APOLLO COMMUNICATIONS

- **Command Module Communication & Data System**
- **Unified S-Band Tracking/Communication Network**
- **Lunar Module Signal Processor**
- **TACSATCOM For Recovery Communication**

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LUNAR MODULE COMMUNICATION SYSTEM

A multi-function subsystem housed in a single equipment unit performs a vital role in Lunar Module communications.

It is the signal processor, supplied by Collins Radio Company under contract to RCA for the LM communications system. RCA in turn is a contractor of Grumman Aircraft Engineering Corporation, which builds the Lunar Module for NASA.

The signal processor is a focal point for all LM communications. Signals transmitted and received by the Lunar Module's two VHF transceivers, S-band transponder and data storage equipment are processed and switched by the signal processor.

This includes voice and bio-medical data of the crew in the LM or an extra vehicular astronaut, and spacecraft telemetry information.

The LM communications system utilizes unified S-band communications with earth for transmission and reception of voice and data. For voice and data exchanges with the command module and extra vehicular astronauts, very high frequency communications are employed.

By means of the signal processor, the LM is able to relay S-band or VHF signals. This includes conversion of received VHF to S-band, or received S-band to VHF for retransmission.

-more-

1st add--LM Communications

The signal processor is one unit with three electrical sections: (1) pre-modulation processor, (2) audio control, and (3) audio center.

The pre-modulation processor section conditions and switches analog and digital inputs to the LM S-band transponder. Digital inputs are pulse code modulation telemetry. Analog inputs are bio-medical data and voice from each astronaut.

The audio control section processes and routes both VHF channels and S-band inputs to the premodulation processor for transmission, or to the audio center section for the astronauts to hear.

The audio center section services the microphones and headsets, including intercom between LM crewmen. Each astronaut is provided separate audio center circuitry on a subassembly, but one subassembly is capable of serving both crewmen.

The signal processor also provides two emergency backup communication modulations, keyed code and clipped voice, which are independent of pre-modulation processing circuits.

The signal processor design employs cordwood circuit construction. Outline dimensions of the unit are 7.2 by 6.9 by 8 inches. Weight is 10.5 pounds. The signal processor is mounted in the aft equipment bay of the Lunar Module.

In addition to providing a part of the Lunar Module communications system, Collins provides the Command Module communication and data system for the Apollo program, and was prime contractor for the Apollo unified S-band ground tracking/communication network.

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APOLLO UNIFIED S-BAND TRACKING/COMMUNICATIONS

An Apollo mission requires continuous, reliable communication between earth and spacecraft from launch until recovery.

To meet the complex communication and tracking requirements of the Apollo program, a network of 14 ground stations serves as the primary link with spacecraft.

Three of the stations provide the only contact with earth for the Command and Lunar Modules while they are in deep space, including lunar distances.

The stations, supplemented by specially instrumented aircraft and ships, are the earth installations of the Apollo Unified S-Band Tracking/Communication System. The Unified S-Band network is a part of the NASA Manned Space Flight Network.

The USB ground tracking/communication network has two basic functions:

1. Tracking. Both the Command Module and Lunar Module must be accurately tracked during missions. Tracking, together with ranging functions, provides information on the location, velocity and course of both spacecraft.

2. Communication. Transmitting information to and receiving information from Apollo spacecraft, including voice, telemetry data, ranging signal and television (spacecraft to earth only).

-more-

The USB system is called unified because tracking and communication are accomplished by one system using a single band of radio frequencies.

The Unified S-Band System stations are located strategically about the globe. Eleven of these, each with a 30-foot diameter antenna, help provide continuous horizon-to-horizon coverage while the spacecraft orbits the earth. These 30-foot stations are supplemented with Apollo Range Instrumentation Aircraft (ARIA) and ships to provide coverage beyond range of land stations.

Three stations with 85-foot-diameter antennas are spaced approximately equidistant around the world. They support the mission when the Command Module (CM) and Lunar Module (LM) are in deep space beyond the range of the 30-foot stations.

The 85-foot stations are located so that despite the rotation of the earth and the movement of the moon around the earth, one of them always has an unobstructed line of sight toward the moon, thus providing continuous coverage of lunar missions.

Design, construction and installation of the ground stations was performed by Collins Radio Company under a contract from NASA's Goddard Space Flight Center (GSFC). In addition, Collins provided partial systems for Apollo range tracking ships and three Jet Propulsion Laboratory stations that serve as back-ups to the primary USB 85-foot stations.

Stations having 85-foot antennas are at Goldstone, California; Madrid, Spain; and Canberra, Australia.

The 30-foot antenna sites are at Kennedy Space Center, Florida; Grand Bahama Island; Bermuda; Antigua Island; Canary Islands; Ascension Island; Carnarvon, Australia; Guam; Kauai Island, Hawaii; Guaymas, Mexico; and Corpus Christi, Texas.

All the stations are fixed installations except the Grand Bahama Island 30-foot site, which has a transportable van-mounted system.

The three 85-foot stations and five of the 30-foot stations, Kennedy Space Center, Ascension Island, Carnarvon, Guam and Hawaii, have dual capability. This means that although they have only one antenna, other electronic equipment is duplicated to permit two-way communication with more than one spacecraft on different frequencies at the same time. Dual capability is especially important when the CM and LM are separated for lunar landing and launching phases of a mission.

The Unified S-Band System permits voice, data and a ranging (distance measuring) sequence to be transmitted simultaneously from an earth station to the spacecraft. Similarly, information from the spacecraft to ground may be combinations of telemetry, voice, slow-scan television, and the ranging sequence. The ranging sequence is transmitted to the spacecraft and immediately retransmitted back to earth automatically. The time necessary for the round trip is used to compute the distance between the two. A change in the frequency of the returning signal (doppler shift) is used to determine spacecraft velocity.

Frequencies used by Unified S-band stations are 2101.8 MHz and 2106.4 MHz for transmitting, and 2272.5 MHz, 2282.5 MHz, and 2287.5 MHz for receiving. Both phase modulation and frequency modulation techniques are employed.

Each station is connected by means such as landline, ocean cable, microwave and satellite communication links with the Manned Spacecraft Center (MSC) in Houston, which will control the missions, and with Goddard Space Flight Center in Greenbelt, Maryland. Voice transmission to and from the spacecraft can be forwarded instantly through the S-Band stations. Some data is used to update information at the ground stations. Other data is relayed from the stations to MSC and GSFC.

High-gain parabolic antennas are used at the stations to enhance tracking accuracy and communications sensitivity.

A complete Unified S-Band facility includes an instrumentation building, an antenna system and a collimation site. The electronic equipment at such a facility includes data equipment, communication/ tracking receiver, ranging subsystem, optical collimation subsystem, RF collimation subsystem, transmitter, and the servo control console.

The instrumentation building contains an operations room, test labs and an office area.

Used only for testing, the collimation system is not directly involved in communication with the spacecraft.

The RF subsystem is used to amplify and transmit the signal to the spacecraft and to receive and amplify the incoming signal before feeding it into other station equipment.

The digital data subsystem includes the timing subsystem, the antenna position programmer, the tracking data processor and the antenna shaft positioner encoding system.

The antenna position programmer (APP) provides antenna steering signals to operate the servo system that moves the antenna.

The tracking data processor (TDP) assembles tracking data, range and range rate data and other station operation data and transmits it to GSFC.

The analog data system is composed of the updata subcarrier oscillator, the signal data demodulator and the updata buffer.

The updata subcarrier oscillator accepts all information to go to the spacecraft, modulates the different inputs and combines them into the single signal before routing it to the RF subsystem for transmission.

Removal of information from the received spacecraft composite signal is accomplished by the signal data demodulator. A number of modulations are involved, such as TV, voice, telemetry and mixed FM-FM subcarrier for biomedical data. After separation from the main S-Band carrier, the various signals are transmitted to displays and recorders in the station and/or in NASA communications network.

In transmitting to the spacecraft, information reaching the S-band station such as voice and digital command data is modulated onto two different subcarriers and the subcarriers are modulated with the ranging code to form the modulating waveform for the S-band carrier.

The entire transmission process, from origination point such as MSC to receipt by the spacecraft, takes place almost instantly on an on-line, real-time basis.

In a single 30-foot station, the composite S-band signal is amplified to 20 kw by the power amplifier and transmitted by the main 30-foot diameter antenna to the spacecraft.

Dual 30-foot stations have only one antenna but most transmission and virtually all receiving equipment is duplicated to allow two-way communication with more than one spacecraft on different frequencies simultaneously.

In a dual transmit mode, two exciters produce two composite signals on different frequencies, separated by 5 MHz. A combiner is used at the input of the single power amplifier to enable both signals to be amplified simultaneously. To prevent interference between signals, the power output per signal is reduced. Each signal is transmitted at 2 kw, with the antenna radiating a total of 4 kw.

In the 85-foot stations, all of which have dual transmitting capability, signals are amplified to 20 kw on each of two frequencies, for a total of 40 kw radiating from the antenna. Processing of information to be transmitted is the same as for the single 30-foot stations except that it is done in duplicate.

The receive subsystem is more complex than the transmit subsystem and handles more types and a greater quantity of information.

Two types of modulation are used on down-link frequencies, PM (phase modulation) and FM (frequency modulation). Television can be handled only by a signal in PM mode. On a single frequency, FM and PM modes cannot be used at the same time.

The down-link frequencies are:

2272.5 MHz: Command Module to earth (FM mode only), scientific analog data, telemetry relayed from the lunar module, recorded voice and telemetry of television. When television is transmitted from the CM, no other information can be transmitted on this frequency.

2287.5 MHz: Command Module to earth (PM mode only), voice including live voice relay from LM, telemetry data and ranging.

2282.5 MHz: Lunar Module to earth (FM or PM mode), voice, biomedical data, telemetry, ranging (PM mode only), and television (FM mode only). Also Saturn S-IVB booster to earth (PM mode only) used primarily for ranging. This frequency can be used either by the S-IVB or the LM, but not by both simultaneously.

2277.5 MHz: Saturn S-IVB to earth (PCM), can transmit 70 kilobits using a PCM telemetry transmitter.

A single 30-foot USB station can receive and demodulate two of the above frequencies providing one is in FM mode and the other is PM mode.

A dual 30-foot USB station or an 85-foot station can receive and demodualte all four of the above frequencies, providing two are in FM mode and the remaining two are in PM mode.

When a signal is received from a spacecraft, several actions take place simultaneously: the S-band carrier is amplified, demodulated and the various parts routed either into recorders or into the Manned Spaceflight Network or both, and the ranging code is extracted.

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COMMAND MODULE COMMUNICATION AND DATA SYSTEM DESCRIPTION

Radio communication furnishes the only contact between a spacecraft and earth. To meet the intricate communication requirements of the Apollo program, a versatile and highly reliable system is required.

The communication system provides two-way voice communication between earth and spacecraft; data transfer between earth and spacecraft; capability for tracking the spacecraft; television transmission from spacecraft to earth, and direction finding and voice communication during recovery.

The Command Module Communication and Data System operates throughout an Apollo mission, maintaining contract with earth, the Lunar Module and extra vehicular astronauts, and relaying communications between earth and Lunar Module-EVA.

Collins Radio Company, with a team of subcontractors, provides the Command Module Communication and Data System under contract to North American Rockwell Corporation, builder of the spacecraft for NASA's Manned Spacecraft Center.

Collins also provides the primary Ground/Tracking Communication System for Apollo, under contract to NASA's Goddard Space Flight Center, and equipment for the Lunar Module Communication System, as a subcontractor to RCA.

-more-

1st add

For Apollo missions, the primary method of communication is unified S-band (USB).

USB combines near earth and deep space communication requirements in a single band of radio frequencies. USB provides the only communication link when the spacecraft is several thousand miles from earth and beyond.

The Communication and Data system also employs VHF (very high frequency) for near earth and Command Module to Lunar Module and EVA communications, and for recovery operations.

The unified S-band method basically involves a ground based transmitting and receiving station working in conjunction with a spacecraft transponder. In ground to spacecraft transmissions, voice and up-link data are modulated onto subcarriers and combined with the ranging code. This composite information is used to phase-modulate the transmitted carrier frequency. The received and transmitted carrier frequencies are coherently related. This permits measurements of the carrier doppler frequency to determine radial velocity of the spacecraft.

In the spacecraft transponder the voice and up-data subcarriers are extracted from the RF carrier and routed to the pre-modulation processor where they are detected to produce the voice and data information.

The spacecraft transponder automatically retransmits the phase modulated ranging code. Operating with the transponder (called USBE, for unified S-band equipment) are the S-band antenna system including a high gain antenna, the S-band power amplifier, and pre-modulation processor (PMP).

The pre-modulation processor detects the voice and up-data signals from the ground and accepts spacecraft voice, PCM telemetry, bio-medical data, television and emergency key signals for transmission to earth through the unified S-band equipment and S-band power amplifier.

-more-

Voice and telemetry data from the spacecraft are modulated onto subcarriers, combined with the ranging signals, and used to phase-modualte the down-link carrier frequency. The spacecraft S-band transponder transmitter also can be frequency modulated for transmitting television, analog data, or recorded voice and data.

The ground-Command Module up-link frequency in the phase modulation mode is 2106.4 MHz. The coherently related down-link Command Module-earth frequency in the phase modulation mode is 2287.5 MHz. A second down-link frequency, 2272.5 MHz operates in the frequency modulation mode.

Simultaneous transmissions can be made on all three S-band frequencies. In the frequency modulation mode, however, television by itself can be transmitted or analog data/recorded voice and data can be sent, but not all at one time.

Average transmitter output of the VHF/AM Transmitter-Receiver is 5 watts. For unified S-band transmissions, two power levels are provided by the S-Band Power Amplifier--approximately 2.5 and 11 watts.

Following are the types of equipment and functions of the Communication and Data System, actually a subsystem of the Command Module provided by North American to NASA. As Communication and Data subsystem manager, Collins is responsible for the system engineering, system testing, and management of the program, as well as performing the design and manufacture of certain of the equipments:

1. AUDIO CENTER -- Links microphones and earphones of each astronaut to voice transmission and reception equipment, and provides inter-communication for the CM crew.

2. VHF/AM TRANSMITTER-RECEIVER -- Dual transmitters and receivers for near earth voice communication; voice communication between CM and LM or EVA; receipt of data from LM and EVA.

3. UNIFIED S-BAND EQUIPMENT -- Dual transponder which generates and receives S-band voice and data signals; receives and responds to ranging signals; generates FM transmission of television and recorded voice and data.

4. S-BAND POWER AMPLIFIER -- Amplifies S-band signals to necessary power level for transmission to earth.

5. PRE-MODULATION PROCESSOR -- Provides multiplexing and modulation of voice and data signals for unified S-band transmission to earth. Also detects and separates voice and data signals received from earth.

6. PCM TELEMETRY UNIT -- Converts biomedical, scientific and operational measurements from crew and spacecraft to digital form for transmission.

7. DATA STORAGE EQUIPMENT -- Records spacecraft voice and data; especially useful during periods when communication with earth is distrupted, such as when CSM is behind moon.

8. DIGITAL RANGING GENERATOR -- Generates and decodes signals through VHF link for ranging information between CM and LM. (Not on Apollo 9.)

9. VHF RECOVERY BEACON -- Transmits a VHF direction finding signal to locate CM during recovery.

10. VHF TRIPLEXER -- Permits VHF transmitter-receivers to share a single antenna.

4th add

The Communication and Data system equipment units are installed in the lower equipment bay of the Command Module, beneath the astronauts' instrument panel.

Total system weight is 196 pounds (89 kg), and average power consumption during a lunar mission is approximately 150 watts.

Design of the system equipment units was strongly influenced by the manned spacecraft physical environmant and the high reliability requirements. Various electronic construction and packaging techniques were utilized, with extensive use of redundant circuits and components.

System units are mounted to coldplates in the Command Module for cooling. Thermal paths from all heat dissipating components in the equipments are provided to cooled equipment bases. All equipment units except the Data Storage recorder are enclosed in rugged gasket-sealed aluminum cases. All units have hermetically sealed, quick-disconnect connectors.

Companies associated with the Communication and Data System as subcontractors to Collins are RCA, Camden, N.J.; Radiation, Inc., Melbourne, Fla.; Motorola, Inc., Scottsdale, Ariz.; Leach Corporation, Azusa, Calif.; and Rantec Corporation, Calabasas, Calif.

Closely related to the Communication and Data system operation are the antennas, central timing equipment, up-data link receiver, signal conditioner, and television camera supplied by other contractors under contract to North American Rockwell or NASA.

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COMMUNICATION FOR APOLLO

Systems supplied by Collins Radio Company perform vital radio communication functions for Apollo missions.

The systems include equipment in the Command Module, in the Lunar Module, and in ground stations, ships and aircraft around the earth.

Systems by Collins used for Apollo are:

1. The communication and data system in the Apollo Command Module. The system provides transmission and reception of all voice, data and ranging (tracking) signals; spacecraft to earth transmission of television and recorded data; voice and data communication for the Command Module with the Lunar Module; intercommunication for the Command Module crew; and recovery communication.

2. The Unified S-Band Tracking/Communication system, consisting of equipment installed in 11 stations and a specially instrumented ship around the earth. These systems provide voice, data and ranging signal transmission and reception and television reception between earth and the Command Module, the Lunar Module and astronauts on the surface of the moon.

3. A multi-function subsystem of the Lunar Module communication system. The signal processor supplied by Collins is a key unit for all LM communication.

-more-

4. Mobile satellite communication terminals used in Apollo recovery operations.

5. Systems aboard Apollo Range Instrumented Aircraft (ARIA) used in relaying communication between spacecraft and earth.

Much of this equipment operates throughout a mission. The Command Module communication and data system is used from pre-launch to recovery, and the Unified S-Band ground systems operate from the time the Apollo-Saturn combination lifts off until Command Module reentry.

Two radio frequency bands are used for Apollo communication. One is S-band, and the other is VHF (very high frequency). S-band, used for all communication with earth from deep space, is referred to as "unified S-band" in Apollo because information such as voice, data and ranging is combined in a single transmission. Both S-band and VHF can be used for near earth communication, and VHF is used between Command Module and Lunar Module.

The Command Module system, provided by Collins under contract to North American Rockwell Corporation, consists of 10 equipment units operating as a system with the capability of continuously handling voice, data and ranging communication.

In addition, it provides television transmissions from spacecraft to earth, and communication with the Lunar Module. It also records information when the Command Module is behind the moon, for transmission to earth when communication is reestablished. A locator signal and voice communication during recovery operations are other functions.

2nd add--Apollo Communication

Maximum power output on unified S-band from Command Module to earth, even at lunar distance, is about 11 watts.

Major subcontractors to Collins providing part of the Command Module communication and data system included RCA, Motorola, Radiation, Inc., Leach, Inc., and Rantec, Inc.

The Unified S-Band Tracking/Communication system network consists of 8 stations equipped with 30-foot diameter antennas and 3 stations with 85-foot diameter antennas. The 30-foot stations, used for earth orbit communication and to assist with deep space phases of missions, are located at Cape Kennedy; Bermuda; Canary Islands; Ascension Island; Carnarvon, Australia; Guam; Hawaii; and Corpus Christi, Texas. One ship equipped with tracking and communication systems is also a part of the network.

The 85-foot stations at Goldstone, Calif.; Madrid, Spain, and Canberra, Australia provide the capability for deep space communication with Apollo spacecraft. They are located approximately equal distances apart around the earth, so that one of them always has an unobstructed line of sight toward the moon despite rotation of the earth and orbiting of the moon around the earth. In this manner, radio contact is maintained at all times with a spacecraft between earth and moon.

Each of the unified S-band stations is equipped with transmitting, receiving, amplifying and computation equipment for communication and tracking, including the capability for determining the course and velocity of the spacecraft.

-more-

3rd add--Apollo Communication

Maximum transmitting power of the ground stations is about 20,000 watts. The 85-foot stations and five of the 30-foot stations have dual capability, for simultaneous communication with both Command Module and Lunar Module.

Collins was responsible for design, construction and installation of the ground station systems under a contract with NASA's Goddard Space Flight Center. Electronic equipment also was provided for ocean ships and ARIA jets which are a part of the tracking and communication network.

Another group of equipment developed by Collins, although not specifically designed for the Apollo program, is being utilized to provide improved communication for Apollo recovery operations.

Known as TACSATCOM (Tactical Satellite Communication) equipment, it is used to provide communication via satellite between NASA control centers and recovery forces in remote areas of the world.

TACSATCOM systems, in the form of shipboard, airborne and mobile ground terminals, have been utilized in past Apollo recovery operations.

Terminals operating in the UHF band were developed and produced by Collins under contract with the U.S. Air Force. The primary application of the systems is in a joint military service program to evaluate the use of satellite communication for tactical operations.

Collins' work in providing a part of the Lunar Module communication system was performed as a subcontractor to RCA. The company's work in systems modifications for the ARIA jets was under a contract from the U.S. Air Force.

Equipment made by Collins has been used in all Mercury, Gemini and Apollo spacecraft, including transmitting the voices of all American astronauts who have flown in space.

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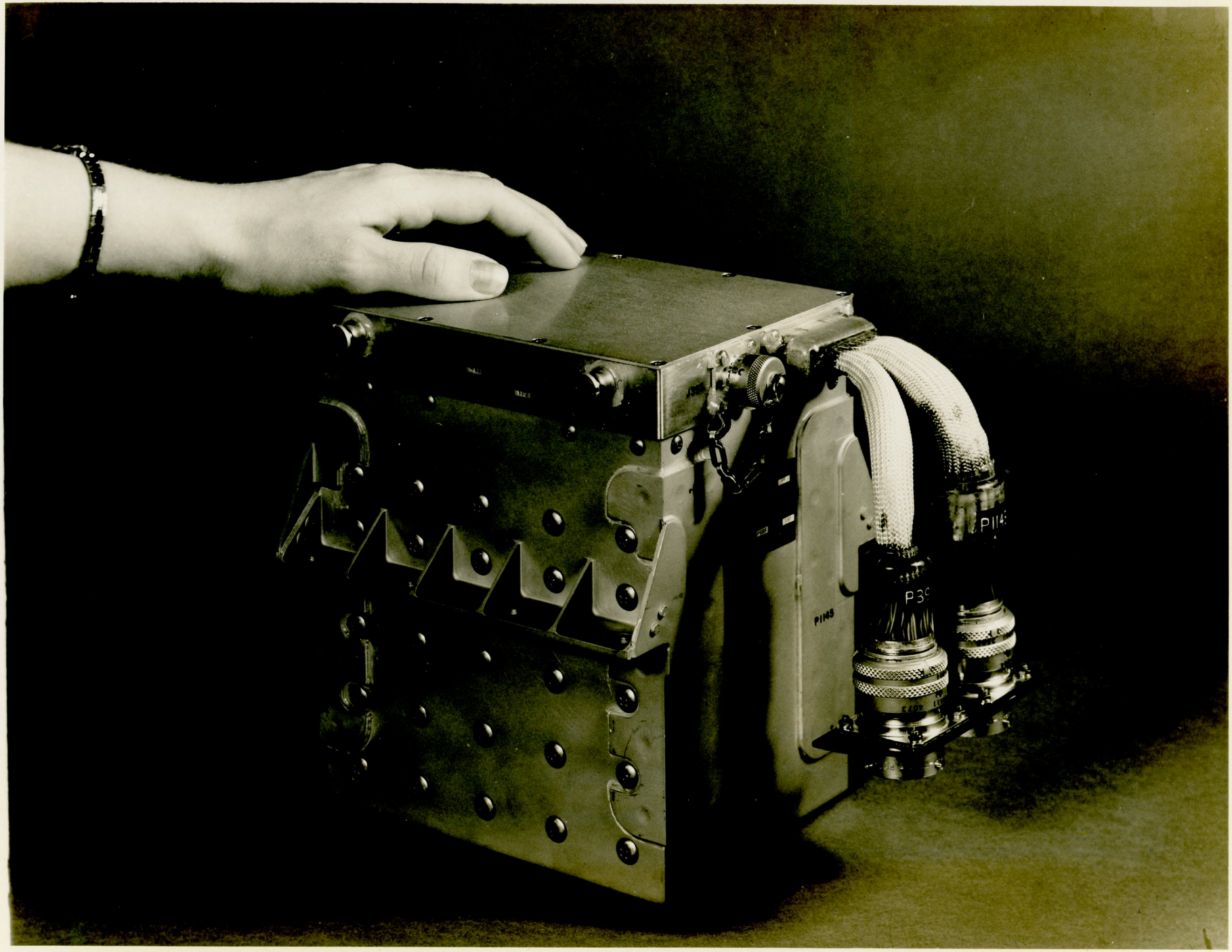
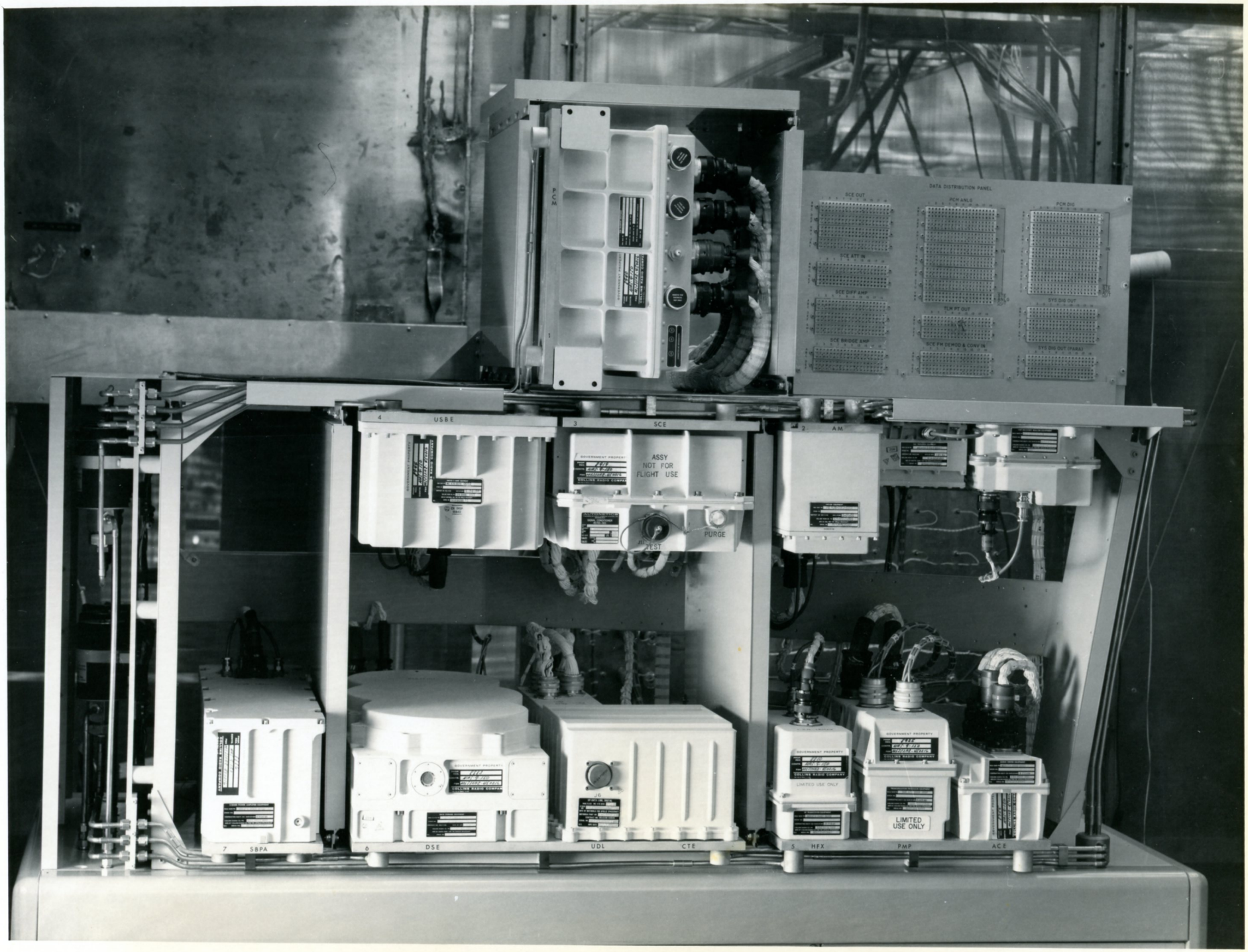


LUNAR MODULE SIGNAL PROCESSOR -- A key unit of the Lunar Module communication system is the Signal Processor. Designed and manufactured by Collins Radio Company, the Signal Processor is involved in processing and switching all signals transmitted and received by the Lunar Module communication system.

UNIFIED S-BAND TRACKING/COMMUNICATION STATION FOR APOLLO -- Goldstone, Calif. station of NASA's Apollo Unified S-Band Tracking/Communication System network is equipped with 85-foot diameter antenna for use during deep space phases of Apollo missions, including when Command Module and Lunar Module are at lunar distances. Two other stations, in Spain and Australia, also have 85-foot antennas and 11 others have 30-foot antennas. The three deep space stations are located at 120-degree intervals around the earth so that one of them will always have the moon in sight. The stations transmit and receive voice, data and ranging signals, and receive TV from the spacecraft. Collins Radio Company was prime contractor to NASA for the unified S-band ground station system.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6 DSE
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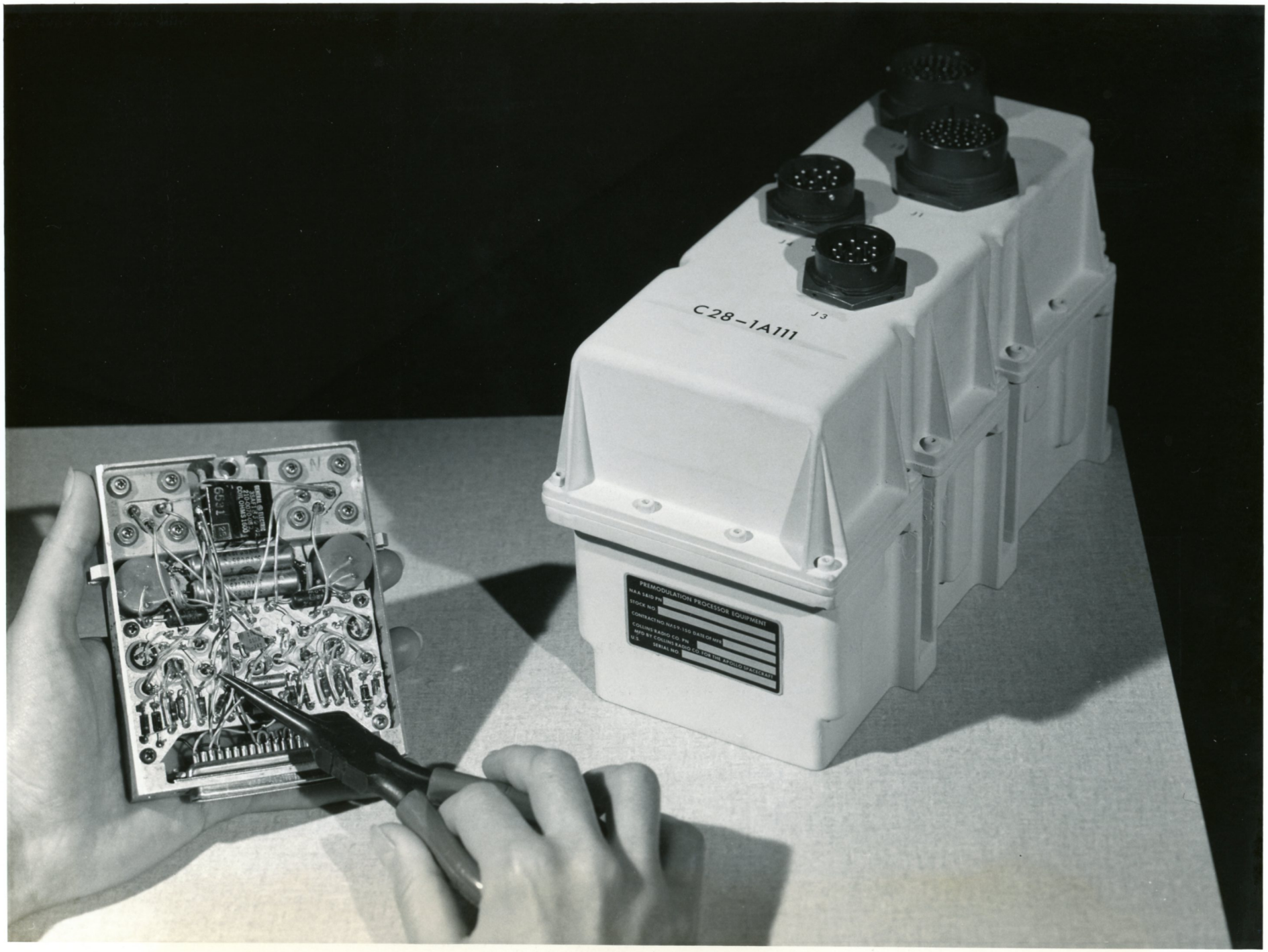
CTE
5 HFX
PMP
ACE

COMMAND MODULE COMMUNICATION AND DATA SYSTEM -- Equipment units comprising the Command Module Communication and Data System operate as a system to provide all voice, data, tracking and TV communication between Command Module and earth, communication for the Command Module with the Lunar Module, and recovery communication for the Command Module and crew. Collins Radio Company supplies the system under contract to North American Rockwell Corporation.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PREMODULATION PROCESSOR EQUIPMENT
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SERIAL NO.

One of the equipment units performing vital functions in the Command Module communication and data system is the premodulation processor, made by Collins Radio Company. Construction of one of the modules in the equipment and a completed unit are shown above. Information such as astronaut speech, spacecraft data, television and recorded data is routed to the premodulation processor for multiplexing and modulation, then to the unified S-band transponder and power amplifier for transmission to earth. Unified S-band voice and data signals received from earth are detected and separated by the premodulation processor.

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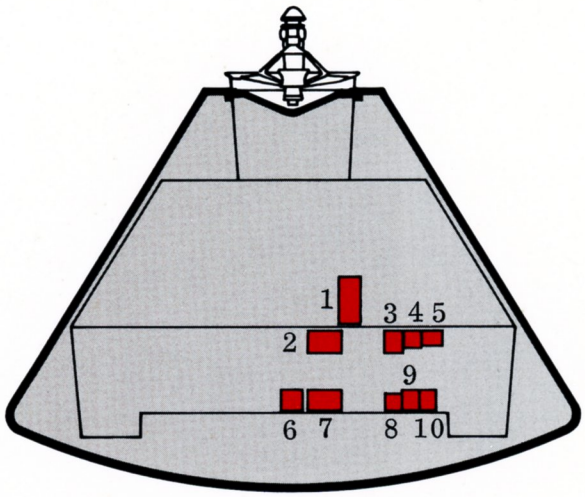
Apollo Command Module Communication and Data System

Provided by Collins Radio Company under contract to North American Rockwell Corporation

Functions of the System

1. Two-way voice communication.
2. Two-way data communication.
3. Ranging information for tracking the spacecraft.
4. Voice and data communication with the LM.
5. Television transmission to earth.
6. Intercommunication for astronauts.
7. Recovery location and communication.
8. Recording and playback of voice and data.



Collins Radio Company had overall responsibility for system design, integration and testing, and program management of the communication and data system. Collins developed and manufactured part of the equipment; remaining elements of the system were developed and manufactured by other companies under subcontract to Collins.

Equipment Units of the Communication and Data System

1. PCM Telemetry unit (Radiation, Inc.) -- Converts biomedical, scientific and operational measurements from crew and spacecraft to digital form for transmission.

2. Unified S-Band Equipment (Motorola) -- Dual transponder which generates and receives S-band voice and data signals; receives and responds to ranging signals; generates FM transmission of television and recorded voice and data.

3. VHF/AM Transmitter-Receiver (RCA) -- Dual transmitters and receivers for near earth voice communication; voice communication between CM and LM or EVA; receipt of data from LM and EVA.

4. VHF Triplexer (Rantec, Inc.) -- Permits VHF transmitter-receivers to share a single antenna.

5. VHF Recovery Beacon (Collins) -- Transmits a VHF direction finding signal to locate CM during recovery.

6. S-Band Power Amplifier (Collins) -- Amplifies S-band signals to necessary power level for transmission to earth.

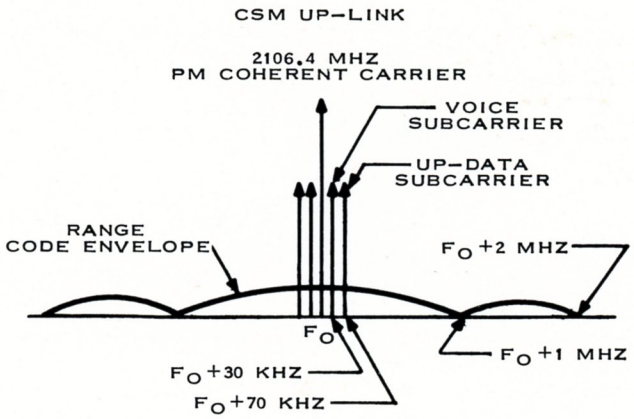
7. Data Storage Equipment (Leach, Inc.) -- Records spacecraft voice and data; especially useful during periods when communication with earth is disrupted, such as when CSM is behind moon.

8. Digital Ranging Generator (RCA) -- Generates and decodes signals through VHF link for ranging information between CM and LM. (Not on Apollo 9.)

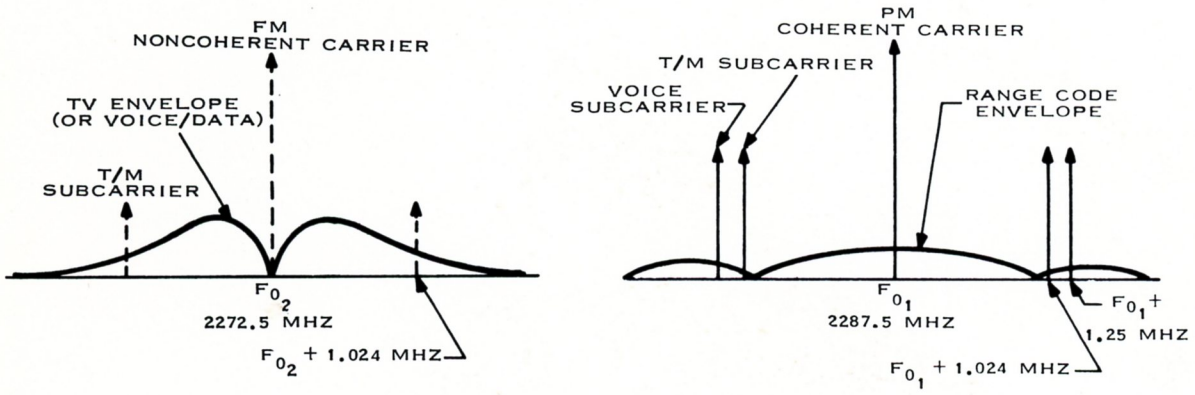
9. Pre-Modulation Processor (Collins) -- Provides multiplexing and modulation of voice and data signals for unified S-band transmission to earth. Also detects and separates voice and data signals received from earth.

10. Audio Center (Collins) -- Links microphones and earphones of each astronaut to voice transmission and reception equipment, and provides intercommunication for the CM crew.

Communication and Data System equipment units operate together in various combinations to perform specific communication functions. For example, for unified S-band voice and data transmission to earth, the Audio Center, PCM Telemetry, Pre-Modulation Processor, Unified S-Band Equipment and S-Band Power Amplifier all are required to operate together as a system to provide the transmission.



USB Up-Link Signal Spectrum



USB Down-Link Signal Spectrum