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MANNED SPACE FLIGHT NETWORK PREMISSION TEST AIRCRAFT SYSTEMS DESCRIPTION

JANUARY 31, 1964

GODDARD SPACE FLIGHT CENTER
GREENBELT, MD.

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PREMISSION TEST AIRCRAFT

SYSTEMS DESCRIPTION

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Prepared by

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SECTION I

INTRODUCTION

The purpose of this document is to serve as a guide for familiarizing technically oriented personnel with the instrumentation systems that are aboard the two C-121G Super Constellation aircraft on permanent loan to NASA from the Air Force. The electronic systems described in this document are used to test the Manned Space Flight Network's capability to support Gemini/Agena missions.

It is planned that Apollo spacecraft equipment will eventually be installed in the aircraft to test the Apollo Network, but this equipment is not discussed herein. However, when major equipment changes are made to the aircraft's instrumentation, this document will be revised.

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SECTION II

FUNCTIONS OF THE INSTRUMENTED AIRCRAFT

The aircraft are initially used to check compatibility between the new ground systems and corresponding spacecraft systems, which are engineering or production prototypes of spacecraft hardware. The compatibility tests take place as soon as the first ground systems are installed and operational so that adequate time will remain for any necessary changes to ground equipment before worldwide deployment of station equipment.

Following the initial compatibility tests, the aircraft are used to completely checkout each new or modified station in the network. After thorough individual system checkouts, the aircraft simulates a spacecraft pass to test the performance of the entire system so that all interaction between systems may be observed. Complete station checkout is expected to require three to six weeks.

After these acceptance tests are completed, an on-station personnel training program begins. If time allows, the M&O personnel training may start at each station as soon as the equipment checkout is complete. It is planned that each station will be visited by one of the aircraft about every three months to conduct training missions and evaluation tests.

Since most stations get no practice in tracking vehicles between actual missions, it is desirable to evaluate the equipment and provide personnel training between missions. The evaluation tests are a condensed version of the acceptance tests, plus a special series of training flights. The training flights are complete simulated missions, including DST's/BST's, abbreviated countdown, and all incoming and outgoing messages. The aircraft flies a flight plan simulating as closely as possible an actual pass and, with the exception of radar range, duplicates all pertinent electrical characteristics of the spacecraft.

At first normal passes are made. Then, as operator proficiency increases, various spacecraft and ground station failures are simulated giving the M&O personnel an opportunity to exercise emergency procedures and backup modes of operation under "actual" flight conditions.

In the past, routine aircraft evaluation tests of Mercury stations almost always resulted in some firm recommendations for improving equipment or operational performance. With the increased complexity of ground station equipment, these tests become increasingly more valuable as a method for training and for evaluating performance.

SECTION III

AIRCRAFT EQUIPMENT ARRANGEMENT

As illustrated by Figure 1, the interior of the aircraft is arranged so that all the electronic equipment is on the right side of the forward fuselage, leaving the left side for cargo space. The aft section of the fuselage is reserved as a passenger area, containing work tables, galley, and overhead racks.

Sixteen specially designed racks with standard 19-inch widths are used for mounting electronic equipment. A rack assembly consists of from two to five individual racks. Each rack assembly is shock-mounted at the fuselage floor and at the attachment points on the upper interior fuselage. Individual equipment is not shock mounted.

The antenna system is designed to simulate the Gemini/Agena electrical characteristics as much as possible. The normal antenna patching arrangement uses the forward fuselage antenna for the Agena electronics and aft antennas for Gemini electronics. Any multicoupler or transmitter/receiver, however, may be patched to any antenna. The antennas, their locations, and normal uses are listed below:

Type	Location	Use
UHF AT-256	Forward fuselage, underside	Agena command receiver
UHF AT-256	Forward fuselage, underside	Agena telemetry transmitter
S-band	Forward fuselage, underside	Agena S-band beacon
C-band	Forward fuselage, underside	Agena C-band beacon
UHF AT-256	Mid fuselage, underside	Telemetry monitoring receiver
HF long wire	Aft fuselage, underside	Gemini HF transceiver

Type	Location	Use
UHF AT-256	Aft fuselage, underside	Gemini UHF multicoupler *
UHF AT-256	Aft fuselage, underside	Gemini playback telemetry
S-band	Lower left and right vertical stabilizer	Gemini S-band beacon
C-band	Lower left and right vertical stabilizer	Gemini C-band beacon

*Includes real time telemetry, standby telemetry, UHF voice, and command receivers.

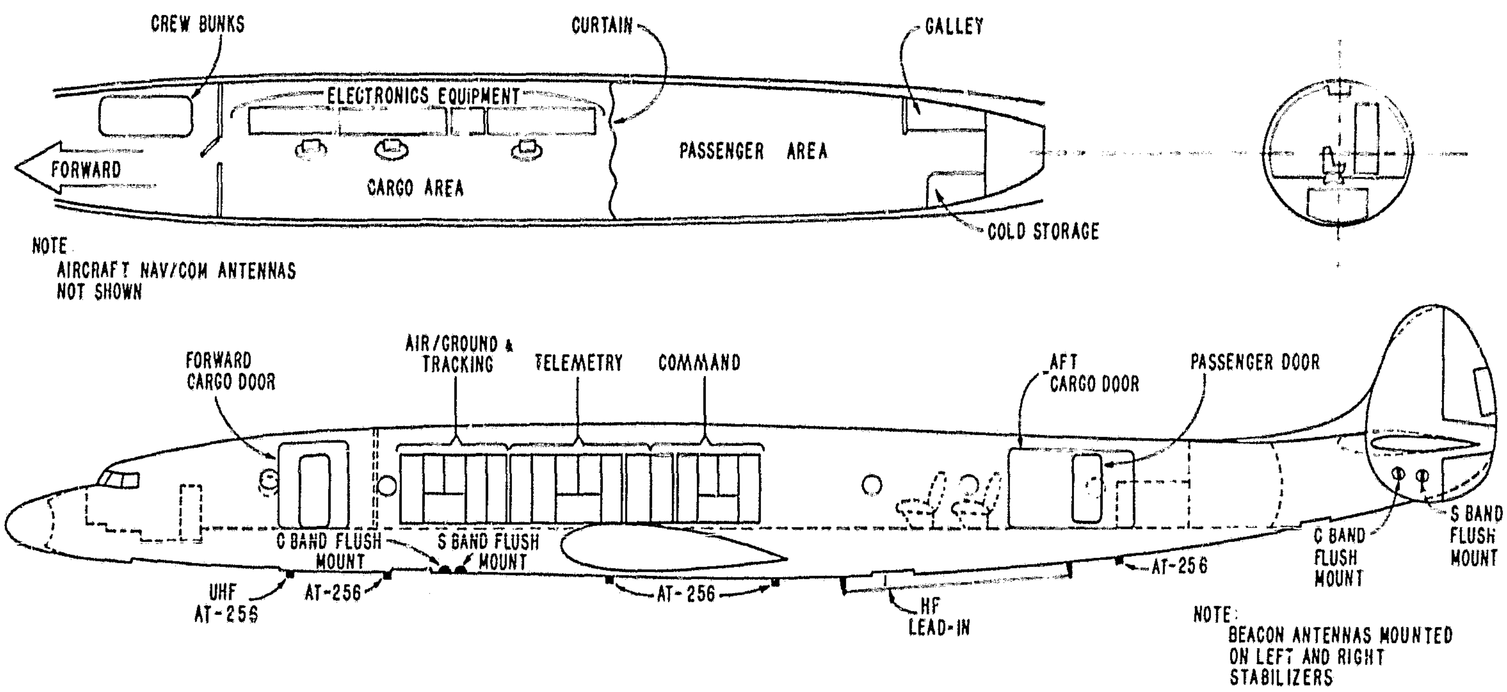

Figure 1. Aircraft Interior Arrangement and Antenna Locations

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SECTION IV

TELEMETRY SYSTEM

The instrumented aircraft telemetry system consists of spacecraft PCM equipment, commercial and spacecraft RF components, test equipment, and input simulators, all of which are combined into a system capable of completely simulating the actual spacecraft. Figure 2 illustrates the layout of the telemetry operator's console.

The aircraft includes separate telemetry systems for Gemini, Agena, and Mercury. The original Mercury configuration has been expanded to be more of a general FM/FM system.

GEMINI TELEMETRY SYSTEM

RF System

This system (see Figure 3) is packaged in two units: a multicoupler and a transmitter chassis. The multicoupler chassis contains the spacecraft quadriplexer which is an RF filter that couples the antennas to the telemetry, air-ground voice, and digital command systems.

The transmitter chassis contains five telemetry transmitters (two spacecraft units, one for real-time transmission and one for stored data transmission; and three commercial units, two to back up the spacecraft units and one to simulate the spacecraft spare transmitter), RF attenuators, power monitoring devices, control switches, and modulation patch panel. Transmitter specifications are as follows:

Modulation:	FM
Deviation Sensitivity:	100,000 cps/volts ±1 db for all frequencies from 25 cps to 150 kc
Carrier Deviation:	Real time, +38 kc for a data 1 −38 kc for a data 0
	Stored data, +84 kc for a data 1 −84 kc for a data 0

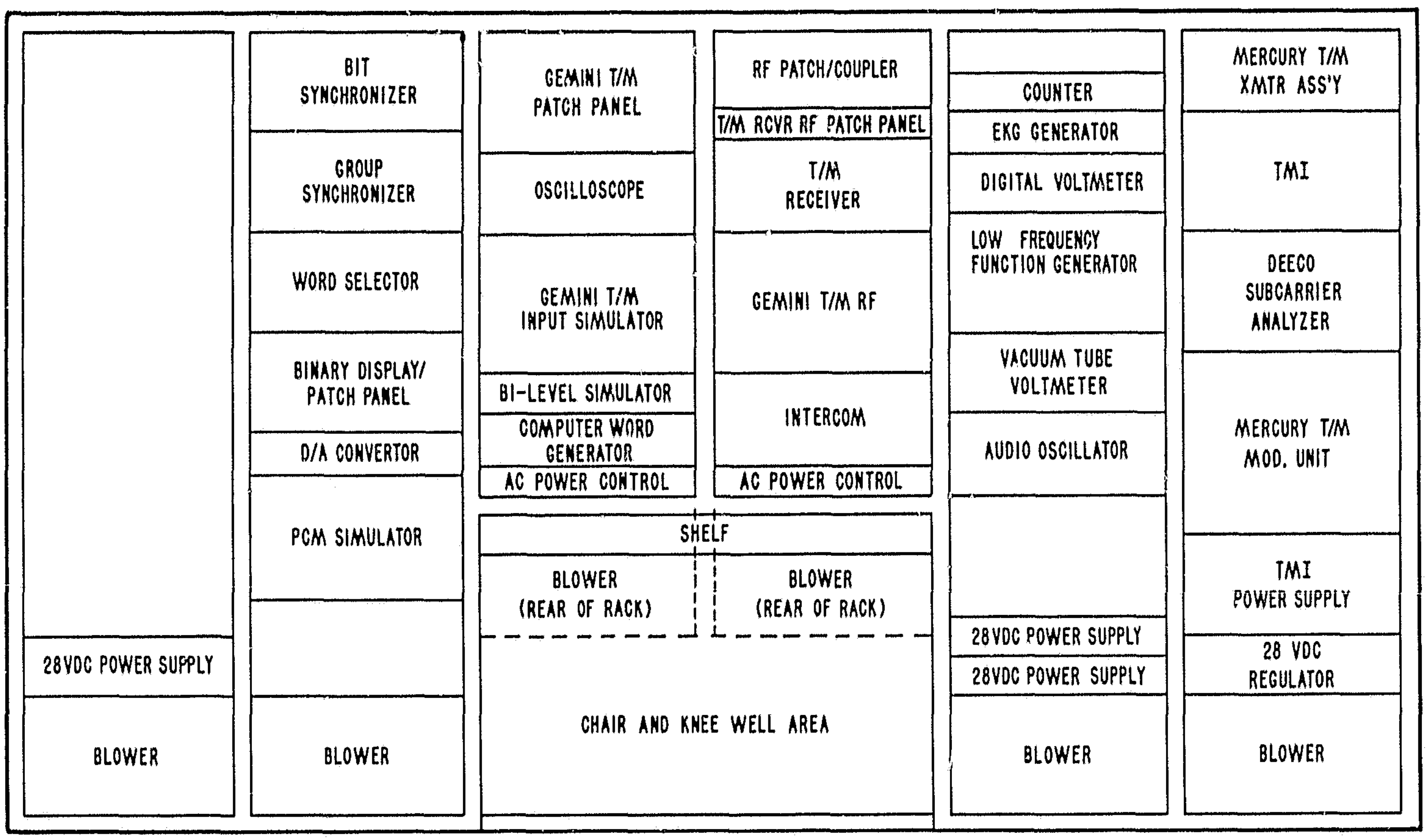

Figure 2. Telemetry Operator's Console Layout

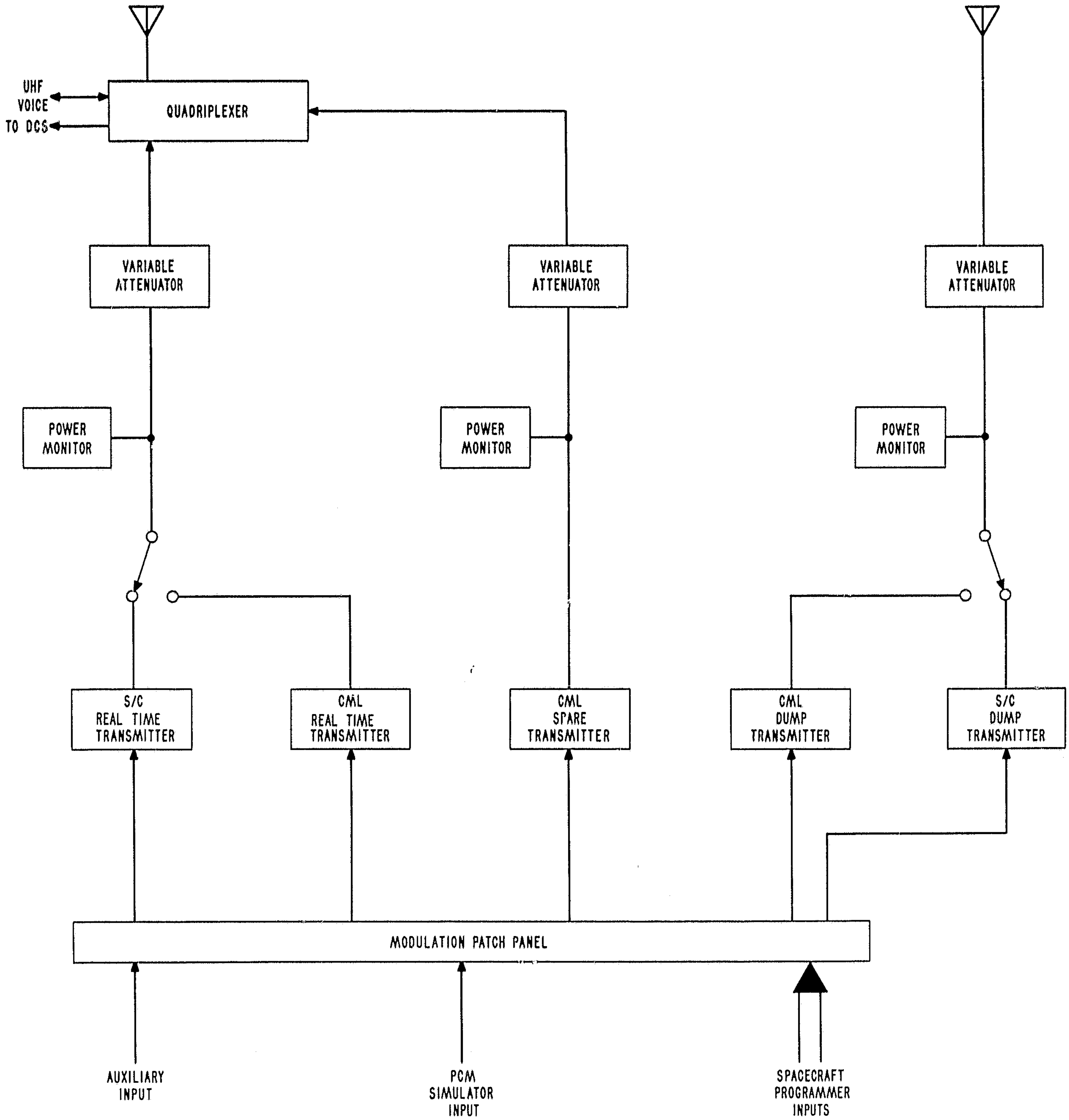

Figure 3. Gemini Telemetry RF System, Block Diagram

Frequencies:

	Real time,	230.4 mc
	Stored data,	246.3 mc
	Spare,	259.7 mc

Detailed specifications are contained in the McDonnel Aircraft Corporation Specification Control Document for the Model 133P Data Transmission System.

Gemini Multiplexers and Programmer

The spacecraft data transmission system uses four multiplexers and a programmer (see Figure 4). The multiplexers are of two types: high level (0 to 5 v input) and low level (0 to 20 mv input). Each multiplexer samples a number of analog sources and converts these samples into a time-division multiplex PAM output. The outputs of the four multiplexers are fed to the PCM programmer.

The PCM programmer accepts signals from the multiplexers and other analog and digital sources, converts all analog inputs to digital, and encodes the samples into a continuous linear coded bit stream. The outputs (real time and dump) of the programmer modulate the telemetry transmitters. The real-time output contains all data in the PCM format; the dump or recorded data output, fed to the spacecraft tape recorder, contains only subcommutated data known as the prime subframe. This recorded data is dumped at a high bit rate through a delay-time transmitter.

Digital data inputs to the programmer come from the computer word generator and the time reference system. These inputs are 24-bit words shifted on command from the programmer.

An additional data input to the programmer is the message acceptance pulse (MAP) from the digital command system. The MAP comes from the DCS to a MAP signal conditioner, which reshapes the pulse in time and amplitude for use as an analog data input, and then goes into the programmer.

Following is a summary of the data inputs to the spacecraft system:

PROGRAMMER

Number of Signals	Type
21	Low-level

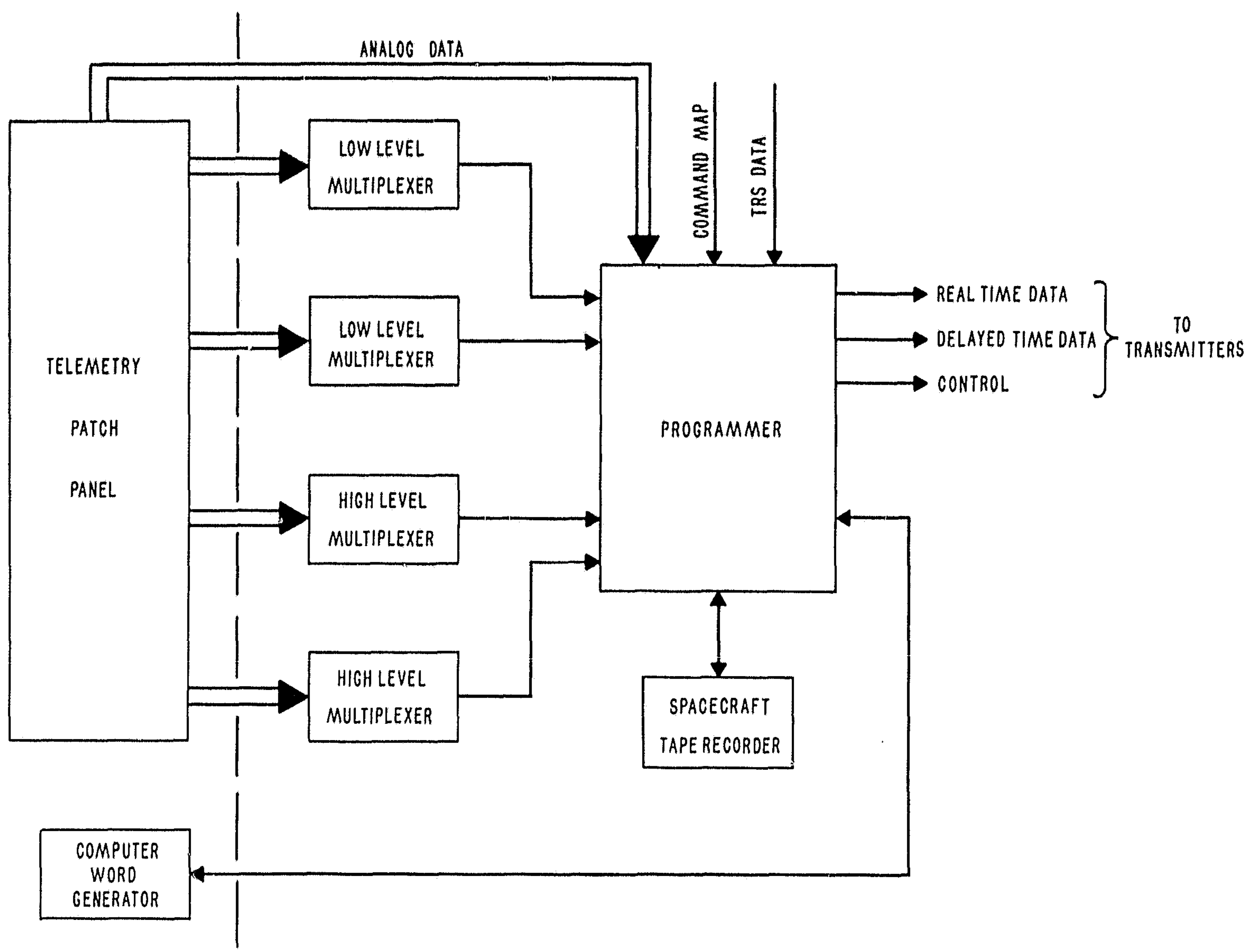

Figure 4. Gemini Telemetry Spacecraft Equipment, Block Diagram

PROGRAMMER (Continued)

Number of Signals	Type
44	High-level
40	Bi-level
24	Digital
LOW-LEVEL MULTIPLEXER (2 units)	
64	Low-level
HIGH-LEVEL MULTIPLEXER (2 units)	
64	High-level
48	Bi-level
32	Bi-level pulse

All analog multiplexer and programmer inputs listed above are connected to the patch board where a maximum of 25 spacecraft inputs may be patched to any simulated source in the telemetry modulation unit (TMU).

Telemetry Modulation Unit

The purpose of the telemetry modulation unit is to provide simulated transducer outputs and complete patching flexibility so that the telemetry format and data output of any given Gemini spacecraft may be closely simulated. The TMU consists of two sub-units: the input simulator chassis and the input patch chassis (see Figure 5).

The input simulator provides precision analog voltages in the high-level range (0—5 v) and low-level range (0—20 mv). Any signal source may be set at any level within these limits. Precision voltmeters are used to determine the exact input level.

A five-level stepping function generator may be used with any group of five high and/or low level analog sources.

The function generator's output will be a voltage that steps between any five pre-set levels. Any number of spacecraft inputs may be patched to the function generator output.

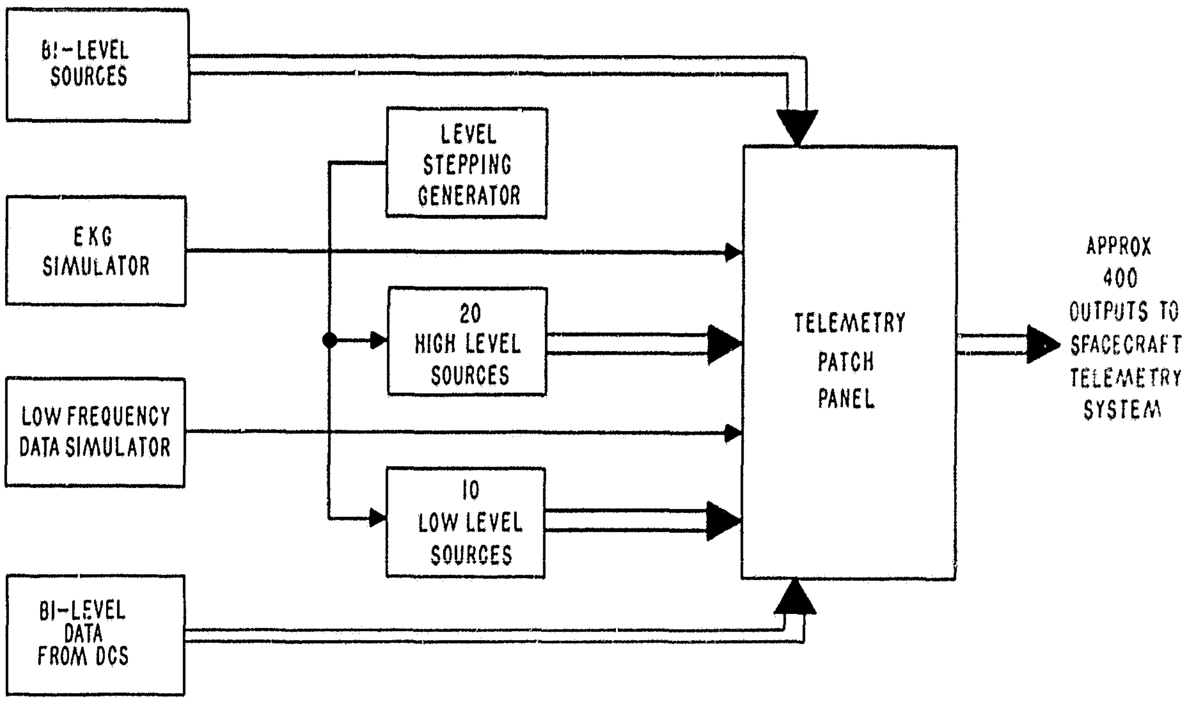

Figure 5. Gemini Telemetry Modulation Unit, Block Diagram

The input patch chassis contains the spacecraft PCM equipment (multiplexers and programmer) and a large patch board. The outputs of the patch board consist of approximately 400 wires which provide inputs to the spacecraft equipment. The inputs to the patch board consist of the 30 analog sources from the input simulator chassis plus other simulated data inputs consisting of the following:

Bi-level manual switches (0—28 v)

Bi-level real time command relay closures

EKG simulator

Low-frequency simulator (dynamic data from low frequency simulators—Hewlett Packard low frequency function generators—may be sine, square, or triangular wave shapes. This data may be patched to most spacecraft inputs whose sampling rates are above 10 samples per second.)

In addition, several inputs are hard-wired directly to the PCM equipment. They are the message acceptance pulse from the DCS, command receiver signal strengths, digital data from the spacecraft electronic timer, and digital data from the computer word simulator.

Spacecraft Tape Recorder

The spacecraft tape recorder records the prime subframe data only from the PCM programmer. (The prime subframe consists of 64 words sampled 10 times per second.) On command, the recorder reverses direction and dumps data through the playback transmitter at 22 times the record speed. Either ground command or manual control can trigger the tape recorder.

The unit records 5.12-kc PCM data from the programmer at 1-7/8 ips and plays back at a bit rate of 112.6 kc. The playback format is NRZ and consists of the prime subframe in reverse (least significant bit first).

Computer Word Generator

The Gemini spacecraft includes an on-board digital computer, but this unit is not used in the aircraft system. In its place, a computer word generator simulates digital inputs to the PCM programmer by shifting 24-bit digital words into it. Switches (24) on the front panel select the word format.

AGENA TELEMETRY SYSTEM (See Figure 6)

RF System

The Agena RF system consists of four transmitters, a multicoupler, RF attenuators, power monitoring devices, modulation patch panel, and control switches. The transmitters are in two groups—real time and delay time—with a spacecraft and commercial transmitter in each group. Specifications are as follows:

Frequencies:	Real time,	240.2 mc
	Stored data,	248.6 mc
Deviation:	Real time,	—21 kc for a data 1
		+21 kc for a data 0
	Stored data,	—45 kc for a data 1
		+45 kc for a data 0

Agena PCM Data System

The Agena multiplexer equipment consists of two 128-channel multiplexers, PCM encoder, and telemetry control unit. The multiplexers accept high-level analog data and convert it to a PAM pulse train. Multiplexer outputs are fed to the PCM encoder, which converts the PAM pulse train to serial encoded PCM. The PCM encoder output is fed to the telemetry control unit along with direct digital data from the command system and pulse analog data from the turbine speed counter simulator. The control unit serializes its various inputs and modulates the TLM transmitters with NRZ PCM data.

Data rates are 16,384 bps for real time data and 65,536 bps for stored data.

Telemetry Modulation Unit

The Agena TMU consists of 20 high-level analog sources, 64 bi-level switches, a function generator, and patch panel. Any multiplexer input may be patched to any source through the patch panel. The function generator may also be used to provide automatic level steps between any five levels for multiplexer inputs. Command status signals can also be patched to spacecraft inputs.

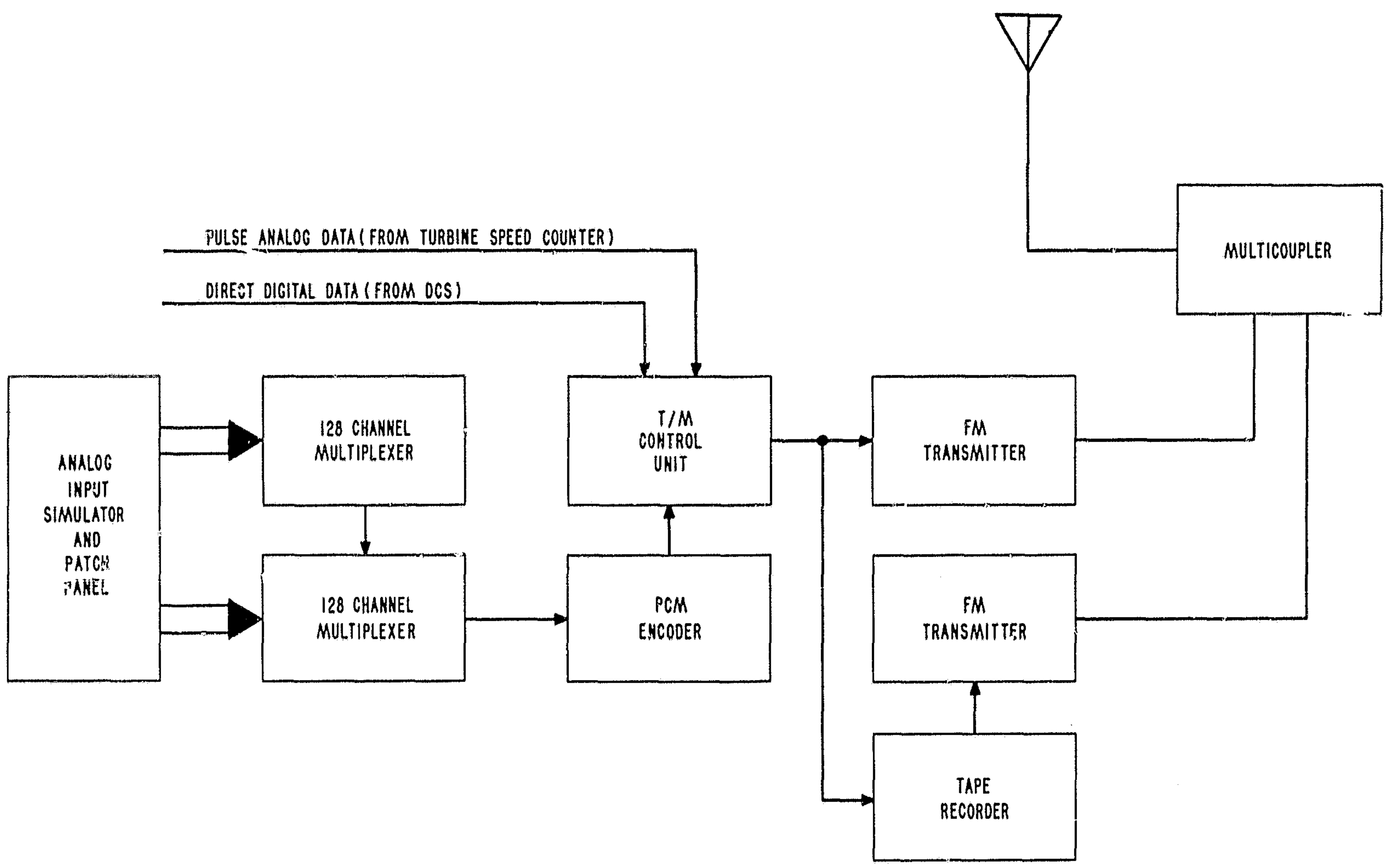

Figure 6. Agena Telemetry System, Block Diagram

The TMU contains the spacecraft equipment, including a tape recorder and its associated controls. The Agena spacecraft tape recorder records PCM data and, as in the actual spacecraft, dumps stored data through the playback TLM transmitter on command. The tape recorder can accept 20 minutes of composite data for playback in 5 minutes.

PCM CHECKOUT EQUIPMENT

The aircraft PCM checkout and monitor system (see Figure 7) consists of a single-channel decommutator, complete with binary and analog display. The decom receives its data from a telemetry receiver, and a bit synchronizer and signal conditioner. This system is capable of decommutating any word in the Gemini or Agena format and displaying its value. Thumbwheel panel switches select the word to be displayed.

FM/FM SPACECRAFT EQUIPMENT

The FM/FM equipment consists of commercial and spacecraft transmitters, commercial VCO's, and multiplexers. Complete IRIG subcarrier capability is available, channels 1 through 18, on two telemetry frequencies. Transmitters are Mercury spacecraft types and Bendix TXV-18 units. Specifications are as follows:

Maximum Deviation:	60 kc
Deviation Sensitivity:	60 kc/volt FM
	5 kc/volt PM

The standard Mercury multiplexer, a 90 by 1-1/4 commutator, is avaiable and, although normally used to modulate the channel 12 subcarrier, can be used on other channels.

MERCURY TELEMETRY MODULATION UNIT

The Mercury TMU has ten analog sources that may be patched to any combination of multiplexer or VCO inputs. These sources are adjustable and may be accurately calibrated. An automatic stepping function generator may also be used to deviate the subcarriers between the band-edges in discrete steps. Ten event switches, patchable to any combination of spacecraft inputs, are available.

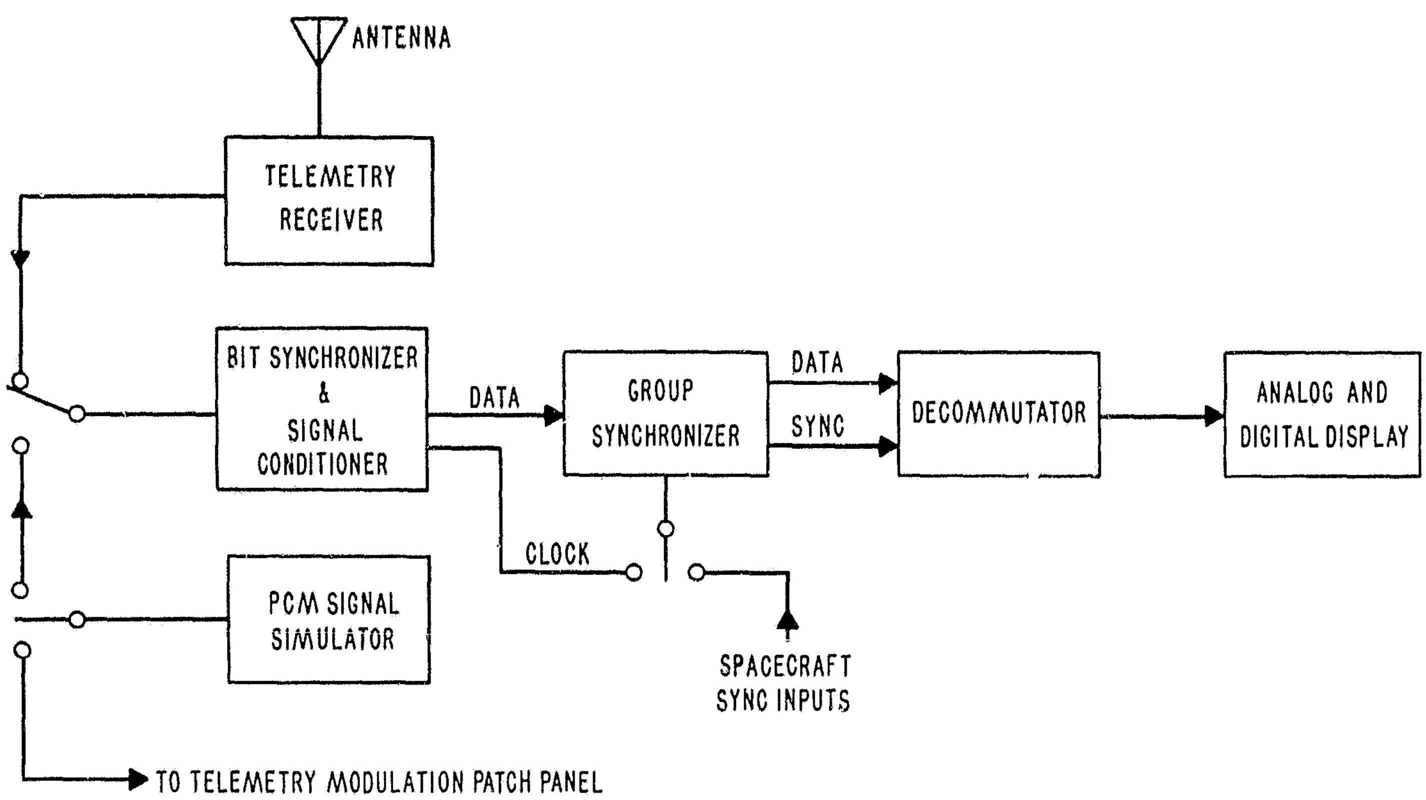

Figure 7. PCM Checkout System, Block Diagram

TEST EQUIPMENT

Following is a list of general test equipment installed in the telemetry console (see Figure 2).

Tektronix RM561A oscilloscope
Hewlett Packard 5232A counter
Hewlett Packard HP400D VTVM
Hewlett Packard HP200CD audio oscillator
Hewlett Packard low-frequency function generator
Cubic Model 45 digital voltmeter
Panoramic TMI spectrum analyzer

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SECTION V

COMMAND SYSTEM

The aircraft command systems consist of actual spacecraft components and additional peripheral equipment to provide simulation and display capabilities. Figure 8 illustrates the layout of the command operator's console.

GEMINI DIGITAL COMMAND SYSTEM (See Figure 9)

The Gemini system receives, demodulates, and decodes digital commands sent from the ground station. Decoded messages meeting certain validity criteria generate a message acceptance pulse (MAP) and are routed to the addressed spacecraft system as follows: real time commands (RTC) to the 32 RTC relays, clock commands to the electronic timer, and computer word commands to the simulated computer (computer response simulator). The MAP is transmitted to the ground station through the telemetry system along with receiver signal strengths, RTC command status, and clock readouts from the electronic timer. On-board simulation and display capabilities are explained in the following equipment descriptions.

RF System

A UHF blade antenna is connected through a quadriplexer, an RF patch board, a 0 to 119-db variable attenuator, and power divider to the receiver/decoder.

Receiver/Decoder

This is an actual spacecraft unit consisting of the following:

- Two superhet FM receivers
- Phase lock loop (detects 1-kc sync tone)
- Integrating type phase detector (detects sub-bits from 2-kc PSK tone)
- Info bit detector (detects correct sub-bit codes)
- Command message decoder (logic circuitry)
- Temporary storage register

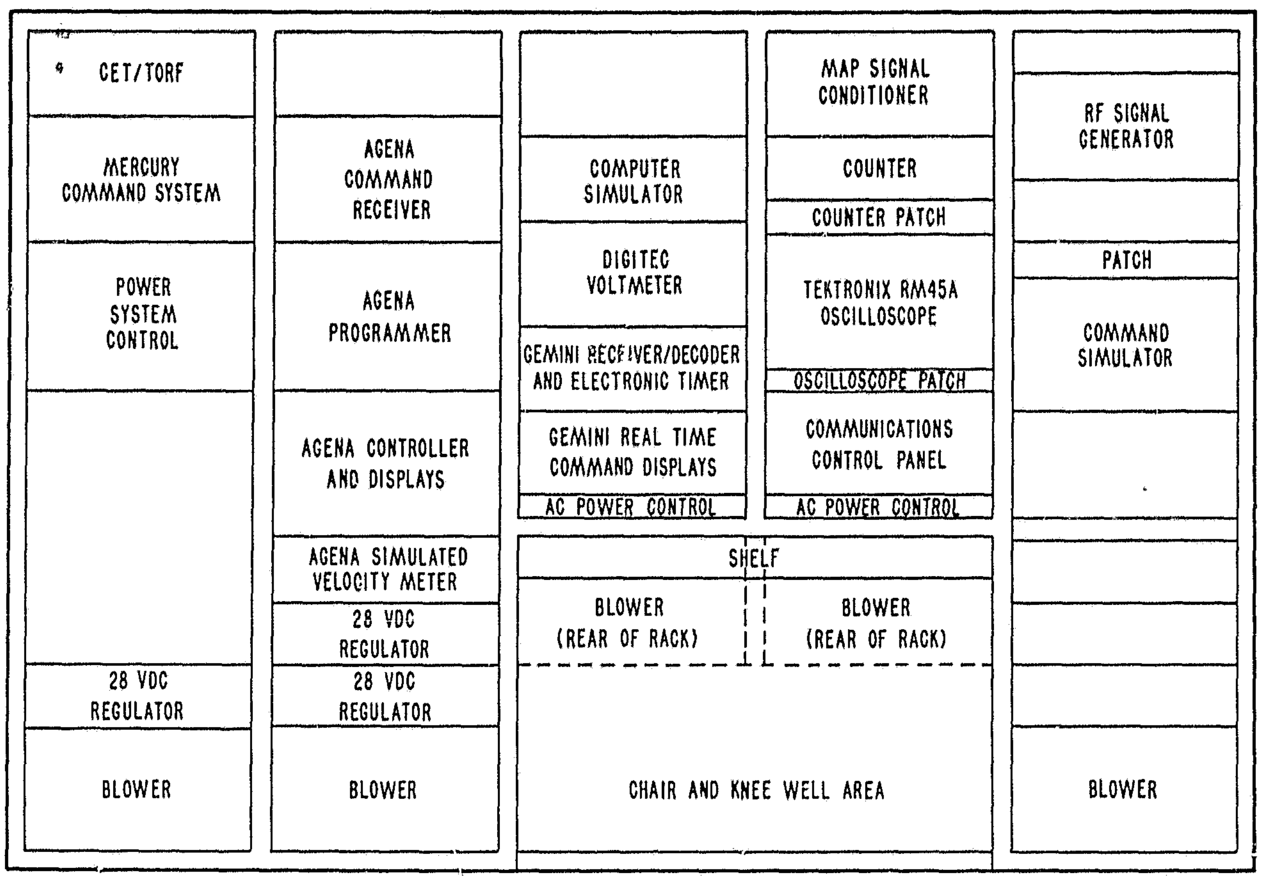

Figure 8. Command Operator's Console Layout

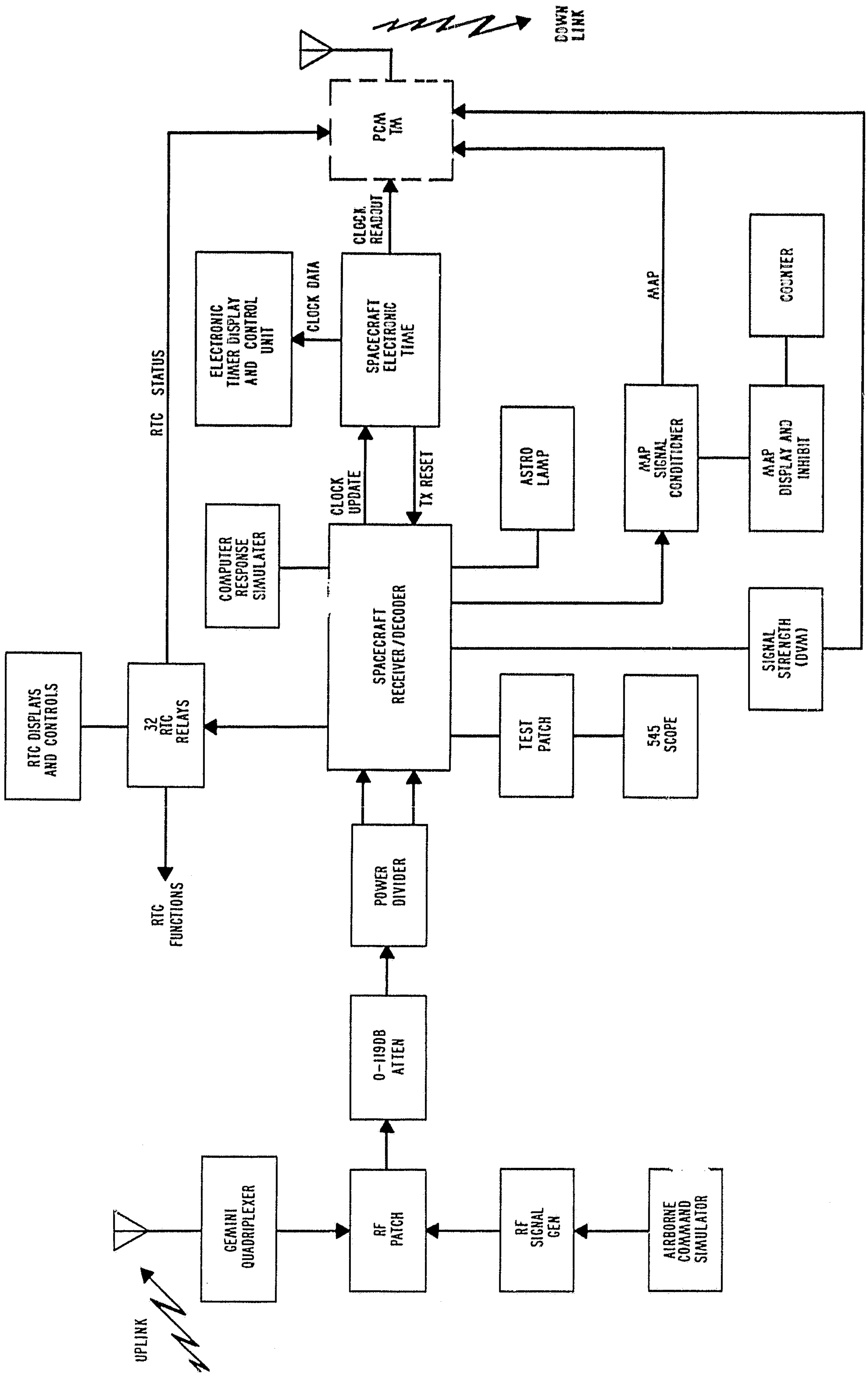

Figure 9. Gemini Digital Command System, Block Diagram

Display Unit

This unit includes the 32 RTC relays (spacecraft equipment) and 32 associated lamp displays to indicate the SET or RESET position of each relay. The relay contact closures are available for on-board operational functions (beacons ON-OFF, etc.). Switches (32) are provided to allow manual set or reset of each relay in the aircraft. An "astro lamp" and switch are included. This lamp is driven by a latching relay in the decoder, and it signifies that data is being transferred to the electronic timer or computer. The switch is used to reset the relay.

The MAP display is a flashing neon lamp driven by the MAP signal conditioner and provides an on-board display of correct command receipt. The MAP inhibit switch inhibits the MAP from passing to the TLM. Thus the aircraft command operator can require the ground station to retransmit a given command by inhibiting the MAP. This will allow an exercise of the automatic retransmit capability of the ground station.

Spacecraft Electronic Timer

This unit contains the registers, arithmetic units, and clock to count down TTG to Tr (time to go to time of retrofire) and TTG to Tx (time to go to equipment reset), and to count up capsule elapsed time (CET) from liftoff. The TTG registers can be updated from the ground through the DCS. Data transfer occurs in the following manner: the decoder sends a ready signal to the addressed system (electronic timer in this case) indicating that it has a data word in storage, ready for transfer. The system responds with a series of transfer pulses, and the data is shifted from the decoder to the system. TTG to Tr and CET are read out to the ground station through the PCM TLM. Relay contact closures occur at Tr—5 min., Tr—30 sec., Tr, and Tx. The relay closure at Tx may be used to reset selected RTC (real time command) relays.

Electronic Timer Display

This unit is used to read out and display data from the electronic timer. A 24-bit binary display of either CET or TTG to Tr is provided. This display allows the aircraft command operator to view the same clock information that would be read out through the digital computer in the actual spacecraft. Lamp displays of Tr—5 min., Tr—30 sec., Tc, and Tx event times are also provided. The countdown of the electronic timer is controlled by switches on this unit. The clock can be inhibited from the aircraft to require an update from the ground station through the DCS.

Computer Response Simulator

This unit allows the ground station to transmit computer words and receive verification of their receipt, although an actual computer is not on-board the aircraft.

The simulator receives the computer-ready signal from the decoder and responds with 24 transfer pulses. This allows the decoder register to be cleared and causes the generation of a MAP for computer commands.

DCS/PCM Interface

The airborne DCS supplies the following signals to the PCM TLM for transmission:

TTG to Tr and CET (digital)
RTC status (analog)
MAP (analog)
Receiver signal strengths (analog)

The MAP signal conditioner is provided to shape the MAP into a pulse of suitable magnitude and length for the PCM TLM system.

AGENA COMMAND SYSTEM

The Agena command system (see Figure 10) receives, demodulates, and decodes digital commands addressed to the Agena target vehicle. As with the Gemini command system, MAP's, generated when messages have been accepted from the ground station, are routed to the Agena telemetry for transmission back to the ground station to indicate the acceptance of messages by the Agena command system. Commands are of two types: real time commands (RTC) and stored program commands (SPC). RTC's are actuated immediately upon receipt, while SPC's

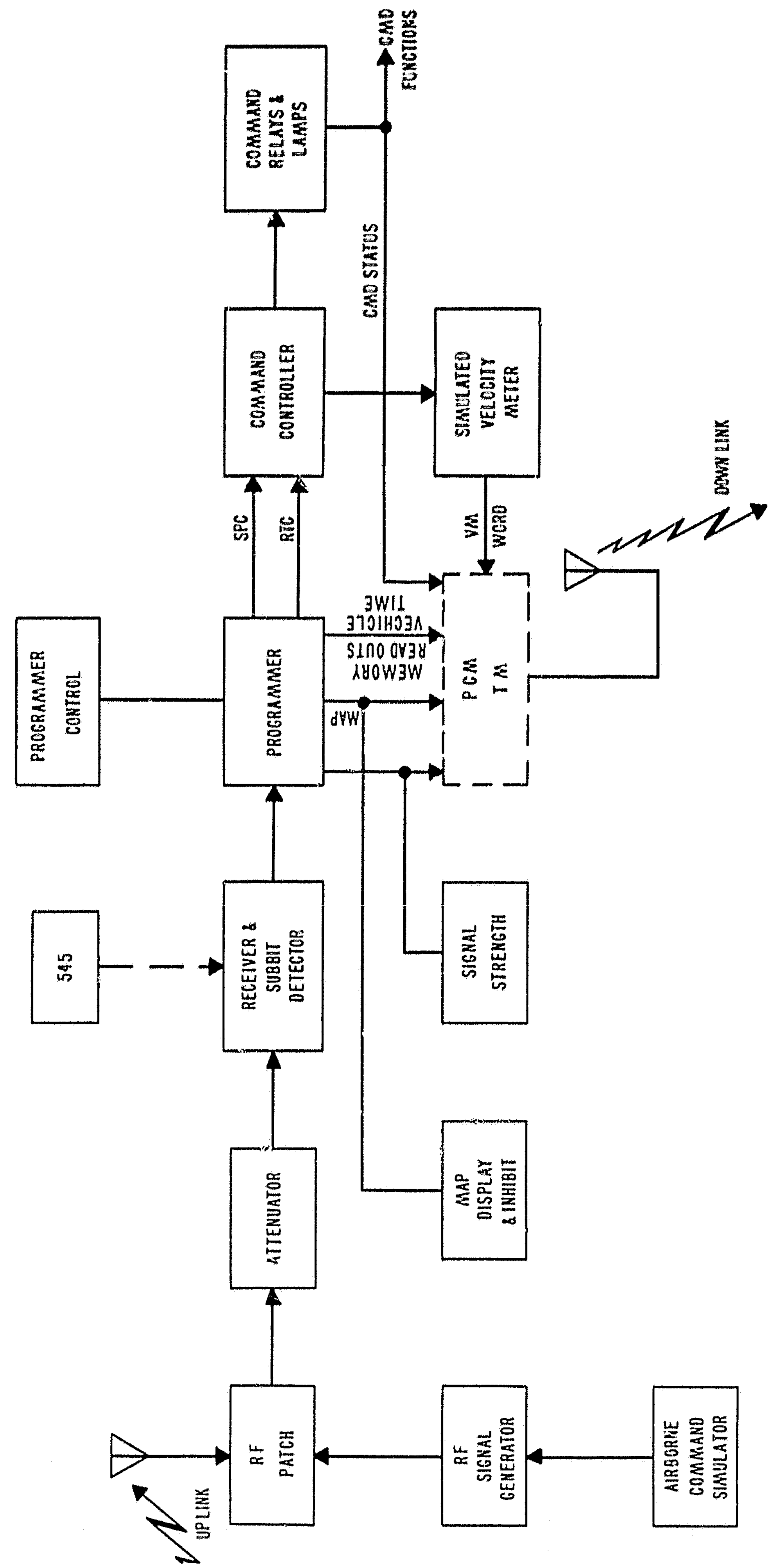

Figure 10. Agena Digital Command System, Block Diagram

(RTC's with a time label attached) are stored in a 64-word memory in the programmer and actuated at the coincidence of vehicle time with the SPC time label.

RF System

A UHF blade antenna is connected through an RF patchboard and a 0 to 119-db variable attenuator to the spacecraft receiver.

Receiver/Sub-bit

This is an actual spacecraft component that receives and demodulates the RF input, and supplies a sub-bit output to the programmer.

Programmer

The spacecraft programmer converts the sub-bit train into info-bits and decodes the message.

Command Controller

This unit is actuated by the RTC or SPC actuation signal and supplies outputs to various relays for on-off functions. The TLM modulation buss is also switched internally by the controller.

Displays

On-board displays consist of the following: Agena command display (lamps indicating on-off status), MAP inhibit display, and receiver signal strength (DVM).

Simulated Velocity Meter

This unit receives the velocity meter (VM) load ONE and load ZERO commands from the controller and shifts them into a 16-bit register. The VM interrogate command then reads this VM word into another 16-bit register, which also has inputs from 16-bit switches so that errors may be introduced into the VM word. An on-board display of the VM word is provided.

AUXILIARY EQUIPMENT

Airborne Command Simulator

The airborne command simulator (ACS) illustrated in Figure 11, is provided to preflight the Gemini and Agena command systems. It consists of a completely selectable word generator, format selector, patchable sub-bit encoder, ground station PSK modulation, and a phase meter. The ACS generates simulated commands which in turn modulate an RF signal generator. The output of the signal generator is then patched into either the Gemini or Agena command receiver.

The phase meter, by measuring the relative phase shift between the 1- and 2-kc tones of the composite audio signal, is used to align the ACS modulator and to analyze the audio output from the command receivers during flyover tests.

Test Equipment

Test equipment available includes a 545A oscilloscope to monitor various operational test points, a 0- to 100-mv digital voltmeter to monitor receiver signal strengths, and a counter to count MAP's.

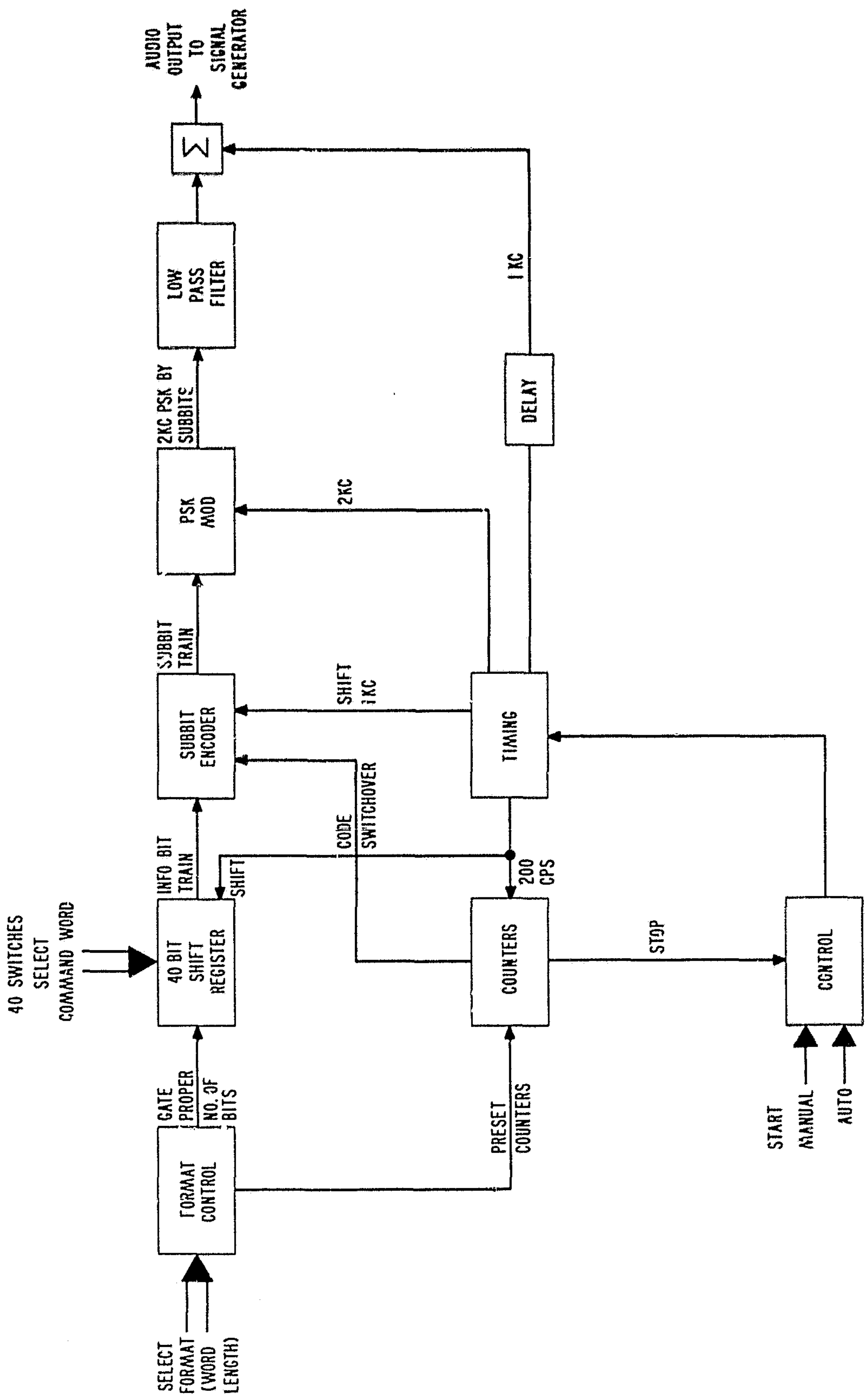

Figure 11. Airborne Command Simulator, Block Diagram

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SECTION VI

TRACKING SYSTEM

The aircraft is equipped with radar beacons similar to those in the Gemini and Agena spacecraft. The beacons and associated equipment are contained in the tracking and communications operator's console, as shown in Figure 12. There are provisions for four beacons, two C-band and two S-band. Figure 13 illustrates the Gemini beacon system. This system arrangement permits radar simulation of the Gemini spacecraft and Agena target vehicle approaching rendezvous or in a docked condition.

The output of each beacon goes through an adjustable 0- to 2.0-microsecond delay circuit so that the radar beacon return may be delayed sufficiently to separate aircraft skin return from beacon return. A 0- to 50-db attenuator is inserted in the RF loop for each beacon to permit radar threshold tests. An RF patchboard is provided to permit patching of beacons to a variety of antenna combinations.

Gemini and Agena Beacon Package

A single chassis houses the Gemini S-band and C-band beacons. In addition to attenuator and delay controls, there are miscellaneous test points and interrogation indications mounted on the chassis front panel.

Rabbit Generator

A specially designed rabbit generator is used to provide realistic training in radar handover procedures. The unit generates a series of pulses that trigger the driver section of the beacon, simulating interrogation by several radars. The effect is to provide an extra return or rabbit to the tracking radar, thus simulating beacon sharing by two radars. The number of rabbits, repetition rate, and delay between rabbits is selectable.

Test Equipment

A sufficient amount of test equipment is provided to completely preflight the beacons. This includes a beacon code simulator that generates a double pulse for beacon interrogation, a converter and counter, and a dual trace oscilloscope.

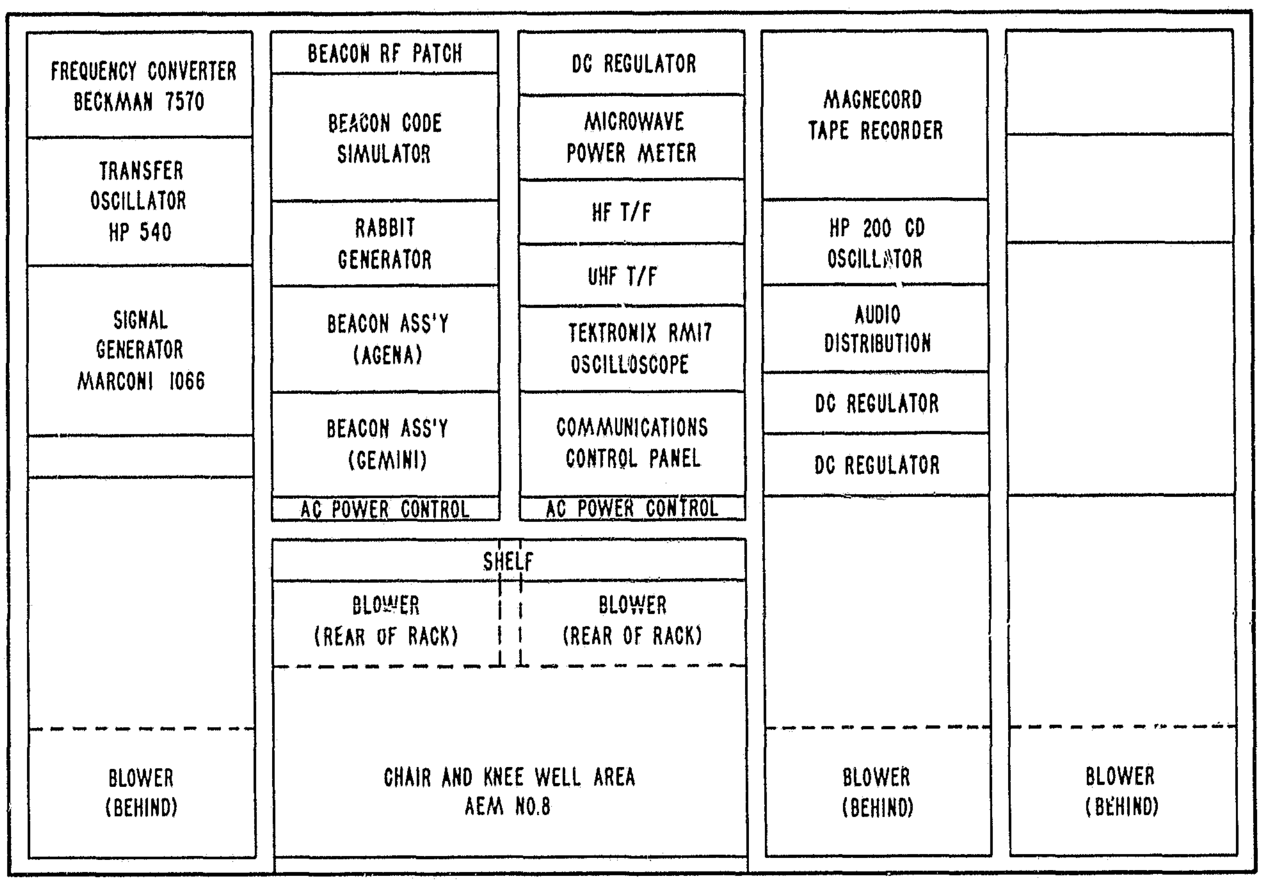

Figure 12. Tracking and Communications Operator's Console Layout

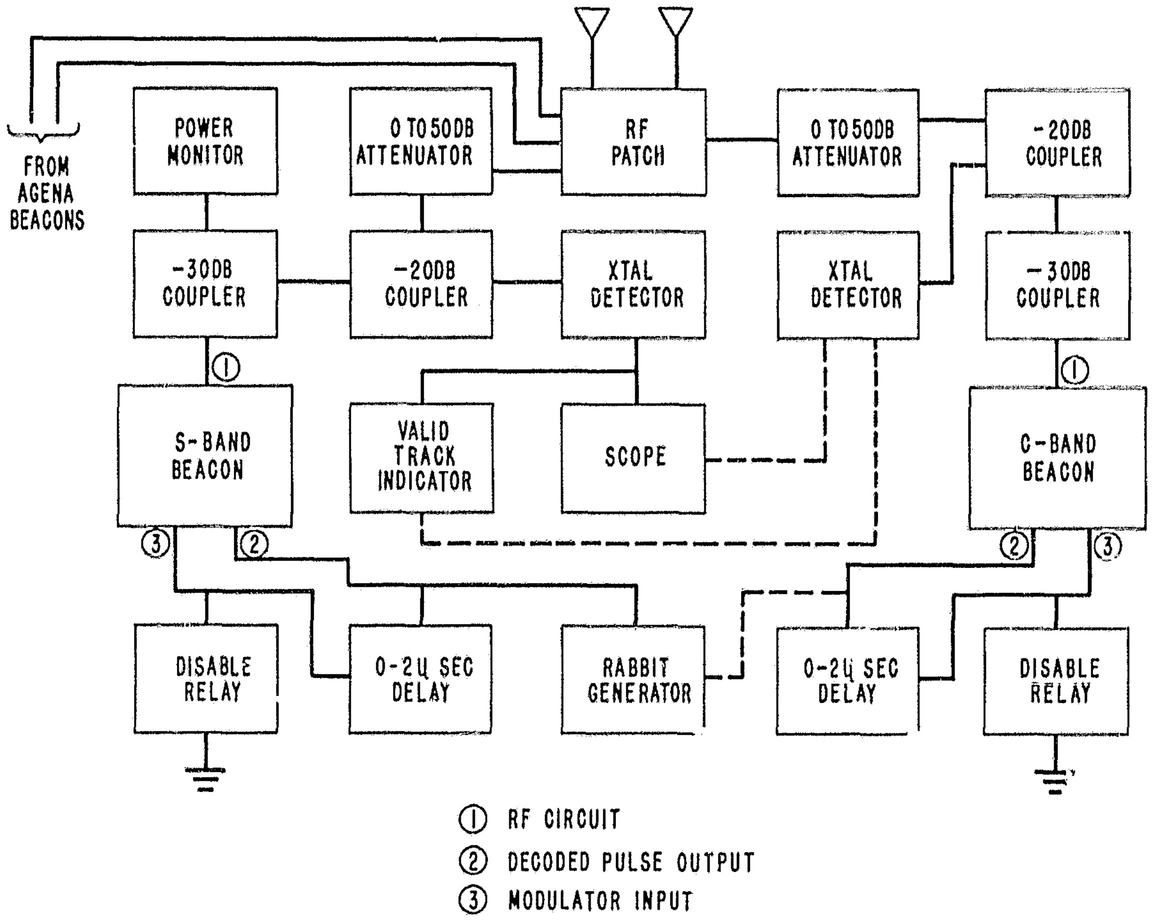

Figure 13. Gemini Beacon System, Block Diagram

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SECTION VII

AIR/GROUND VOICE SYSTEM

Since the UHF and HF frequencies for the Gemini spacecraft are identical to Mercury frequencies, the Mercury spacecraft hardware is used in the aircraft to exercise ground station air/ground communications equipment.

The Mercury system is modified to the extent that a second audio center is provided so that both the air/ground operator and the command operator have the capability to key either HF or UHF transmitters.

A block diagram of the spacecraft equipment is shown in Figure 14.

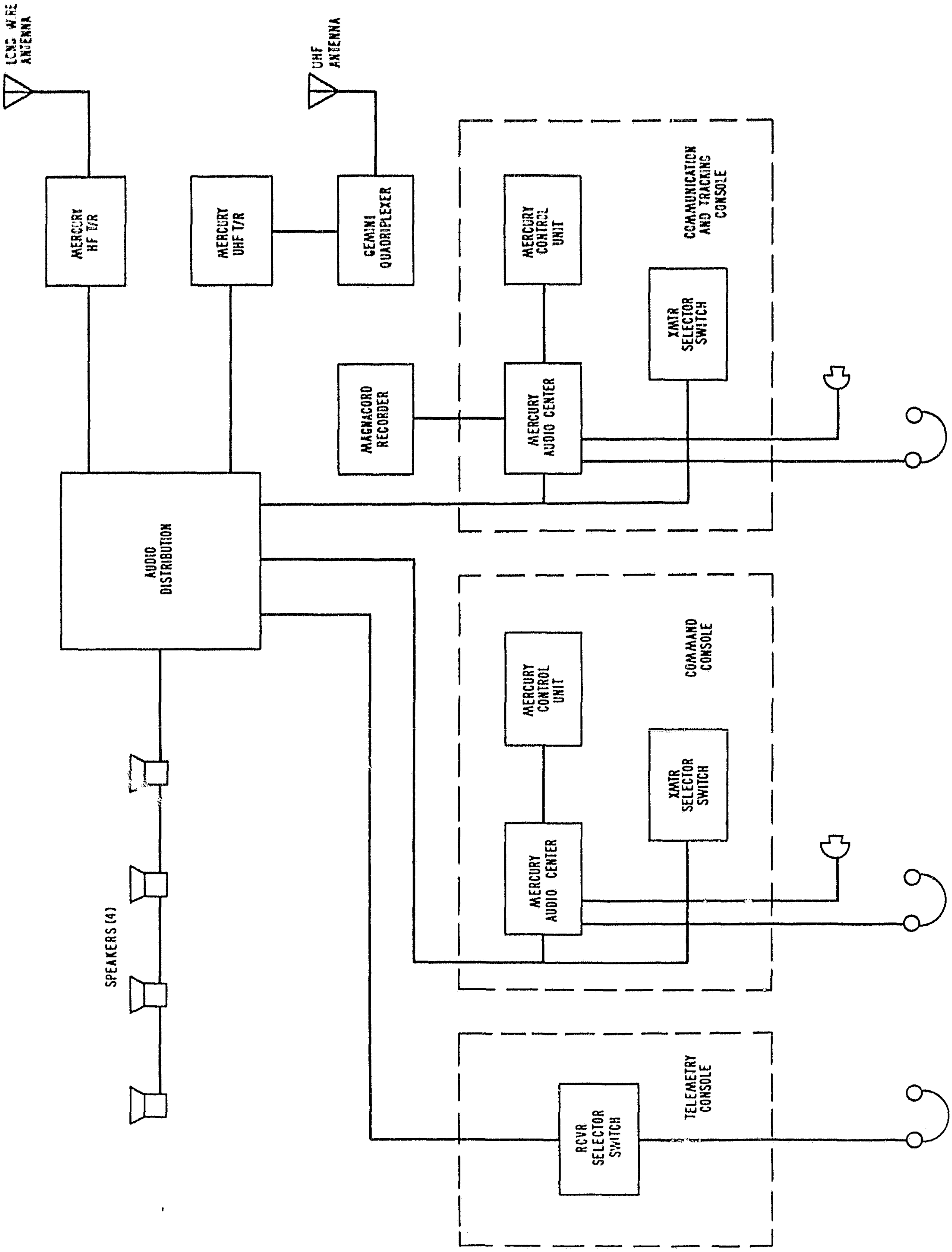

Figure 14. Air/Ground Communications, Block Diagram