retrieved at random for projection.

The Slide Transmission Unit consists of a single-bay cabinet (refer to Figure 50) that mounts the slide bank and power control assemblies. Hinged doors at front and rear of the cabinet provide access to the rack area. In the front of the cabinet, a panel mounts various indicator lamps, control switches, test jacks, etc., as well as a printed circuit card cage. The slide bank and power supply components are easily reached from the rear of the cabinet, as are the cabling and power control assemblies. An elapsed time indicator on the power control box provides total operating time.

TV TRANSMISSION UNIT

The TV Transmission Unit converts the digital data into equivalent video for transmission on the closed-circuit television lines. When required, it interlaces slide video with the display data and the resulting composites are transmitted.

The TV Transmission Unit consists of a single-bay cabinet that mounts its various assemblies. Access to the cabinet interior is provided by hinged doors at front and rear. With the front door open, the various controls are exposed for operating the unit. At the top of the cabinet, a TV camera is positioned to scan the screen of a vertically oriented cathode ray tube.

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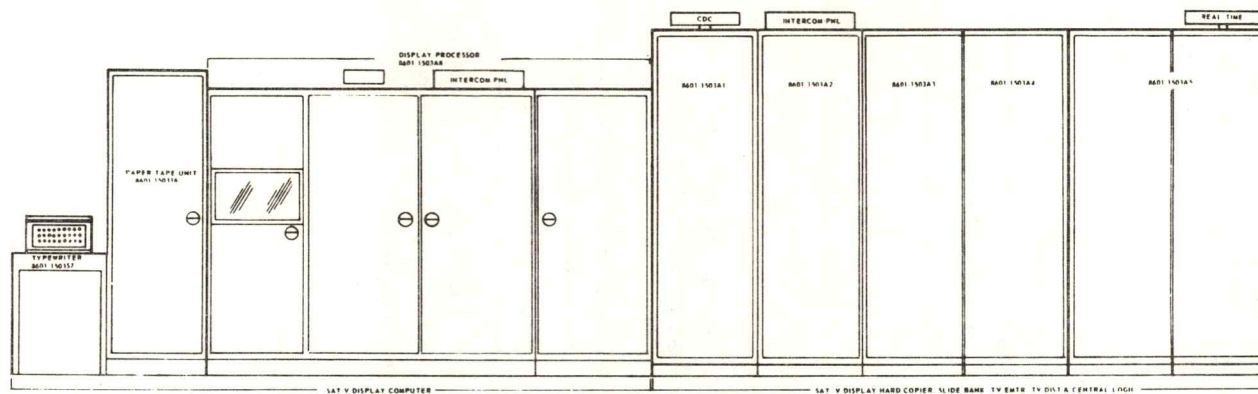


Figure 50. Saturn V Operational Display System Racks

TV DISTRIBUTION UNIT

The TV Distribution Unit switches the closed-circuit television channels and slide video to the display consoles within the system, and controls transmission of slide video to the Hard Copier. Actual control of the switching functions emanate from the Central Logic Display Processor Unit where the various requests are processed.

The TV Distribution Unit consists of a single bay cabinet. Hinged doors at front and rear of the cabinet provide access to the rack area. With the front door open, the two monitor display screens are exposed for viewing. A patch panel conveniently located beneath the two monitors, is readily reached by the operator and is used to select the desired displays. Access to the circuit cards for the camera control and video switch matrix assemblies is provided by opening the hinged covers.

HARD COPIER UNIT

This unit converts digital data in to a visual display on a CRT, and interlaces slide video (when required) into this display, then photographs the CRT screen by an electrostatic process to give a hard copy output.

The Hard Copier Unit consists of a single-bay cabinet. Access to the cabinet interior is provided by hinged doors at front and back. With the front door open, the various controls are exposed for operating the unit. At the top, a hinged door provides access for servicing the front portion of the hard copier assembly, changing film, lens adjustment, etc.

POWER AND INTERFACE PARAMETERS:

Input power requirements to the Operational Display System is 115VAC, 60 cycles per second at 46 amperes.

The following table presents the interface and logic level data for communication between the display system and other equipment.

Table 4

Interface

Communication Data

RCA 110A Computer

26 status & control lines

50 data lines

logic levels = logical "1" = 0V

logical "0" = 6.5V

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Table 4 (Cont.)

3C DDP-224 Computer	52 status & control lines 98 data lines logic levels = logical "1" = 6.5V logical "0" = OV
Display Console(s)	11 status & control lines 11 line data, sync, clock composite logic levels = logical "1" = +4V logical "0" = OV
Hard Copier	5 status & control lines 1 line data, sync, clock composite logic levels = logical "1" = +4V logical "0" = OV
TV Transmission	2 status & control lines 1 line data, sync, clock composite logic levels = logical "1" = +4V logical "0" = OV
Interface	Communication Data
Slide Transmission	5 status & control lines 8 data lines logic levels = logical "1" = +4V logical "0" = OV
TV Distribution	4 status & control lines 9 data lines logic levels = logical "1" = +4V logical "0" = OV

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Table 5 gives the data transfer rates for input and output data to and from the operational display system.

Table 5

Interface	Data Transfer Rate
Input from RCA 110A Computer	Up to 39 Kc for 25-bit words
Input from 3C DDP-224 Comp.	Up to 1.9 Mc for 24-bit words
Output to Associated Equip.	Up to 50 Kc for 24-bit words

SUMMARY

The Saturn V Operational Display System provides a communications link between the test engineer and the checkout computers of the Saturn V system. In operation, the display operator can initiate a preprogrammed checkout procedure, and real time operation of the checkout computer provides digital data reflecting the requested test information. The display system converts this data into either an alpha numeric or graphic display on a CRT screen. The operator can evaluate the displayed test data with information at hand, or he can select reference material from slide bank storage for interfacing into the display. Closed circuit television from various selected points complement these capabilities, enabling the operator to gain a complete and comprehensive picture of checkout progress. If a permanent record of any displayed data is desired, the operator can command hard copy to be made.

CHAPTER III

SECTION V

DIGITAL COMMAND SYSTEM

INTRODUCTION

The Digital Command System (DCS) provides the digital command link between ground stations located around the world and the Saturn V Apollo vehicle. The DCS accepts, verifies and stores commands from local and remote ground command stations and then transmits the command data to the Saturn V vehicle computer. It also verifies the valid receipt of the command data by the Saturn V vehicle.

DCS number four located at the Mission Control Center (MCC), Cape Kennedy, Florida, is the command back-up for the primary boost-phase radio guidance link. Thus, a vehicle may be inserted into proper orbit if the primary guidance link should fail during flight. System number 4 also has a digital-to-teletype translator that enables transmission of stored commands to remote stations.

LOCATION AND DESCRIPTION

There are nine digital Command Systems located around the world for command data link to the Saturn V vehicle. The following chart lists the serial number of the systems and their geographical locations:

SERIAL NUMBER	LOCATION
001	Wallops Island, Virginia
002	Cape Kennedy, Florida
003	Carnarvon, Australia
004	Cape Kennedy, Florida
005	Corpus Christi, Texas
006	Grand Canary Island
007	Rose Knot Tracking Ship
008	Kauai, Hawaii
009	Coastal Sentry Tracking Ship

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The DCS is housed in six cabinets assembled in a rack unit measuring 134 3/4 inches wide, 32 1/2 inches deep, and 80 inches high (refer to Figure 51). Logic functions are performed by throw-away-modules.

The modules are inserted into contact blocks mounted on sliding drawers for ease of maintenance. In addition to the logic modules, the DCS utilizes three Sola DC power supplies, a FABRI-TEK magnetic-core memory, an indicator power supply, two filter box assemblies, two control panels and one display panel. All connections to the DCS are through connector boxes at the rear of the cabinets (refer to Figure 52). Cooling for the system is provided by fans at the top and bottom of the cabinets and inlets at the base of the cabinets.

Input power required to operate the DCS is 117 VAC, 60 cps, three wire single phase, with current capability of 30 to 35 amperes. Power consumption of the DCS is approximately 4000 VA.

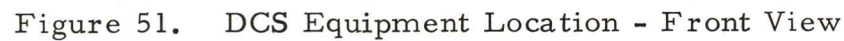
The individual cabinets are numbered 00 through 4 as depicted in Figure 53. The slides and rigid mounted components comprising the cabinets are identified by the cabinet reference with the letter A and one or two following numerals. Each slide contains contact blocks designated with a letter. Each contact block is capable of housing 50 modules and is subdivided into 10 columns and 5 rows, thus each module is identified by column and row as A/L.

OPERATION

The DCS operates in four principal modes. These are (1) input mode, (2) display mode, (3) transmit mode and (4) test mode. The input mode permits command words and velocity meter words (command words used to achieve a desired velocity in the vehicle) to be loaded into the memory from remote sources or to be inserted manually. The display mode permits the stored words to be displayed and revised at control panel 1A6. The transmit mode enables the transmission of data either from the memory or from manual inputs. It also permits the updating of vehicle clocks. Many transmit mode functions can be controlled in real time from remote consoles. The test mode enables operational and maintenance testing of the DCS without inputs from other equipment.

The DCS incorporates a number of precautions to insure reliability of operation. The validity of every word is checked repeatedly from input to transmitting antenna. Circuits from the memory to the transmitting antenna are completely redundant, with automatic self-checks and automatic re-routing. A sub-bit encoding technique is employed which transmits discrete patterns rather than single bits. If the vehicle fails to return a "valid word received", transmission is automatically repeated.

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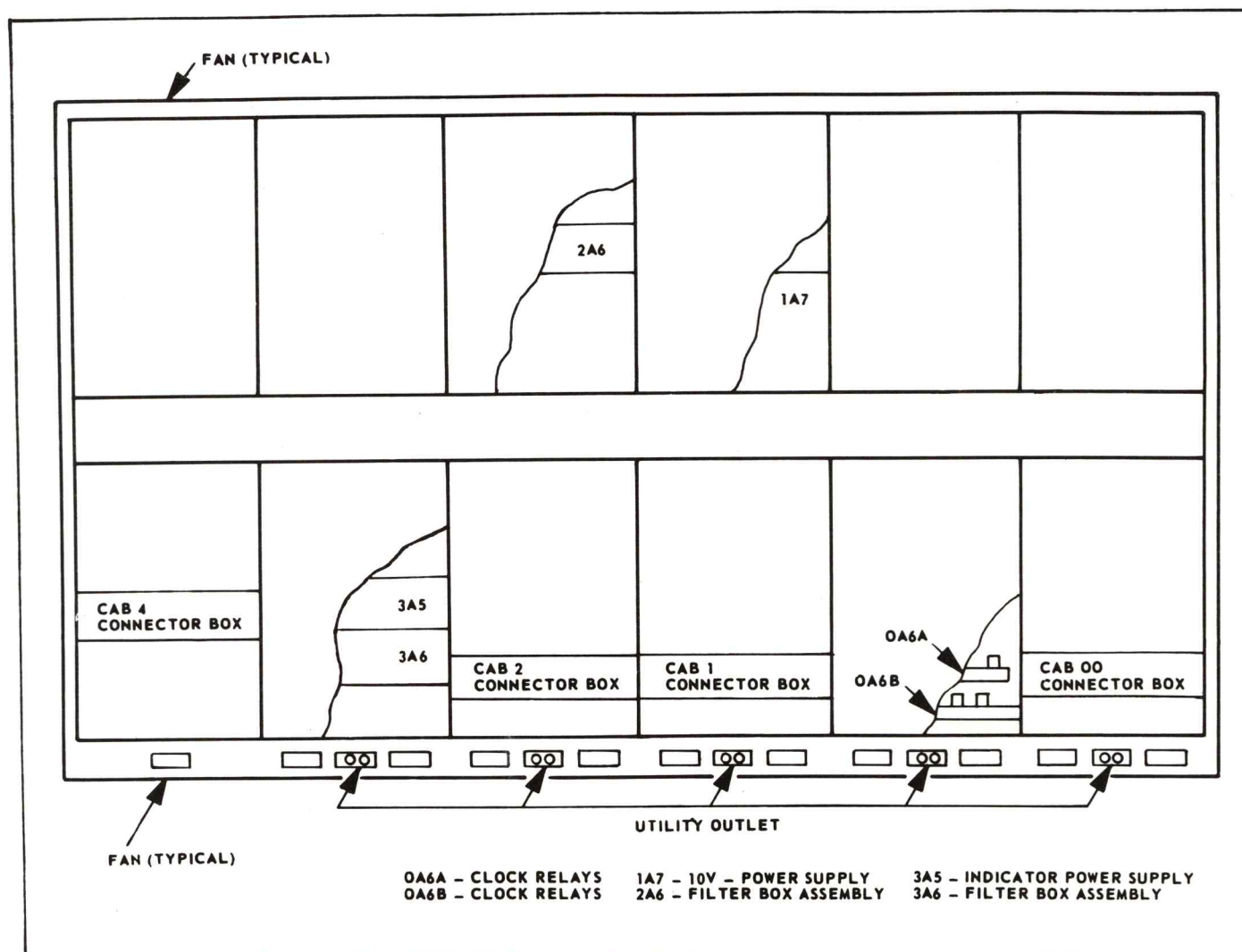


Figure 52. DCS Equipment Location - Rear View

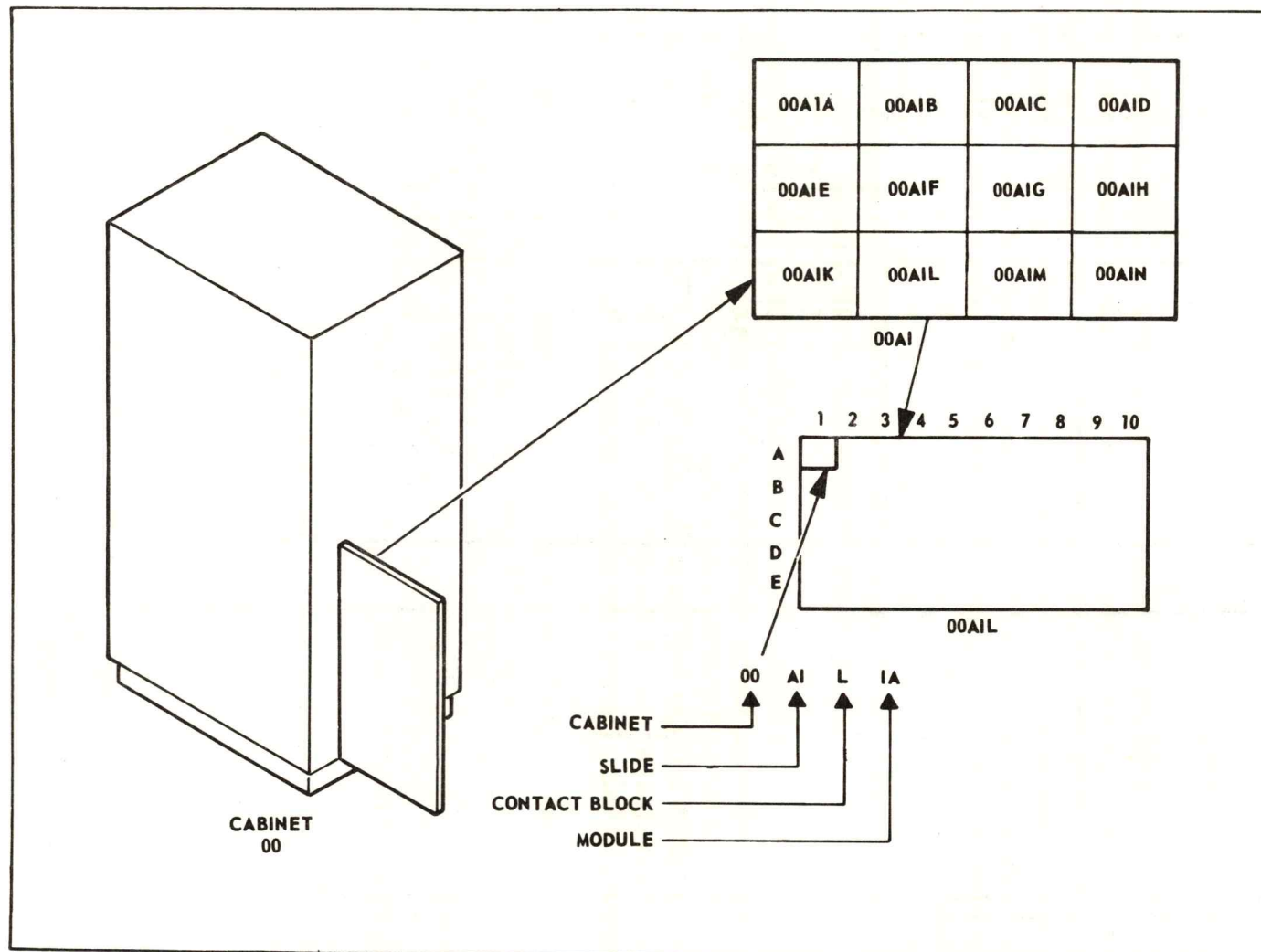


Figure 53. DCS System Reference Designations

Figure 54 is simplified block diagram of the DCS. The following is a brief explanation of each subsystem in the block diagram. Figure 55 is a detailed block diagram of the DCS and provides more detailed information as to signal flow and signal definition.

INPUT SUBSYSTEM

The DCS Input Subsystem receives serial inputs from teletype and from a high-speed data transmission line. It also receives parallel inputs from a computer. Data can also be entered and controlled manually. The teletype and high-speed inputs include transmitted odd or even parity indications. The input subsystem (ISS) checks these transmitted parity indications against internally generated parities to assure the validity of the transmitted words. The incoming word includes a memory address for storing the word. If the parity checks show that a valid word has been received, the word is parallel-loaded into an input/output buffer register in the Memory Control Subsystem and the memory address is sent to the core memory in the Memory Control Subsystem.

When inputs are received from a local computer, they are furnished in parallel format, and there are no transmitted row or column parities. However, there is a parity bit for parity of the entire stored word excluding a word length portion. The memory address portion of the input is routed through the ISS to the memory, and the remaining part of the word is routed directly to the Memory Control Subsystem. Timing for the load function is supplied to the ISS.

The DCS also provides for manual inputs. In this case, the memory address is set into an input register in the ISS using ten pushbutton switches, and the rest of the input word is entered into the Memory Control Subsystem using forty pushbutton switches.

MEMORY CONTROL SUBSYSTEM

The Memory Control Subsystem (MCS) includes two input/output buffers, a core memory and validity circuits. Incoming words are loaded broadside from the ISS into an input/output buffer. They are immediately loaded into memory at the designated address and readout from the memory into a second input/output buffer. The contents of the two buffers are compared and if they agree, a "valid word stored" signal is generated. The memory is a random/sequential-access, magnetic-core memory with non-destructive read-out. It has 512 storage addresses, each capable of storing a 40-bit word. Only 365 addresses are used: These are displayed on the control panel 1A6.

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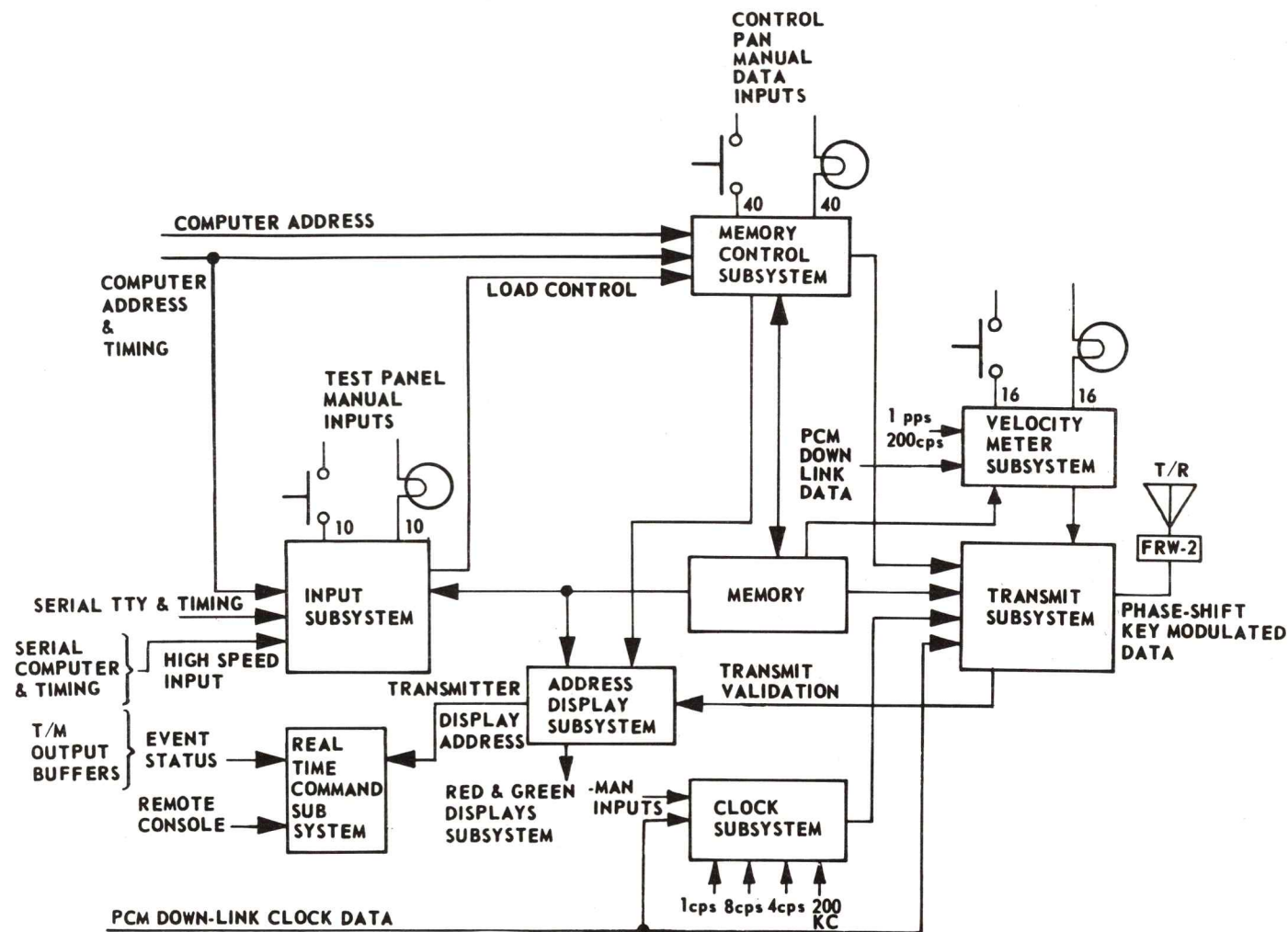


Figure 54. DCS Simplified Block Diagram

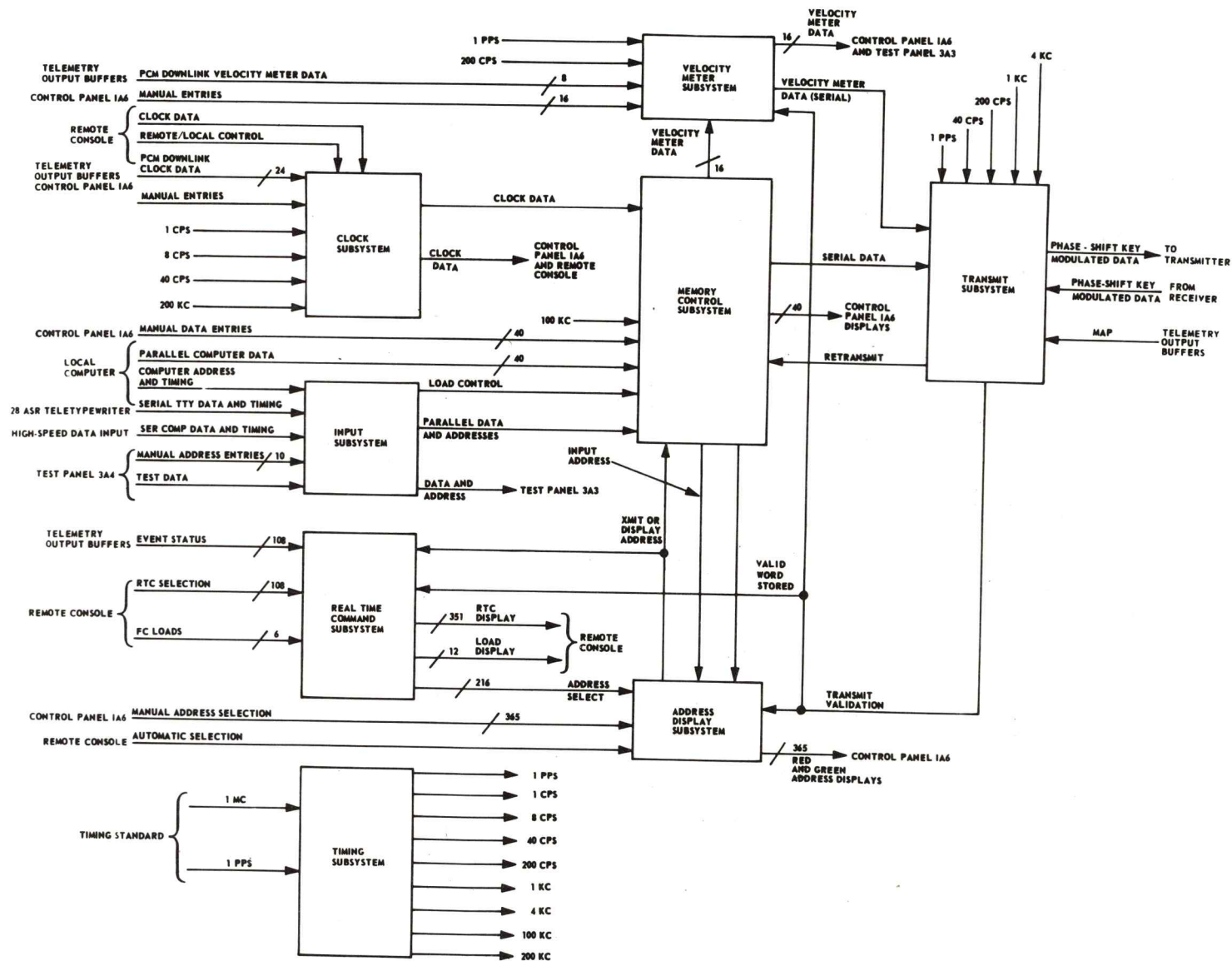


Figure 55. DCS Detailed Block Diagram

ADDRESS DISPLAY SUBSYSTEM

The Address Display Subsystem (ADS) controls a display of green lights on control panel 1A6. There are 368 of these green indicators, one for each memory of the 365 addresses used (three lights are blanks). The address of each incoming word is decoded and controls one of these green lights. If a "valid word stored" signal is received from the MCS, the ADS turns on the green light for that particular memory address. The ADS also controls red indicators for 365 memory addresses and provides automatic and manual selection capabilities for transmission and manual selection for display.

TRANSMIT SUBSYSTEM

The Transmit Subsystem (TSS) consists of two completely redundant paths from the MCS to the transmitter, with automatic validity checks and automatic routing at two steps in the transmission paths. It performs a sub-bit encoding function and provides a phase-shift-keyed modulated output to the transmitter.

VELOCITY METER SUBSYSTEM

The Velocity Meter Subsystem (VSS) receives and momentarily stores 16-bit velocity meter words from the memory, or permits direct manual inputs using pushbutton switches on control panel 1A6. Upon command, each bit of the stored words is translated to a 7-bit pattern plus a 5-bit address, and is then fed directly into the redundant transmission paths of the TSS.

CLOCK SUBSYSTEM

The Clock Subsystem (CSS) includes three ground clocks. These count time to retrofire (TR), time to function (TF) and time to reset (TX). The spacecraft carries a TR clock corresponding to the ground TR clock. The spacecraft TR clock readings are transmitted over the PCM downlink to the DCS clock subsystem. The readings of the ground clocks and the vehicle TR clock are displayed on control panel 1A6 and are supplied to a remote console. The CSS calculates the difference between the vehicle and ground TR clocks and displays the difference on control panel 1A6.

TIMING SUBSYSTEM

The Timing Subsystem (TSS) generates the basic timing used in the DCS from a 1-megacycle timing input. It is also synchronized by a 1-PPS input. Both inputs are supplied by the site Timing Standard. Figure 55 shows the timing used by each subsystem.

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SUMMARY

The DCS provides a means of updating the Saturn V Apollo computer from the ground after vehicle launch. The DCS output is used to modulate an AN/FRW-2 transmitter which in turn transmits frequency modulated signals to the vehicle. The vehicle transmits back to the DCS via a pulse code modulated (PCM) telemetry link. The DCS transmission is designated at the FM uplink and the return signals via the PCM telemetry link are designated the PCM downlink.

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CHAPTER III

SECTION VI

ST-124M CHECKOUT STATION AND ESE

INTRODUCTION

The ST-124M checkout equipment will be utilized to calibrate and test the inertial platform system for accuracy prior to installation in the vehicle Instrument Unit. The Final Checkout (FCO) equipment will be identical at the manufacturer's plant, launch site, and any intermediate location where verification or system operation is required. The FCO will calibrate all subsystems, servoloops, accelerometers, gimbal pickoffs, and the resolver chain. Platform drift rates will also be measured with the FCO equipment.

The FCO equipment will consist of two main assemblies:

1. Electrical Console

The electrical console will contain the control panels, monitor panels, guidance system simulator panels, program panels, and power supplies. Auxiliary equipment, such as oscilloscopes and voltmeters, will also be contained in this console.

2. Mechanical Stand

The mechanical stand will be used to mount the inertial platform. The stand will contain a gimbal system to simulate vehicle motion and an automatic theodolite to verify the azimuth laying system.

FUNCTION AND DESCRIPTION

The electrical support equipment (ESE) necessary for activation and prelaunch checkout of the ST124-M inertial platform system is integrated into the Saturn launch complex equipment. The turn-on sequence and checkout procedure is fully automated. Critical measurements and responses will be monitored by the launch computer on a go/no-go basis. Visual displays and readings of the most critical measurements such as the steering signals, azimuth heading, accelerometer outputs, and phi signals (from the data adapter) will be available for monitoring by launch personnel. (Refer to Figure 56 for platform acquisition block diagram).

The ST-124M ESE is located in three areas. Figure 57 is a block diagram of the ESE located in the LUT. Figure 58 is a block diagram of equipment in the theodolite hut, and Figure 59 is a block diagram of the ESE located in the launch control center. Figure 60 shows how the platform subsystem and its ESE are

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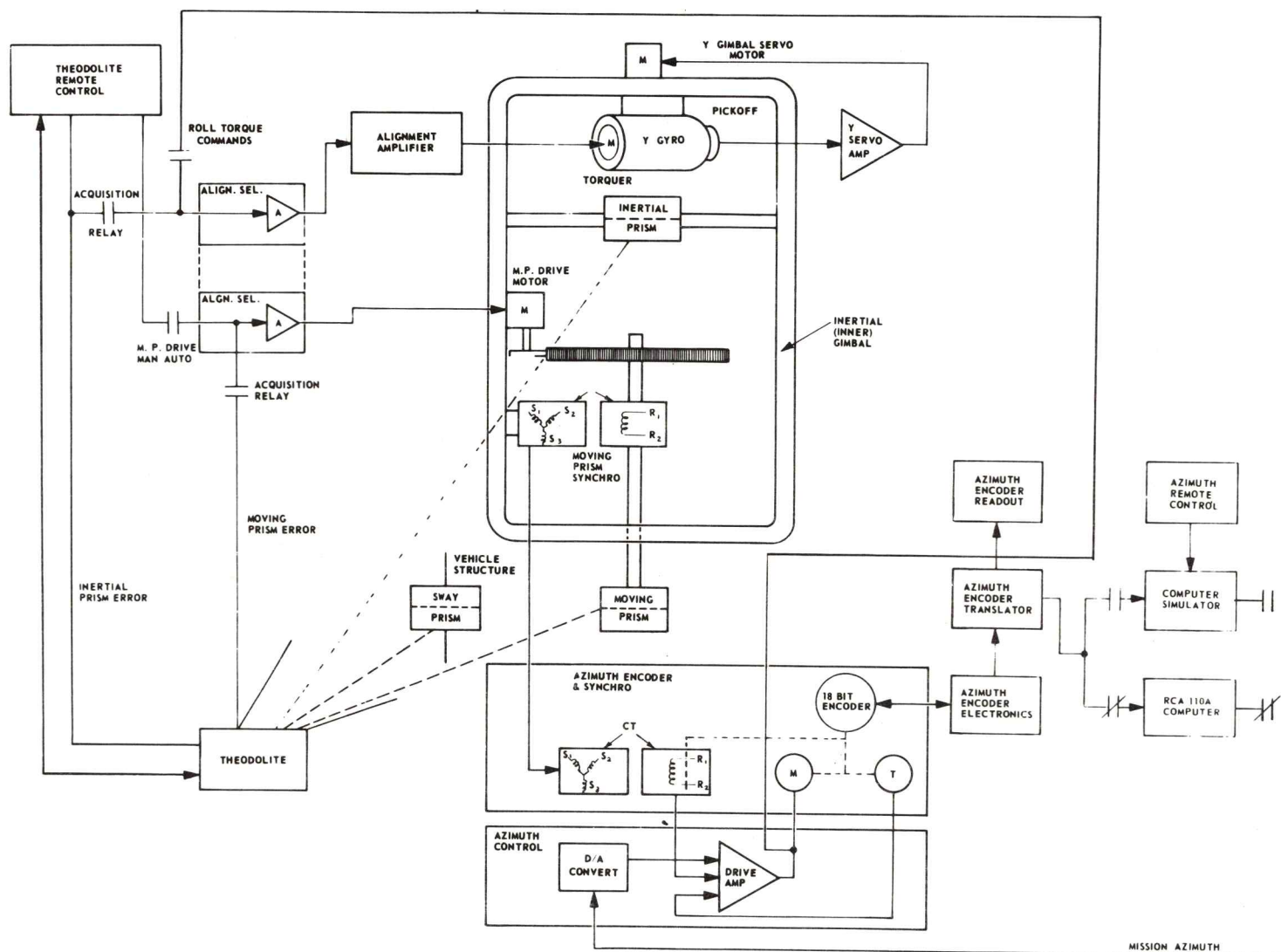


Figure 56. Stable Platform Acquisition Block Diagram

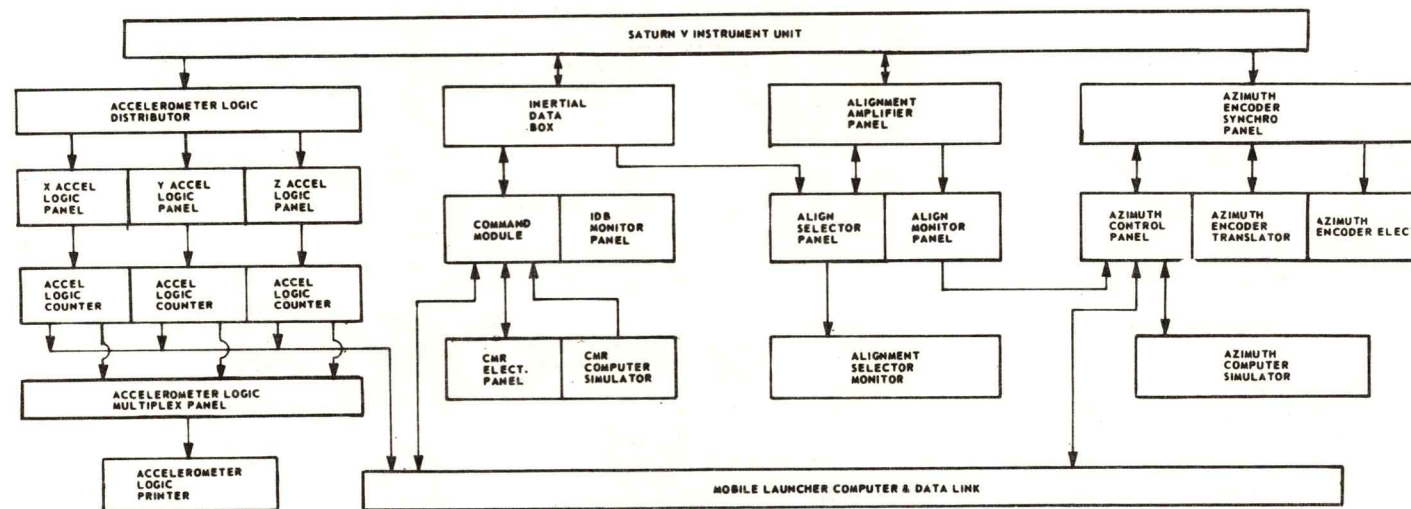


Figure 57. Block Diagram of ST-124M ESE Located in LUT

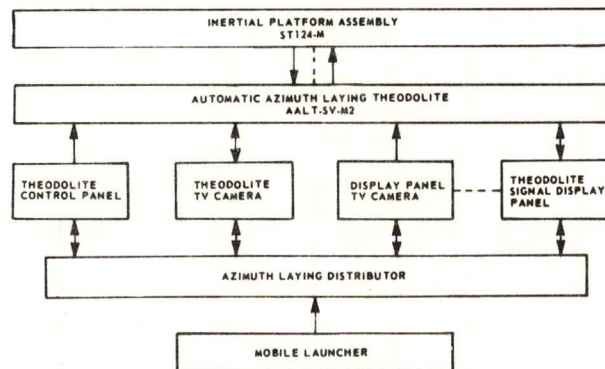


Figure 58. Block Diagram of ST-124M ESE
Located in Theodolite Hut

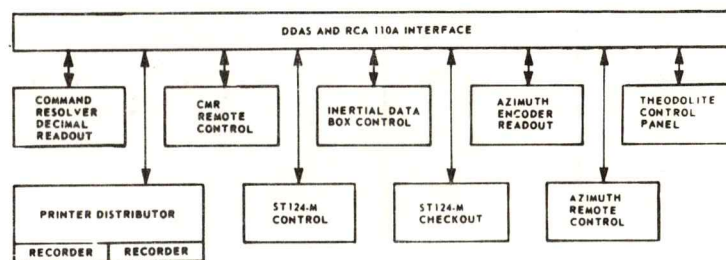


Figure 59. Block Diagram of ST-124M ESE Located in LCC
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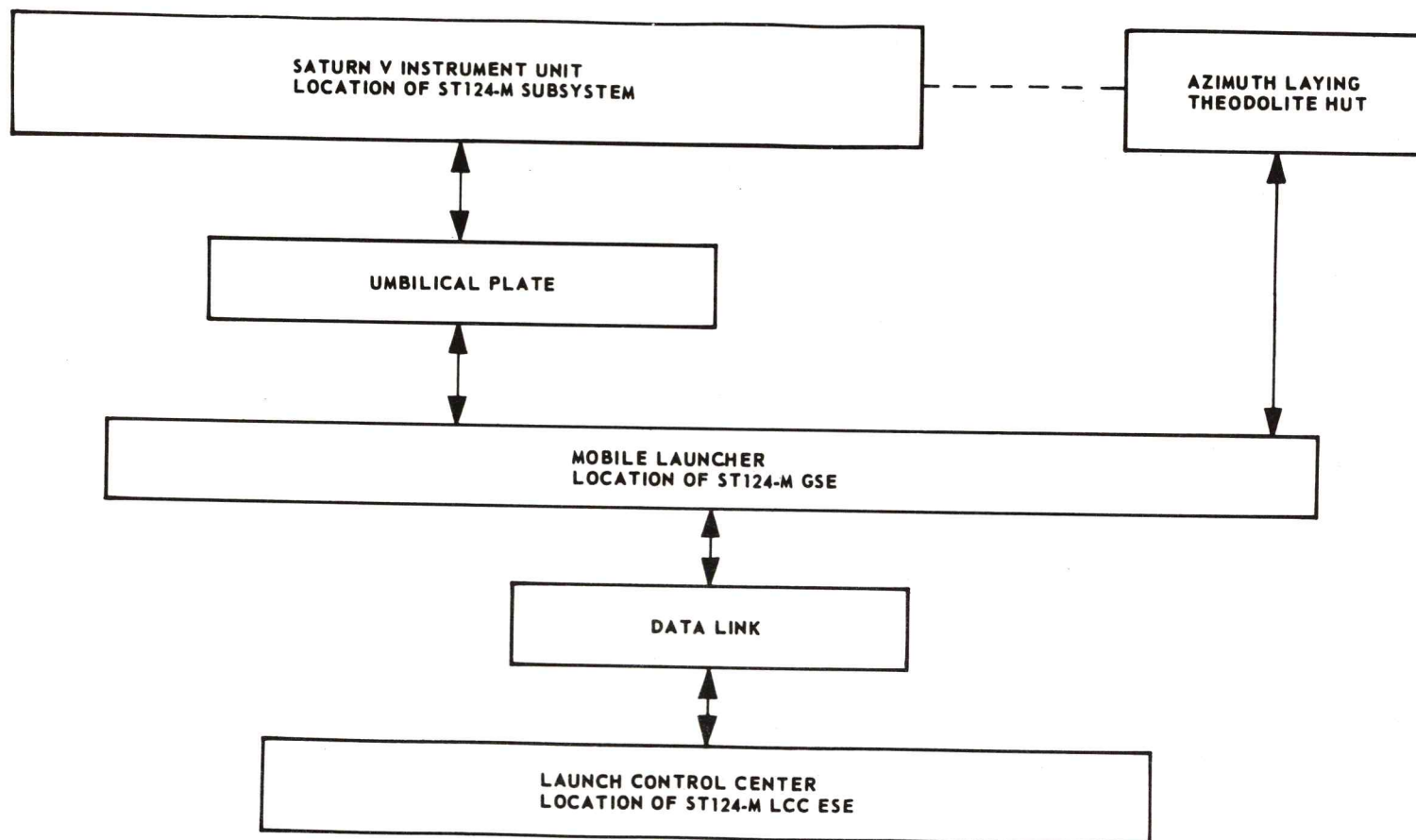


Figure 60. Block Diagram of ST-124M and Launch ESE

connected for communication.

The following is a description of the individual panels which constitute the electrical support equipment.

ALIGNMENT AMPLIFIER PANEL

The alignment amplifier provides circuitry to erect the platform to the local vertical and to align the platform in azimuth to the Y_R pivot sensor or to the inertial prism.

Three similar systems (refer to Figure 61) are provided for these functions, one for each of the attitude sensors. Each is composed of an integrating amplifier, a motor tachometer, a potentiometer, and a torquer amplifier for providing power to the gyro torquer. The signals for leveling the platform are received from the pendulums and fed to the integrating amplifiers. The potentiometers are driven to a setting to compensate for earth's rate, and the loop is closed through the respective X and Z gyro torquers. The roll loop differs in that it receives its input from a synchro located in the Y_R pivot.

The gyro torquing mode of operation, which is commanded external to the alignment amplifier, provides the means for slewing the platform by applying voltages to the gyro torquers. When torquing, the servo system of Figure 61 is switched out. Any of three different rates in either direction can be manually switched in during torquing.

Individual manual controls for each channel are provided within the alignment amplifier for checking out the system. This is accomplished by switching in a reference voltage to the integrator amplifiers and monitoring the torquer amplifier outputs. Verification of the entire amplifier may be commanded externally. Integrator cutouts are incorporated in all loops (X, Y, and Z). Integrator cutout can be commanded (externally) to enable the positioning of any gimbal to any prescribed position for test purposes and still counteract earth's rate. The integrator cutout circuits are activated with the ignition command to "freeze" and thus isolate the three integrators from vibration and erroneous inputs. A test plug is provided for monitoring the functions in the alignment amplifier.

ALIGNMENT SELECTOR PANEL

The alignment selector performs the functions of alignment control and distribution, inertial and synchro prism control, and alignment signal conditioning. All commands for this panel are given by applying 28 v dc to the proper pins on plug J1, which activates relays in this panel. A test plug is provided for monitoring.

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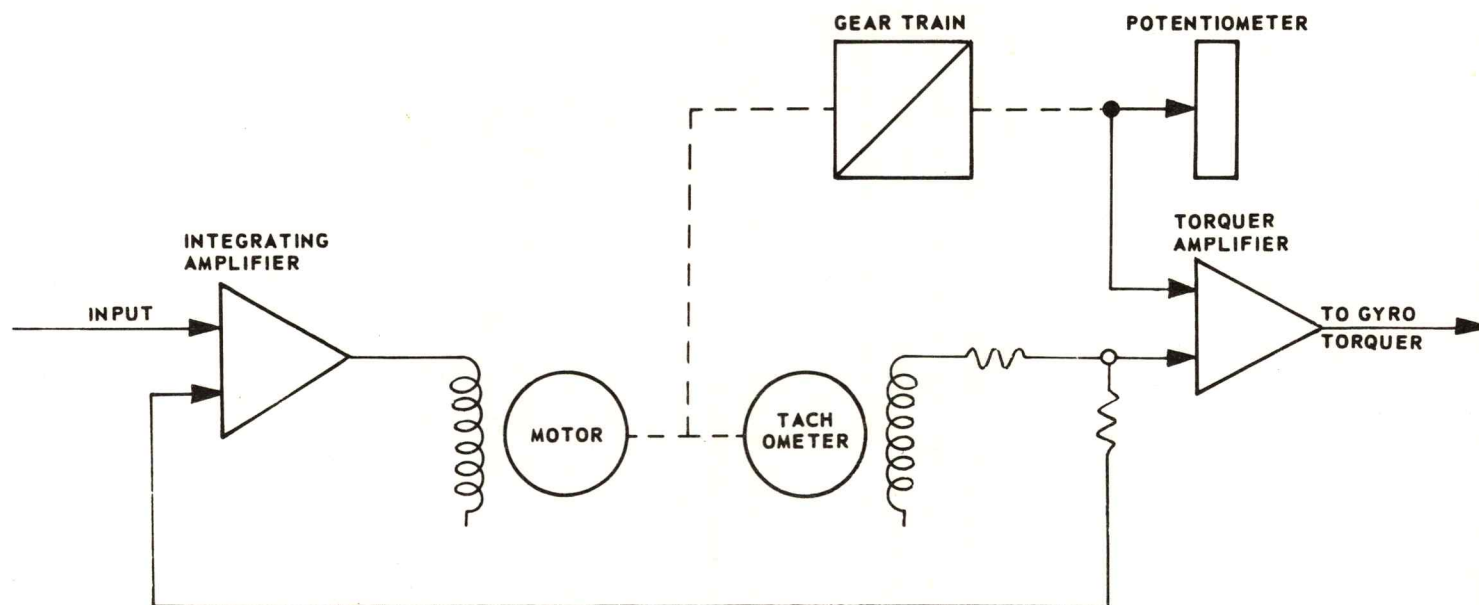


Figure 61. Alignment Servo Control System

The synchro prism may be driven in several operating modes. Manual slewing of the prism in either direction may be commanded at either slow or fast slewing rates. In the automatic slewing mode, prism direction and speed are determined by the output of a phase detector sensing the azimuth synchro repeater position. (This phase detector is in the azimuth control panel.) Upon acquisition of the synchro prism by the theodolite, prism drive modulator--amplifier AM5 is turned on and closes the prism loop as depicted in Figure 62.

The dual prism mode allows both the synchro and inertial prisms to be captured simultaneously by the theodolite. Since the inertial prism is rigidly attached to the inner gimbal, the Y alignment loop is used for inertial gimbal control. A slewing mode is obtained by feeding a voltage to the Y gyro torquer through a transformer. The polarity of this voltage is set by a polarity detector which examines the phi roll signal. In this slewing mode, a command to the Y earth rate bias potentiometer is given to the alignment amplifier. Once the inertial prism is acquired by the theodolite, the Y gyro torquer is controlled by the output of the Y channel of the alignment amplifier, and the torquer is controlled by the output of the Y channel of the alignment amplifier, and the inertial prism signal from the theodolite is modulated and amplified and fed to the input of the Y channel of the alignment amplifier. This closes the inertial prism loop as seen in Figure 63.

Phi signal alignment uses the error voltages from the inertial-data-box command-voltage demodulators as alignment signals for the platform. Since these signals are dc, three modulators, roll (AM6), yaw (AM7), and pitch (AM8), are necessary. The outputs of these modulators may be switched into the input of the alignment amplifier individually by command. In the Y alignment channel, phi roll is used for alignment as a basic mode when the theodolite has not acquired the synchro prism.

The output of the Y repeater (either coarse or fine, depending upon the state of the null detector in the azimuth control panel) is fed to a synchro preamplifier, whose output is switched into the input to the Y channel of the alignment amplifier with synchro prism acquisition.

Alignment of the platform to the buffered 400 CPS gimbal resolver repeater outputs may be commanded in each channel individually.

ALIGNMENT MONITOR PANEL

The alignment monitor panel monitors the various voltages used in aligning the VT124-M platform and receives its inputs directly from the alignment amplifier.

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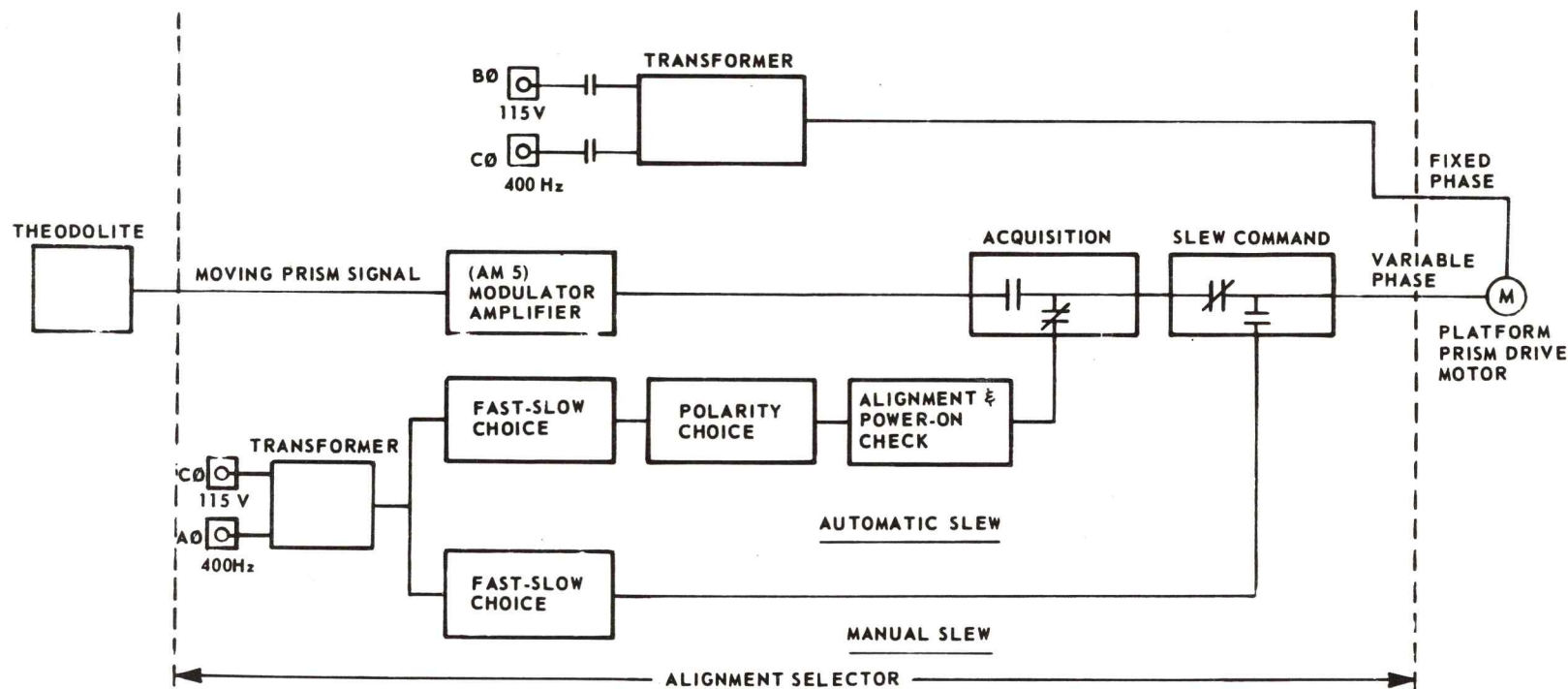


Figure 62. Synchro Prism Control Block Diagram

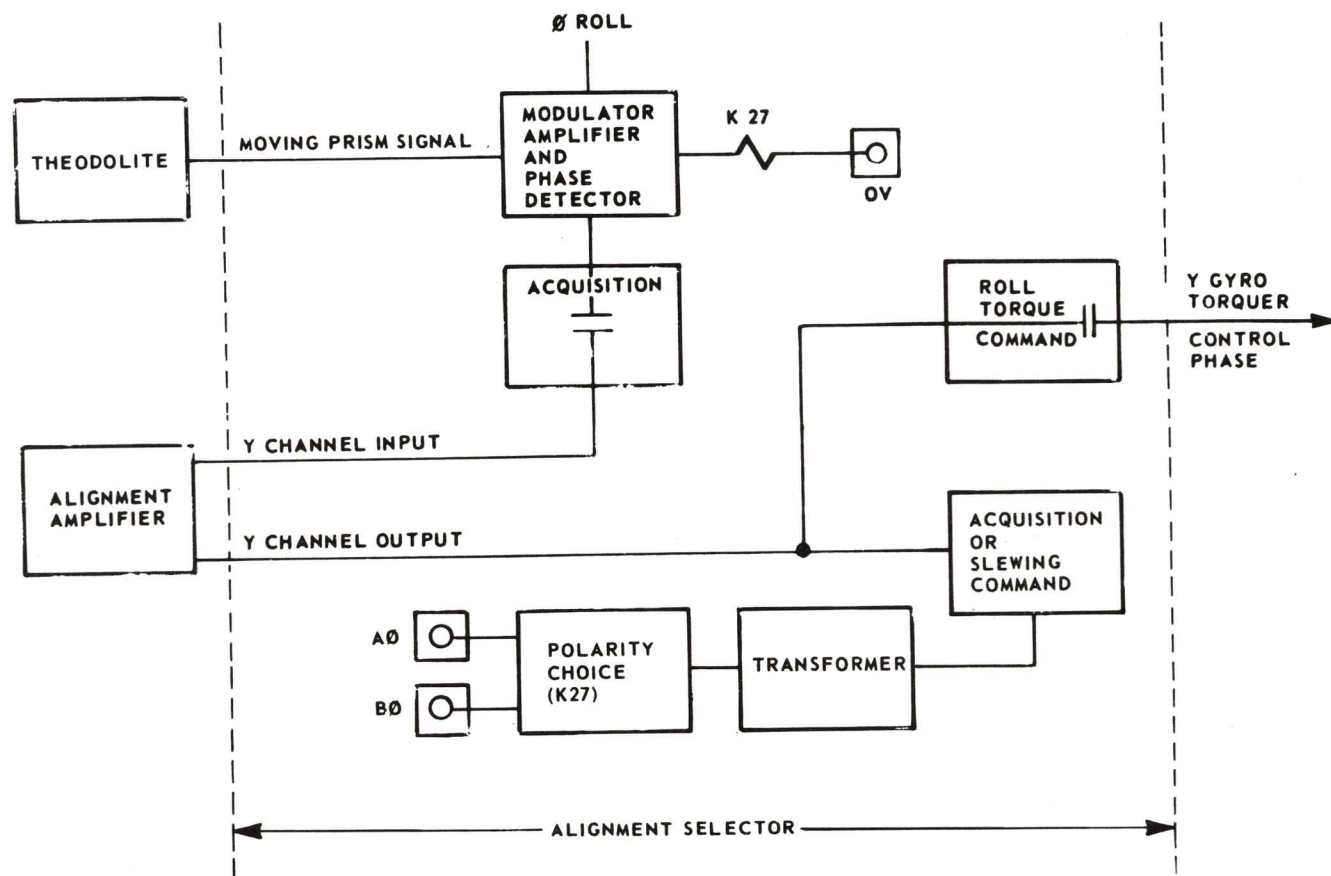


Figure 63. Inertial Prism Control Block Diagram

The panel includes meters for measuring the following voltages:

- a. X torquer amplifier output
- b. Y torquer amplifier output
- c. Z torquer amplifier output
- d. X integrator amplifier output
- e. Y integrator amplifier output
- f. Z integrator amplifier output
- g. 28-V dc power supply
- h. 115-V 3-phase 400-CPS supply (line AB, BC, or AC phase a manually selected)
- i. Additional voltmeters are used to measure the excitation voltages to the earth rate bias potentiometers, earth rate bias potentiometer outputs, and tachometer outputs of the X, Y, and Z loops. The position of a rotary switch selects the individual function that the operator requires for measurement.

Each of the meters is equipped with jacks for calibration or for use in external measurement. Jacks are provided for measuring the X, Z, and azimuth alignment amplifier input voltages and phases. Lamps are also included for indicating the following:

- a. Proper phasing of the 3-phase 400 CPS supply
- b. Erection ON
- c. Y earth rate bias zero command ON

A parallel output plug is provided for automatic data acquisition of all monitored voltages.

ALIGNMENT SELECTOR MONITOR PANEL

This panel is used to monitor the operation of the alignment selector. It contains 8 voltmeters, 8 indicators, and 27 banana jacks. Three of these meters (M_1 , M_2 , and M_3 ,) read the output of the X, Y, and Z phi signal demodulators in the inertial data box. The next three meters (M_4 , M_5 , and M_6) monitor the buffer stages output in the gimbal resolver programmer. M_7 can be switched in to measure the synchro-fixed phase or variable phase or the Y torquer amplifier output. M_8 can be switched in to read 115-volt 400 CPS AC, BC, or AB phase. The indicators show the presence in the alignment selector of +28 V dc, Y repeater phi detector output, phi roll phase detector output, prism drive relay timer, moving prism

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drive relay, inertial prism acquisition, and moving prism acquisition. The banana jacks provide monitoring points for the pivot resolver's outputs, inertial prism theodolite output, and moving prism theodolite output.

AZIMUTH CONTROL PANEL

This panel has two modes of operation. The two modes are controlled by either the platform-follow-command switch or the dual-prism-alignment-command switch (both on the theodolite control panel). A block diagram showing the signal flow of this equipment is given in Figure 64. This panel contains the following pieces of equipment:

- a. Null detector
- b. Phase detector and null detector
- c. Preamplifier
- d. Drive amplifier
- e. Digital to analog converter

In the first mode of operation, the platform-follow-command switch or dual-prism-alignment switch is in the OFF position. Launch control computer functions are fed into the digital to analog converter to the drive amplifier which drives the servomotor/tachometer combination. Since the servomotor is connected mechanically to the stator of the 25:1 synchro repeater, the servomotor drives the control transformer and the platform follows. Essentially, this mode of operation is used to program the platform in azimuth by programming the necessary information into the launch computer.

In the second mode of operation, the platform-follow-command switch or dual-prism-alignment switch is in the ON position. Turning either switch on switches a series of contacts which activate the second mode. In the second mode the control transformer on the 25:1 synchro repeater follows the 25:1 control transmitter on the platform until the rotor on the repeater is at a null voltage. Thus the 25:1 synchro repeater is slaved to the baseline reference on the platform.

AZIMUTH ENCODER ELECTRONICS PANEL

The electronics panel is used with the 18-bit encoder in the azimuth encoder synchro panel. It contains the power supplies for the encoder as well as equipment for operation and interrogation of the encoder. The output is conditioned and sent to the azimuth encoder translator.

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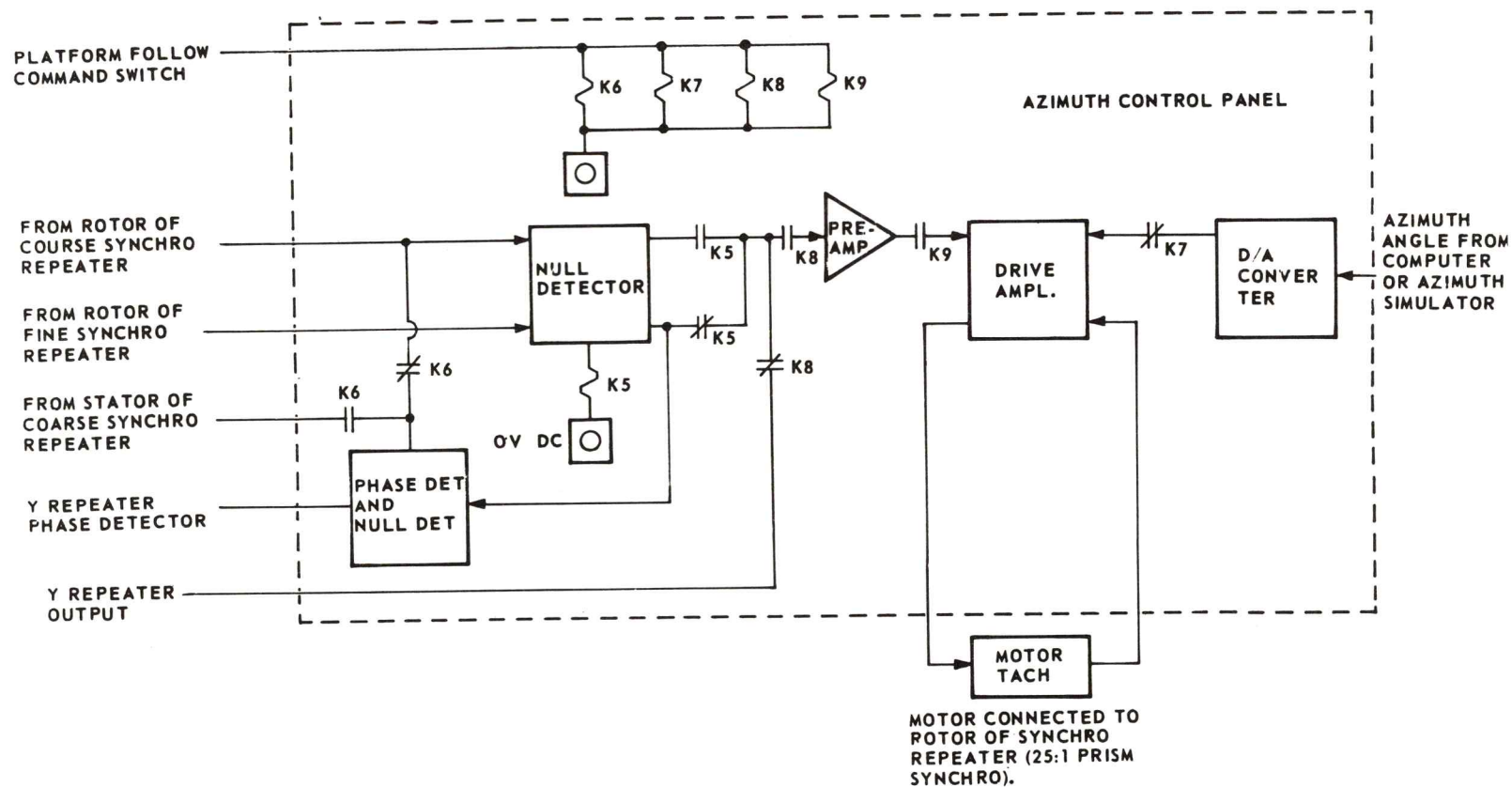


Figure 64. Block Diagram of Signal Flow for the Azimuth Control Panel

AZIMUTH ENCODER TRANSLATOR PANEL

This panel converts the low-level information outputs from the azimuth encoder electronics panel to 9 and 28 V dc gray code levels to be used by the RCA-110A and the azimuth encoder readout. It also converts the same information into a binary output for test purposes.

AZIMUTH ENCODER SYNCHRO PANEL

This panel contains a 25:1 two-speed synchro control transformer which is a backup to the 25:1 synchro transmitter on the ST124-M Y_R pivot. Mechanically ganged to the control transformer is a drive-motor/tachometer combination with a 10^5 :1 gear box and an 18-bit encoder. The units are kept in a special panel enclosure with its own temperature control system. Maximum synchro drive rate is 18 degrees per minute.

AZIMUTH ENCODER READOUT PANEL

The azimuth and command module repeater (CMR) encoder readout units perform substantially identical functions. Both receive parallel gray-coded angular information from their respective encoders and display the encoder angle as a decimal number in degrees, minutes, and seconds of arc. The same panel functions for both applications with a resolution switch to choose between 16-, 17-, 18-, or 19-bit gray-coded inputs. The azimuth and CMR encoder readout units differ only in that the former requires conversion of an 18-bit input while the latter converts a 16-bit input.

As determined by the resolution control, the number of gray-coded binary bits to be displayed are converted, after buffering the level shifting, to a natural binary number in the gray-to-binary converter. This number is preset into the binary countdown counter and then counted down to zero at a rate of 2.62144 megacycles. Concurrent with the countdown process, a binary coded decimal (BCD) counter is counted up from an initial zero state at a rate of 6.48 CPS. When the binary countdown reaches zero, both its clock and that of the BCD counter are stopped. The number in the BCD counter is the BCD representation of the gray-coded input angle times a scale factor equal to the ratio of the two clock frequencies. This ratio is approximately 2.47:1, which is dictated by the conversion factor of 2.47 arc seconds equal one input bit at a conversion accuracy of one part in 2^{19} . This BCD number is stored in a flipflop register, converted to a decimal number, and displayed. The decimal number is also available as parallel output to a printer. The sampling rate may be over the range of 0.2 to 10 seconds.

ACCELEROMETER LOGIC PANEL

The accelerometer logic panel accepts accelerometer inputs from an optisyn

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transmitter, determines the error in precession rate, and measures drift rate. The rate error and drift rate are properly scaled to read in units of meters per second squared and are displayed on a printer.

The accelerometer optisyn has three outputs, two sinusoidal outputs (sine and cosine) yielding 6000 pulses per revolution and a marker channel yielding one pulse per revolution. After the reception of the marker pulse, the leading sinusoid from the optisyn is determined by the rotation sensor. The sinusoid is amplified, shaped, and then counted in the velocity preset counter, which is initially cleared. When the velocity counter reaches 100, it resets itself and starts the 100 KCPS period preset counter. The count to 100 provides a delay of sufficient length for the printer to reprint the previous result. Both the velocity counter and the period counter continue to count until either one records a preset value. The first counter to reach its preset value starts the error counter at a 48 KCPS rate. The second counter to reach its preset value stops the error counter. The velocity counter counts until it reaches 6000 counts, which is the number of pulses in one complete revolution of the optisyn. The period counter will count a 100 KCPS rate until it reaches the number that represents the nominal time for one accelerometer revolution. Thus, if the velocity counter starts the error counter, the precession rate is too high; but if the period counter starts the error counter the precession rate is too low. The sign of the error thus derived is noted at the printed output by the color of the typing. The ratio of the two clocks (100 and 48 KCPS) is such as to cause the error rate to read directly in units of meters per second squared.

The drift rate measurement is initiated manually. Pressing the manual reset clears all counters and starts the period counter counting at a 1 KCPS rate.

Coincidentally, the velocity counter starts counting the optisyn pulses, which actually represent incremental position changes. When the period counter reaches 313 seconds, it starts the error counter counting at a predetermined rate and starts the velocity counter counting down at a 1 KCPS rate. When the velocity counter reaches zero, counting is stopped, and the number in the error counter represents the drift rate in meters per second squared. The value and direction of drift, as determined by the rotation sensor, are printed.

ACCELEROMETER MULTIPLEX (MEMORY) PANEL

The accelerometer multiplex is designed to accumulate and assemble the data from three accelerometer logic panels simultaneously so that these data may be printed out on a single printer.

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ACCELEROMETER PRINTER PANEL

This printer is commercially purchased. It prints on paper tape the data fed to it by the accelerometer multiplex panel.

ACCELEROMETER LOGIC DISTRIBUTOR

The accelerometer logic distributor is a junction box where interconnections between the patch rack, X accelerometer logic, Y accelerometer logic, Z accelerometer logic, and the accelerometer logic multiplexer are made. Accelerometer channel data are fed through the patch rack to the respective accelerometer logic blocks together with 26-volt 400 CPS power. Accelerometer logic outputs (X, Y, and Z) are fed to the accelerometer multiplexer.

LONG RANGE THEODOLITE

The azimuth alignment theodolite required for the various Saturn vehicles operates at distances of 91.5 to 305 meters (300 to 1000 ft) at elevation angles to 25 degrees. It measures separately the azimuth deviation angle of two different vehicle prism with 5-second accuracy and provides automatic acquisition indications. The theodolite system continues to provide azimuth measurement during vehicle sway of 35.5 cm (± 14 in.) amplitude, and sway compensation is made at a rate of 0.76 m/s (30 linear in./s).

The optics of the theodolite provided for this program is a 20.3 cm (8 in.) aperture automatic autocollimator which measures azimuth deviations of two target prisms. A sway compensation system, including a servodriven penta mirror and sway-sensing detectors in the autocollimator, automatically translates the line of sight of the autocollimator to follow the vehicle motion while maintaining precise angular alignment. The autocollimator and the translating penta mirror are on a lathe-bed-type base which may be elevated during setup to acquire the two vehicle prisms. The penta mirror projects the autocollimator beam to the 5 x 5 cm (2 x 2 in.) prisms, and the energy reflected back to the autocollimator generates separate error signals whenever either prism moves from its desired azimuth orientation. The vehicle can be seen on the launch control center TV monitor at all times by the TV camera which views it through the autocollimator. The theodolite can be remotely controlled to center the prisms in the field. The prisms may translate (sway), but once the prisms are acquired, the sway tracking feature automatically translates the penta mirror set to maintain the centering within 1.27 cm ($\pm 1/2$ in.) over a 71 cm (28 in.) range. Since penta mirror deviation is virtually unaffected by small rotations, its use permits accurate readout of the vehicle prism alignments, even in the presence of sway.

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The long range theodolite is equipped with a reference prism located within the range of penta mirror travel and is oriented to the desired alignment direction by survey. Autocollimator zero alignment can easily be checked by positioning the penta mirror in front of the reference prism; therefore, the reference prism is used to check the final alignment of the theodolite and its electronics. The long range theodolite accomplishes simultaneous but separate alignment of two prisms, the lower or synchro prism and the upper or inertial prism, by spectral separation of the transmitted energy from the two prisms and by spectral discrimination of the returned energy. Spectral separation refers to the spatial separation of the electromagnetic energy in a light beam on the basis of its wavelength. In the long range theodolite system, a spectral separation is accomplished by the use of dichroic coatings on various optical elements and is utilized to allow the system to serve three independent functions. These functions are alignment of the inertial prism, alignment of the synchro prism, and adjustment of the theodolite with respect to the vehicle (sway compensation).

THEODOLITE OPERATIONS DISPLAY PANEL

The theodolite operations display is a portion of electrical support equipment found in the theodolite hut; it consists of a panel with three meters. One meter indicates penta mirror position (in inches) and the other two meters indicate azimuth error (in arc seconds). On the panel are a sway servo acquisition light, two angular error acquisition lights, and a scale factor control (potentiometer) or gain control. This panel is monitored in the launch control center with a closed loop TV monitor.

THEODOLITE POWER AND CONTROL PANEL

The theodolite power and control panel consists of a master switch to activate the theodolite and controls to operate the penta mirror horizontally and vertically. This equipment will be found in the theodolite hut.

THEODOLITE DISTRIBUTOR PANEL

The theodolite distributor, located in the theodolite hut, serves as an interface between the theodolite equipment, the power, and the alignment selector panels in the mobile launcher. The distributor provides voltage monitoring of the theodolite's 28-V dc and 115-volt 400 CPS supplies. A shutter test is manually initiated by pressing a button on the distributor panel.

THEODOLITE CONTROL PANEL

The theodolite control panel contains switches and indicators for controlling the azimuth laying scheme of the platform. All switches are three-position (ON-AUTOMATIC-OFF), as is true of the switches on all control panels. Located in

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the launch control center, this panel has been designed to control the long range theodolite system at the launch site. The controls are:

- a. Synchro prism power
- b. Inertial prism power
- c. Penta mirror drive (left and right)
- d. Theodolite elevate and depress
- e. Automatic checkout
- f. Dual prism align
- g. Synchro prism manual control

Indicator lights are:

- a. Azimuth alignment null
- b. Inertial prism acquisition
- c. Synchro prism acquisition
- d. Remote power control
- e. Sway control acquisition

COMMAND MODULE REPEATER PANEL

This panel is used to convert RCA-110A position commands into a form that can be used to position the inertial data box chi modules or to read out their position. It contains an 8:1 dual resolver for electrical followup of the 8:1 dual resolver in the inertial data box. The followup dual resolver is mechanically coupled at a 16-bit optical encoder and through a gear train to the drive motor. The panel consists of a single followup servoloop and switching circuits. These are used to select one of the three chi resolvers of the inertial data box to be positioned. Also included in the panel are two digital to analog converter cards, drive amplifier, preamplifier, demodulator, null detector, and a 16-volt transformer for resolver excitation. Figure 65 shows a block diagram of the command module repeater system.

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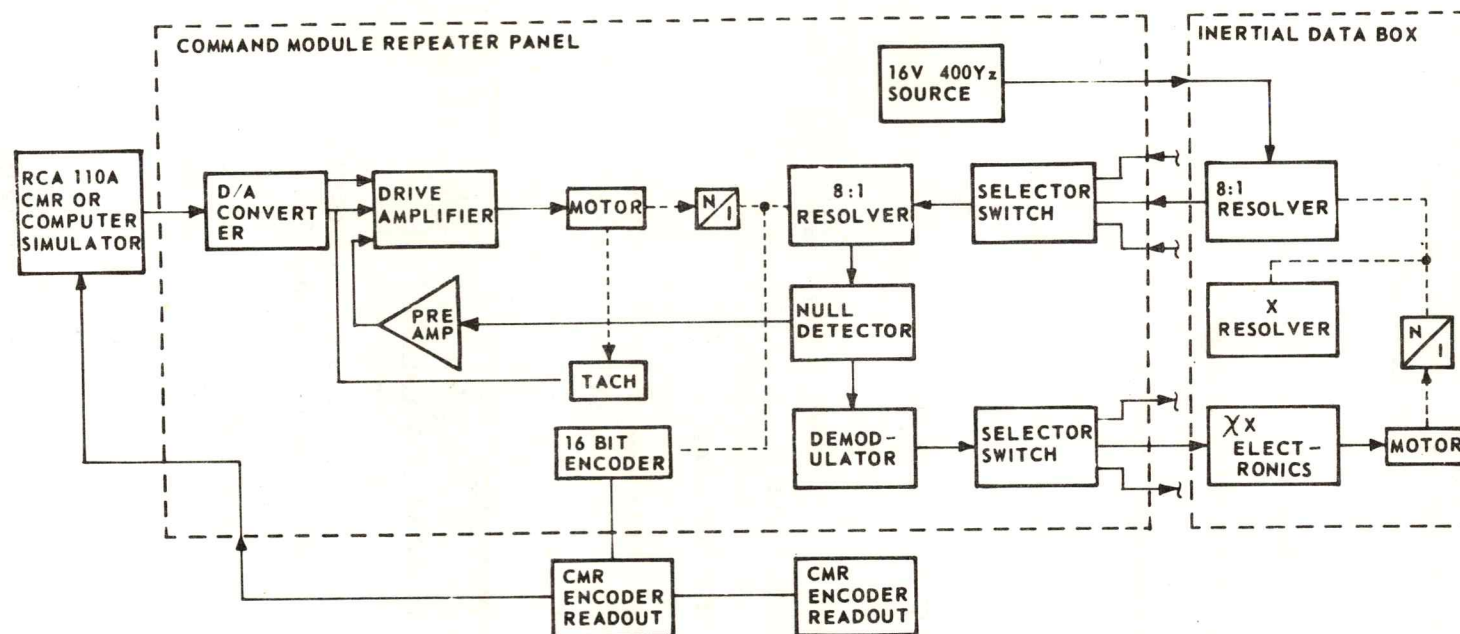


Figure 65. Block Diagram of 3 Phase 400 cps Power Amplifier

COMMAND MODULE REPEATER (CMR) ENCODER READOUT PANEL

This panel contains logic circuitry necessary to give a decimal indication of the CMR angular position. It is essentially identical to the azimuth encoder readout.

COMMAND MODULE REPEATER (CMR) ENCODER ELECTRONICS PANEL

This panel provides the buffering for the output of the CMR encoder. It receives a parallel 16-bit, cyclic gray-coded number from the encoder upon interrogation. It amplifies these encoder signals and sends them to the CMR. Input to this panel is in the form of low-level pulses of 5 microseconds duration, occurring at interrogate time. These are amplified and level detected, resulting in a 20-microsecond pulse from the amplifier detector. These pulses are gated into a flipflop buffer register by a 9-micro-second gate pulse. Output amplifiers attached to the buffer register provide high-level outputs.

INERTIAL DATA BOX

The inertial data box has the following functions:

- a. The chi programmers generate signals needed to calibrate platform gimbal angle transducers.
- b. The command voltage demodulators supply signals proportional to the angular difference between desired gimbal attitudes and programmed attitudes.
- c. The electronic cards condition the accelerometer outputs to the inputs of the computer.

The following modules are used in the inertial data box:

- a. Three chi programmers
- b. Three command voltage demodulators
- c. 1.6 and 1.92 CPS power amplifiers
- d. 20-V dc supply
- e. Provision for 12 accelerometer buffers and shapers (for flight units only).

The chi programmer consists of three channels. Each channel consists of a motor/tachometer, a program resolver, an 8:1 resolver, a potentiometer, a

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brake, and associated gearing. The chi programmer drives a resolver, which is a unit in a resolver chain, and generates the error signals needed for the correct determination of the vehicle attitude. The input signal to the chi programmer is a step input of 48 Mv, 5 ms increments. This is summed with the output of the tachometer which is a 400-CPS signal. The tachometer output is converted to a dc signal by means of a buffer, demodulator, and filter. The buffer presents a high impedance to the tachometer to avoid loading. The filter will attenuate any noise and stray signals. The dc input is converted to a 400-CPS signal by a modulator which in turn feeds the chi servo-amplifier.

The command voltage demodulator (CVD) provides a dc signal proportional to the error between the platform gimbal and the programmer. Three CVD's are in the inertial data box, pitch, roll, and yaw. The pitch and roll CVD uses a 1.6 KCPS and 1.92 KCPS signal. Since the signal is common to both pitch and yaw CVD, a crisscross feedback arrangement is used to cancel out the 1.6 KCPS signal in the 1.92 KCPS yaw channel and the 1.92 KCPS signal in the 1.6 KCPS pitch channel.

The pitch CVD has three dc outputs: The computer output, the telemetry output, and the error-nulling-signal output. The computer output signal is proportional to the pitch error 1.6 KCPS input signal. The telemetry output consists of two dc signals used for telemetry information. The error nulling signal provides a 1.6 KCPS output in opposite phase with the input that is fed to the input summing junction of the yaw CVD. The signal cancels the input 1.6 KCPS signal entering the yaw CVD and leaves only the 1.92 KCPS yaw error signal. The operation of the yaw channel is the same as the pitch channel except that its carrier is 1.92 KCPS.

The 1.6 and 1.92 KCPS power amplifiers each supply a 26-volt rms sine wave to excite the program resolver chain and a 20-volt peak-to-peak square wave to the keying circuits of the CVD.

INERTIAL DATA BOX CONTROL PANEL

This panel contains switches and indicators necessary for controlling functions related to the inertial data box. Switches are three-position (ON-OFF-AUTOMATIC). The functions controlled are:

- a. Chi mode select (X, Y, and Z)
- b. Chi brakes (X, Y, and Z)
- c. Phi signal zero (X, Y, and Z)
- d. Power
- e. CMR follow or drive

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This panel monitors the operation of the inertial data box. It contains six voltmeters, two indicators, and a number of banana jacks. The meters have double scales and are connected across binding posts for monitoring and calibrating purposes. Meter M_1 can be switched in to measure the drive amplifier output of either the X_x , X_y , or X_z system; and Meter M_3 can be switched in to measure the tachometer output of either the X_x , X_y , or X_z system. Meters M_4 , M_5 , and M_6 Monitor the output of the yaw, roll, and pitch demodulators in the inertial data box. Of the two indicators in this panel, one monitor is 28 V dc and the other is 56 V dc. Banana jacks are employed to monitor the X_x , X_y , and X_z telemetry potentiometer outputs, the 26-volt 3-phase 400-CPS supply, and the input and output of the 1.6 KCPS power amplifiers. A parallel output plug is provided for automatic data acquisition of all monitored signals.

ST124-M (STABILIZER) CONTROL PANEL

This panel contains a series of lights and switches that are used to turn on the relays in the platform electronics assembly as well as to turn on power to the 56-volt power supply and the ESE panels. The switches all have three positions (ON-OFF-AUTOMATIC). If all the switches are in the AUTOMATIC position, the launch control computer is allowed to control the command lines. In either the OFF or the ON position, the computer is inhibited. Whenever a command line is excited, either manually or by the computer, an indicator will light. Three phase meters are included on this panel along with three manual gyro torquer switches for small angle platform positioning. The functions controlled are:

- a. Dc power
- b. 4.8 KCPS reference
- c. Platform blowers
- d. Gyro and accelerometer power
- e. X, Y, and Z gyro loops
- f. Accelerometer and gyro loops
- g. Platform heaters

ST124-M (STABILIZER) CHECKOUT PANEL

This panel contains the command switches and indications for the automatic checkout of the ST124-M platform, i. e., circuit-selection and pulse-application

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switches. The same computer switch principle as used on the stabilizer control panel is applied here. Switches and indicators are also provided for slaving the platform alignment to the attitude (ϕ) signals. Relays are incorporated within the panel for use with the pulse select indicators for automatic checkout.

SERVO MONITOR (PORTABLE) PANEL

The servo monitor is used to monitor voltages and currents supplied to and generated within the platform electronics assembly for the gyro and accelerometers motors and servoloops. The panel includes provisions for measuring the 400-CPS 3-phase voltages and currents, input and output voltages of the servoamplifier power stage, and associated voltage such as amplifier dc supply and 4.8 KCPS keying voltage.

Six ammeters continuously monitor the A-, B-, C-phase gyros and accelerometers. Similarly, the driver outputs for the X, Y, and Z gyro and X, Y, and Z accelerometer servoloops are measured using ammeters with the added provisions of a manual switch for each meter for scale change. This permits a reading under normal conditions (no input disturbance) and when input disturbances are present. The servo amplifier input voltages are measured by switching each in separately to a voltmeter. Binding posts are provided to measure all these voltages with a portable voltmeter, which can also measure the 56-V dc supply, a 4.8 KCPS supply, and 26-volt 400-CPS supply.

A spin detector circuit is provided for protection of the platform gyros and accelerometer. Its function is to detect any malfunction by monitoring the gyro and accelerometer preamplifier outputs. If any output goes over 25 volts, a relay is energized that sends a 48-V dc command through the platform electronics assembly and patch panel to the power distribution panel which shuts off the loops and wheels. An override switch is provided on the front panel.

THREE-PHASE 400-CPS POWER AMPLIFIER PANEL

This panel will supply 100-A 115-volt 3-phase power to the ST124-M ESE. The output voltage is referenced to the 26-volt platform ac power supply. Each phase contains a 115-volt to 26-volt stepdown transformer, a Variac, and a transistorized power amplifier. The panel contains three ac ammeters, one ac voltmeter, and a selector switch. One ammeter is used to monitor each phase while the voltmeter monitors all three phases by means of the selector switch. A block diagram of the power amplifier panel is shown in Figure 66.

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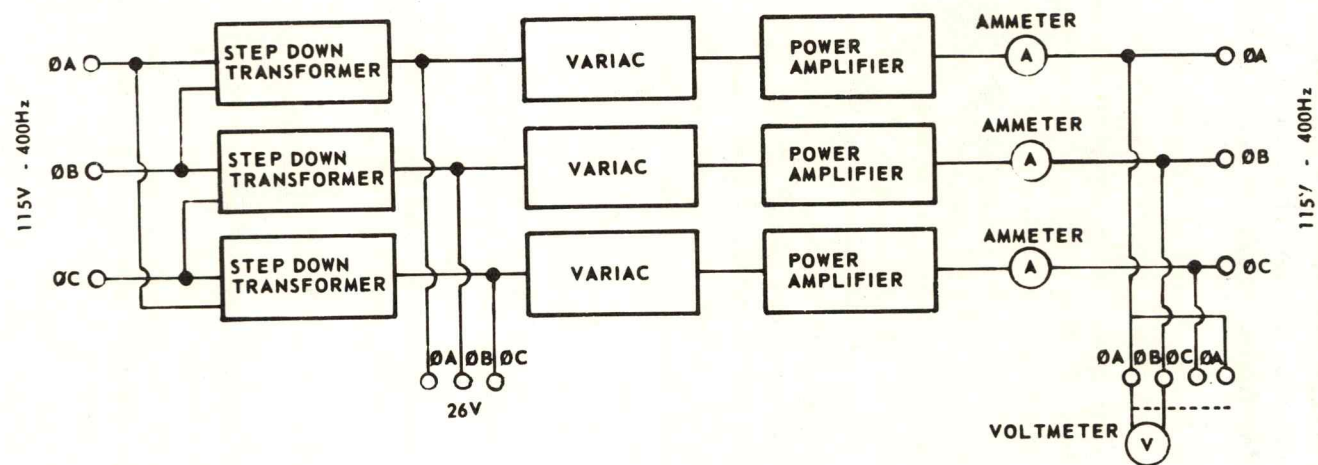


Figure 66. Block Diagram of 3 Phase 400 cps Power Amp

SUMMARY

The ST124-M platform system was designed for use with the Saturn V launch vehicles to support the Apollo mission. It is the latest generation of the ST124 series of platform systems. The ST124 platform system was a system concept developed early in the Saturn program to support the Saturn launch vehicles. The ST-124M-3 platform used in the Apollo program is a 3 gimbal limited to ± 45 degrees in the X(yaw) axis.

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CHAPTER III

SECTION VII

MISCELLANEOUS INTEGRATION EQUIPMENT

INTRODUCTION

The systems integration ESE provides the means to interface between the Saturn V vehicle stages, stage ESE, ground computers, and operational control and monitoring of normal and emergency functions that are concerned with the integrated vehicle system. The integration equipment that provides interface for monitoring and control functions of the integrated vehicle is our primary concern here.

DESCRIPTION

The system integration ESE provides displays, interlocking logic, distribution equipment, checking and timing devices, and test equipment, which provide monitoring and control of the Saturn V vehicle and launch operation facilities.

In the Launch Control Center, the integration system consists of three junction racks. These junction racks contain program distributors, patchboards, test panels, etc. The purpose of the racks is to interface with other vehicle integration junction racks and provide stage status signal and control interlock functions.

In the LUT, system integration equipment is composed of three standard distributor racks containing relays and patchboards. The purpose of these racks is to interface with other vehicle stage relay racks and provide status, signal, and control interlock functions. The electrical integration equipment is composed of the following:

1. Launch Vehicle Operations Status Display
2. Range Safety Supervisor Panel
3. Integration S-IC Operations Status Display Panel
4. Integration S-II Operations Status Display Panel
5. Integration Sapce Vehicle Test Supervisor Status and Event Display Panel
6. Integration Operations Safety Supervisor Panel
7. Integration Sequence Recorder

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8. Integration I. U. Operations Status Display Panel
9. Integration Measuring Recorder
10. Integration S-IVB Operations Status Display Panel
11. Integration Vehicle Network Panel
12. Three Junction Racks
13. Three Relay Racks

The signal interface with the LCC Computer is with Input/Output registers (IOR). IOR #4 is the output register to the payload systems and IOR #6 is the input register to the computer from the spacecraft systems. IOR #5 is the input register to the computer from the telemetry systems. The IORs are 24 bit, individually addressable buffer registers used to both receive and send information to the peripheral systems as required.

SUMMARY

The integration equipment provides a means of communication between the RCA-110A computer and the launch vehicle systems. Signals are routed through distributors, patch board, etc., as required to computer IOR #6. The computer performs its assigned functions as determined by the program and applies output signals to the integration equipment through output IOR #4. The output from IOR #4 is applied to equipment such as telemetry, guidance computers, payload and transmission lines.

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APPENDIX A

OFTEN USED ABBREVIATIONS FOR SATURN V PROGRAM

ACE	Automatic Checkout Equipment
ADPS	Automatic Data Processing System
AGE	Aero-Space Ground Equipment
A&M	Assembly and Maintenance
AMR	Atlantic Missile Range
APU	Auxiliary Power Unit
ASE	Automatic Support Equipment
BATC	Boeing Atlantic Test Center
BECO	Booster Engine Cut-off
BTU	British Thermal Unit
BOE	Boeing Company
CCP	Contract Change Proposal
CDS	Command Destruct System
CFAE	Contractor Furnished Airborne Equipment
CFE	Contractor Furnished Equipment
CFP	Customer Furnished Property
CIF	Central Instrumentation Facility
C/O	Checkout
CPFF	Cost Plus A Fixed Fee
CPIF	Cost Plus Incentive Fee
CPS	Cycles Per Second
CSM	Command and Service Module
DAC	Douglas Aircraft Company
DCS	Digital Command System
DDAS	Digital Data Acquisition System
DRL	Drawing Release List
DEE	Digital Events Evaluator
EASE	Electrical Automatic Support Equipment
EBW	Exploding Bridge Wire
ECP	Engineering Change Proposal
ECS	Environmental Control System
EDP	Electronic Data Processing
EDS	Emergency Detection System
EO	Engineering Order
EOR	Earth Orbit Rendezvous
ER	Event Recorder
ESE	Electrical Support Equipment

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FCO	Functional Checkout
FCS	F light Control System
FGE	Fa ctory Ground Equipment
FSE	Factory Support Equipment
FR	Firing Room
GE	General Electric
G&C	Guidance and Control
GETS	Ground Equipment Test Set
GFE	Government Furnished Equipment
GFP	Government Furnished Property
GG	G as Generator
GHE	Ground Handling Equipment
GN ₂	Gaseous Nitrogen
GSE	Ground Support Equipment
GTE	Ground Transport Equipment
H	Hydrogen
He	Helium
IBM	International Business Machines
IC&C	Installation Calibration & Checkout
In. HG	Inches of Mercury
In. H ₂ O	Inches of Water
IPB	Illustrated Parts Breakdown
IRFNA	Inhibited Red Fuming Nitric Acid
IU	Instrument Unit
I-V-G	Saturn V Launch Vehicle GSE Office
KSC	Kennedy Space Center
LC	Launch Complex
LCC	Launch Control Center
LEM	Lunar Excursion Module
LH ₂	Liquid Helium
LN ₂	Liquid Nitrogen
LO ₂	Liquid Oxygen (Preferred)
LOX	Liquid Oxygen
LUT	Launch Umbilical Tower
LOC	Launch Operations Center
LVDC	Launch Vehicle Digital Computer
LVGSE	Launch Vehicle Ground Support Equipment
MLF	Mobile Launch Facility
MST	Mississippi Booster Test

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MCC	Mission Control Center
MLLP	Manned Lunar Landing Program
MRB	Material Review Board
MS	Military Standard
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
MTO	Mississippi Test Operations
MAB	Mechanical Automated Breadboard
MILA	Merritt Island Launch Area
MGSE	Mechanical Ground Support Equipment
ML-1	Mobile Launch No. 1
NAA	North American Aviation
NASA	National Aeronautics and Space Administration
NEC	National Electric Code
N ₂ O ₄	Nitrogen Tetroxide
OATS	Overall Test Set
OD	Operations Directive
OGE	Operating Ground Equipment
OMSF	Office of Manned Space Flight
OP	Operating Procedure
OR	Operations Requirements
PCN	Production Change Number
PE	Purchased Equipment
PERT	Program Evaluation Review Technique
PMR	Pacific Missile Range
PLS	Propellant Loading System
POC	Production Order Change
psi	Pounds per square inch
QRA	Quality and Reliability Assurance Dept.
RACON	Radar Beacon
R&D	Research and Development
RFNA	Red Fuming Nitric Acid
RFP	Request for Proposal
RFQ	Request for Quotation
RTV	Return to Vendor
RDO	Redundant Discrete Output
SAUTF	Service Arm/Umbilical Test Facility
SDS	Scientific Data Systems
SOI	Standard Operating Instruction

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SOP	Standard Operating Procedure
SPEEA	Seattle Professional Engineering Employees Association
SPED	Saturn Production Engineering Document
STE	Special Test Equipment
SDF	Systems Development Facility
SDBF	System Development Breadboard Facility
SIM	Simulator
TCTO	Time Compliance Technical Order
T/L	Task List
TN	Technical Note
TO	Technical Order
TVC	Thrust Vector Control
TWS	Technical Work Statement
TM	Telemetry
UDMH	Unsymmetrical Dimethyl Hydrazine
UR	Unsatisfactory Report
VAB	Vehicle Assembly Building (MILA)
VAB	Vertical Assembly Building (Michoud)
VLF	Vertical Launch Facility
VABH	Vertical Assembly Building High Bay
VABL	Vertical Assembly Building Low Bay
WFNA	White Fuming Nitric Acid

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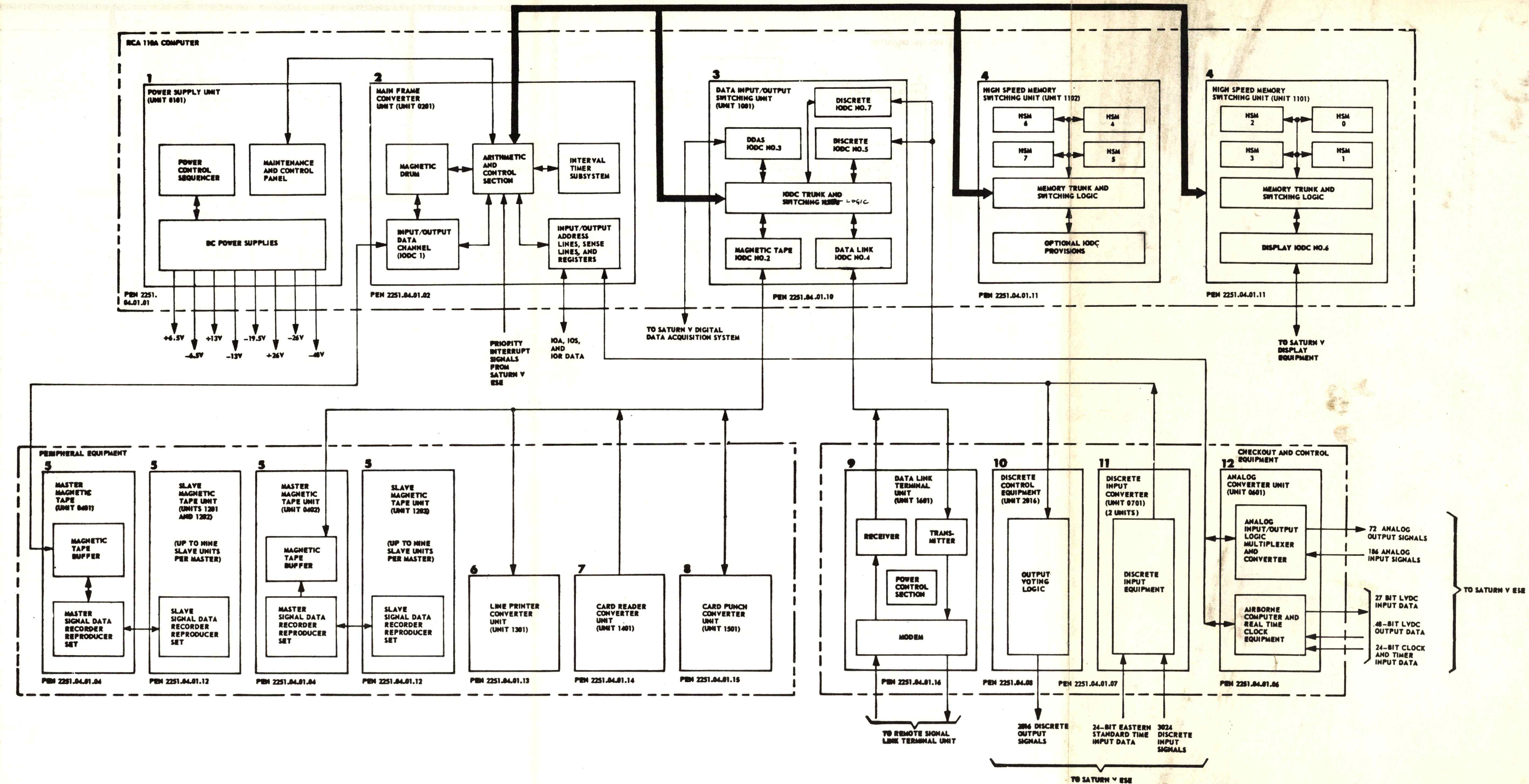


Figure 15. Saturn V Ground Computer System Signal Flow
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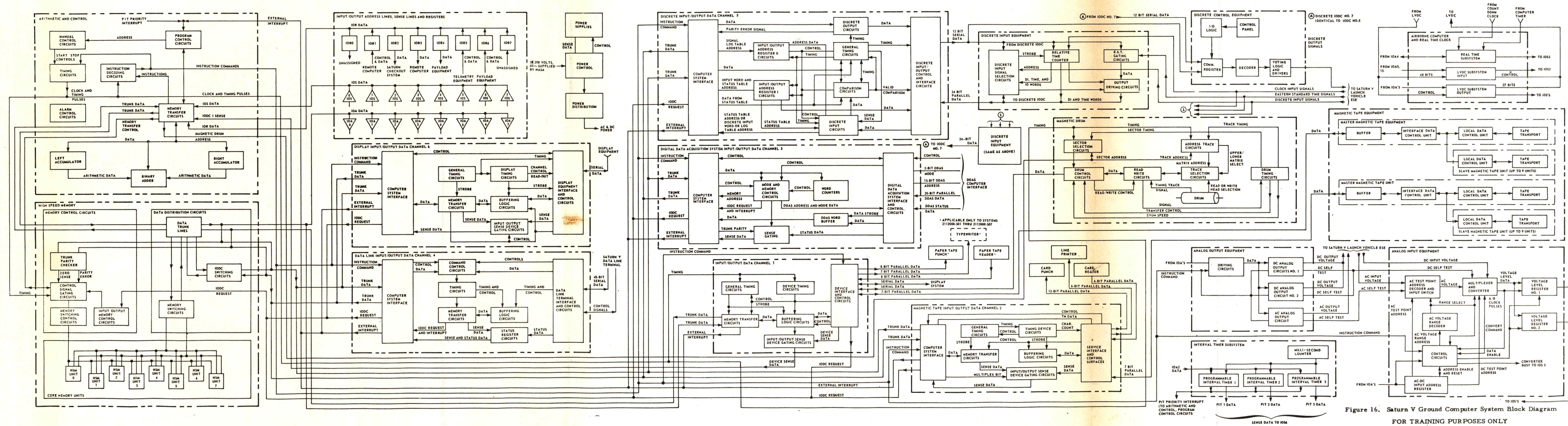
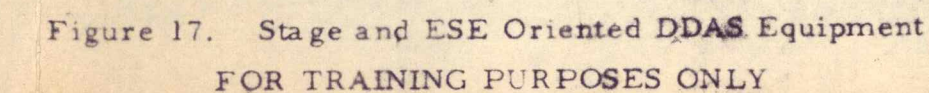
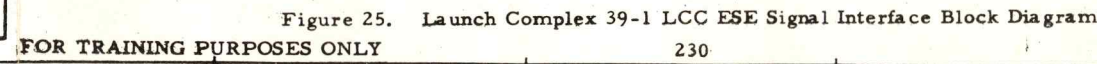


Figure 16. Saturn V Ground Computer System Block Diagram
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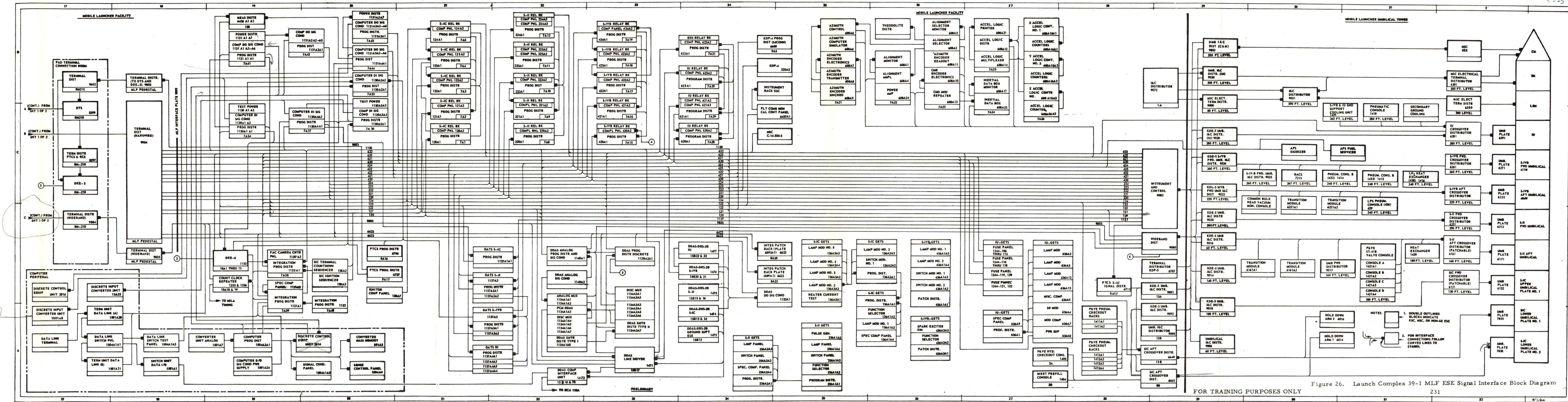


Figure 26. Launch Complex 39-1 MLF ESE Signal Interface Block Diagram

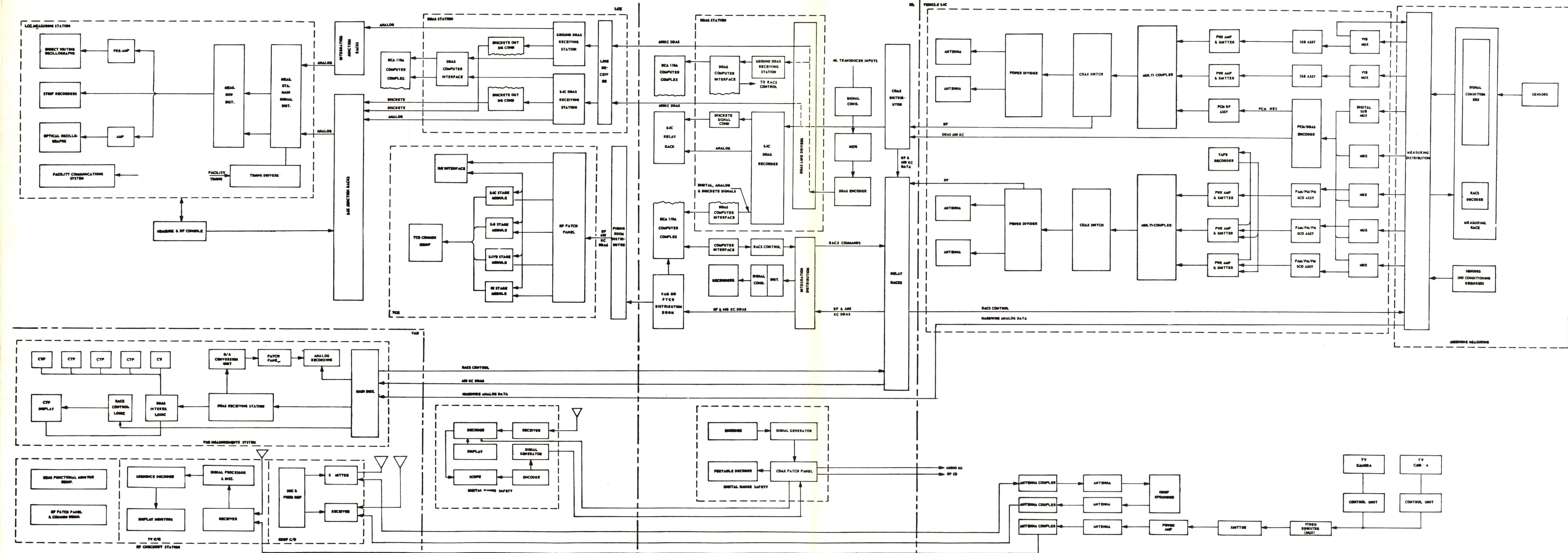
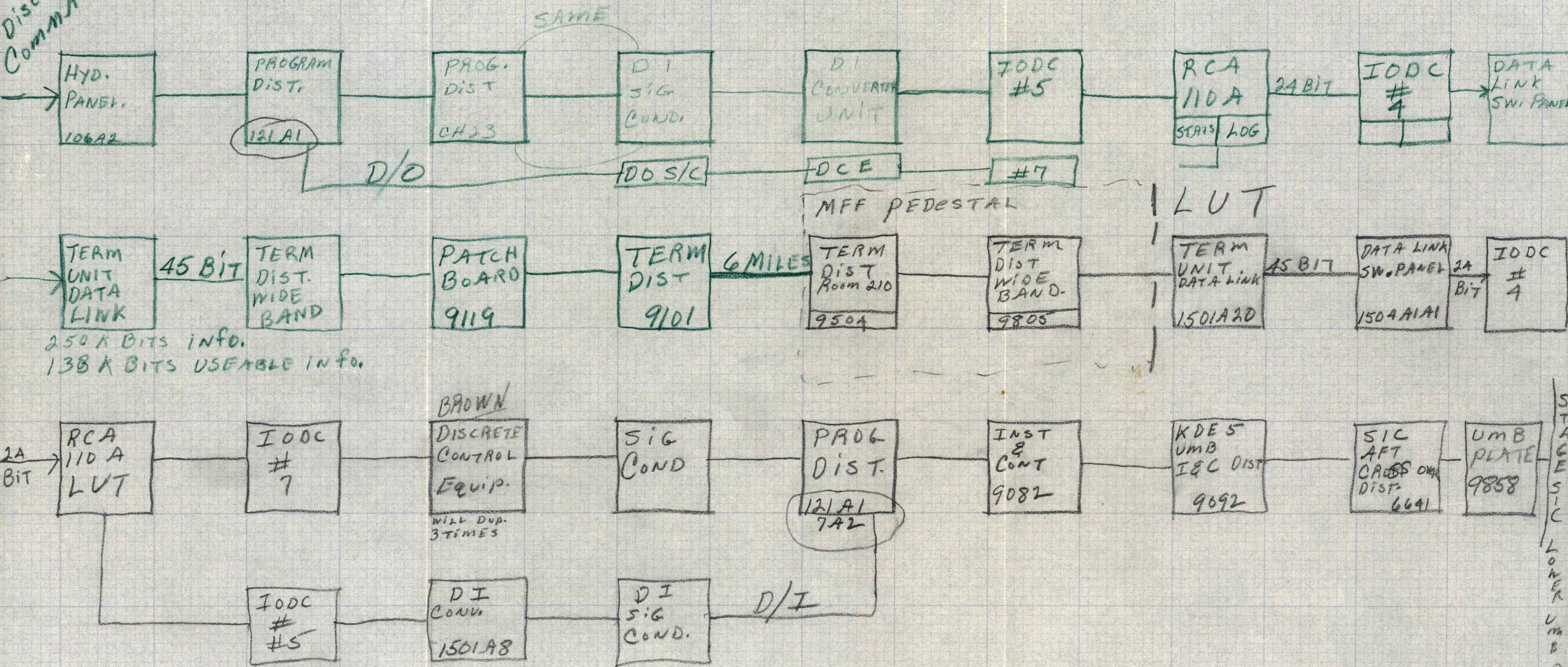


Figure 27. Instrumentation and RF Ground C/O Station
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DISCRETE
COMMAND.

LCC



CONTINUOUS SCAN - (TILL TERMINATION)

SINGLE SCAN - LOGS THE INFO (POSITION) IN STATUS TABLE.

CONTINUOUS SCAN - LOGS THE CHGS. OF POSITION AND TIME TAG, IN A LOG TABLE & UPDATE STATUS TABLE.

MONITOR MODE - WITH SELECTIVE PORTATORY INTERRUPT.

STATUS
TABLE
SIC
LOWER
UMB
PLATE
H2