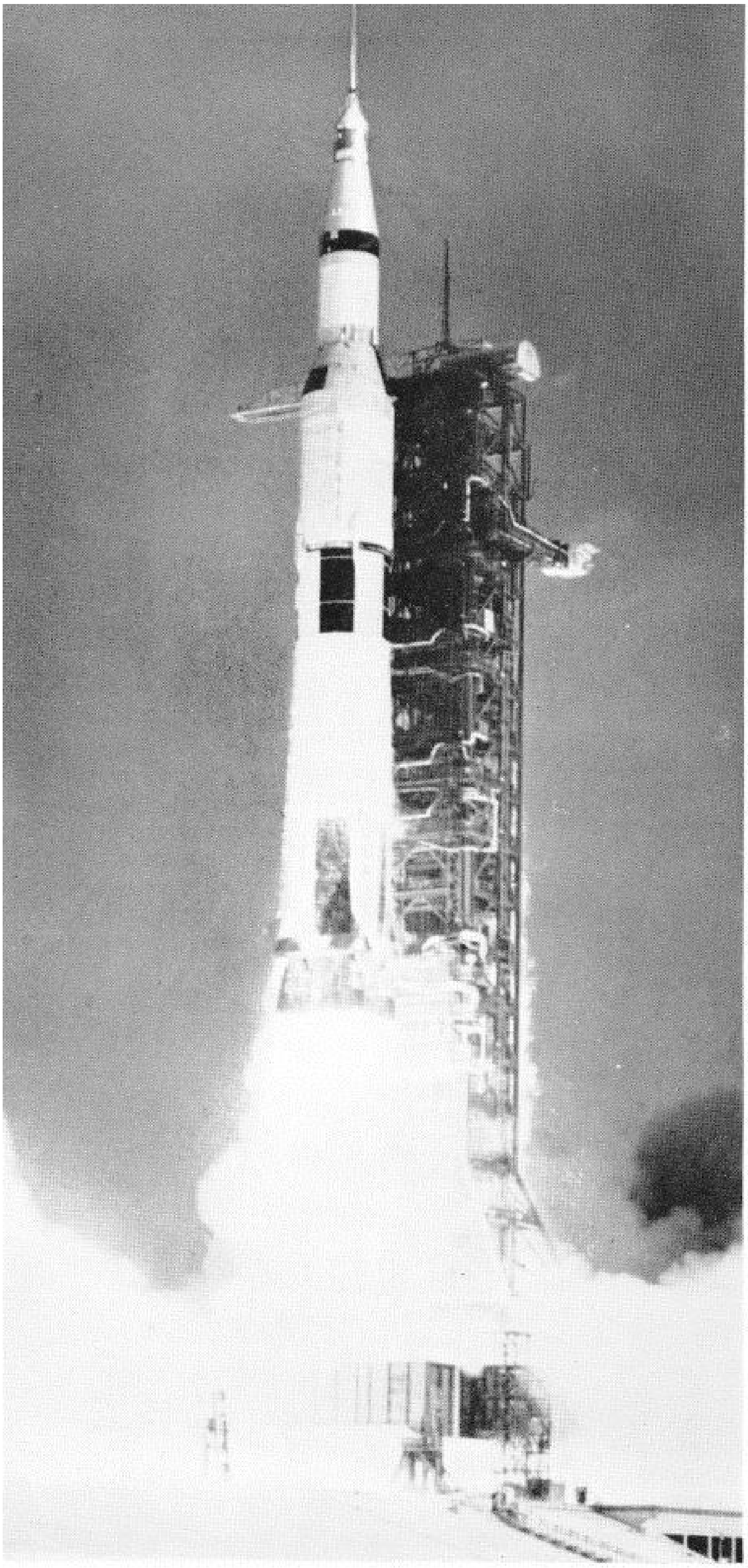
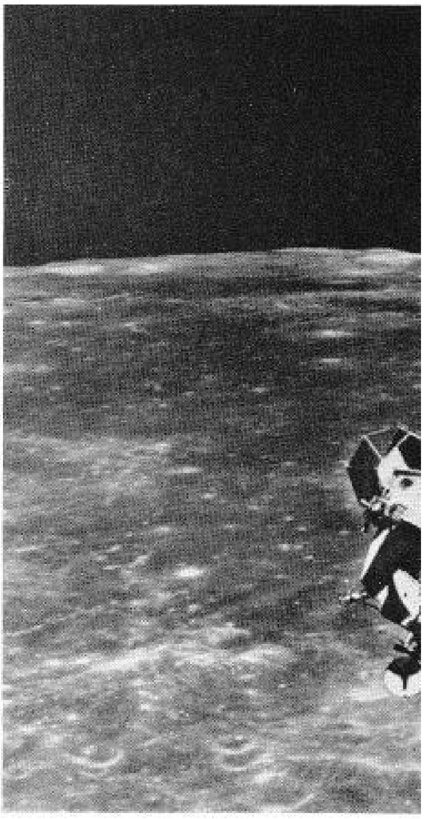


VOICES



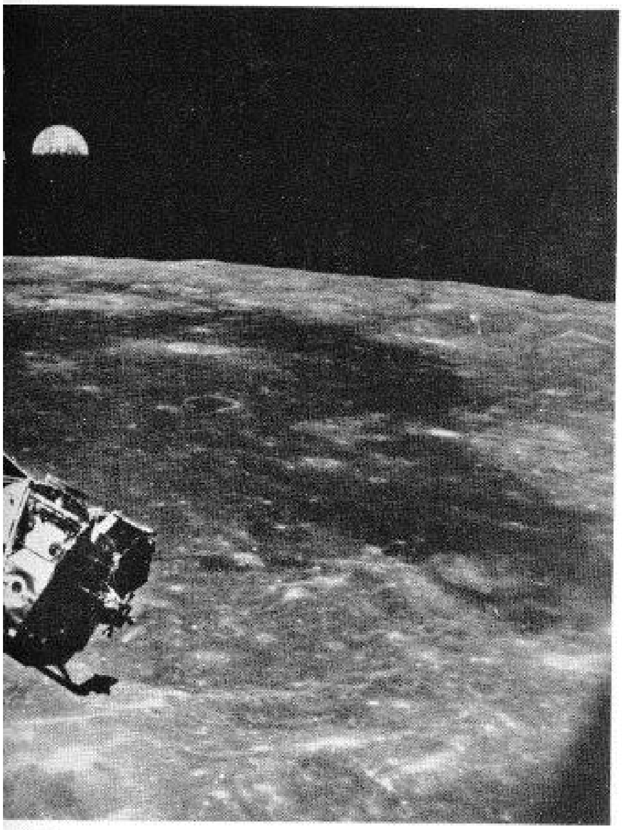
LEFT: *Apollo 11 at the moment of take-off on the flight to the Moon. Apollo 12 is now in the final stages of countdown: the mission is due to start on 14 November*

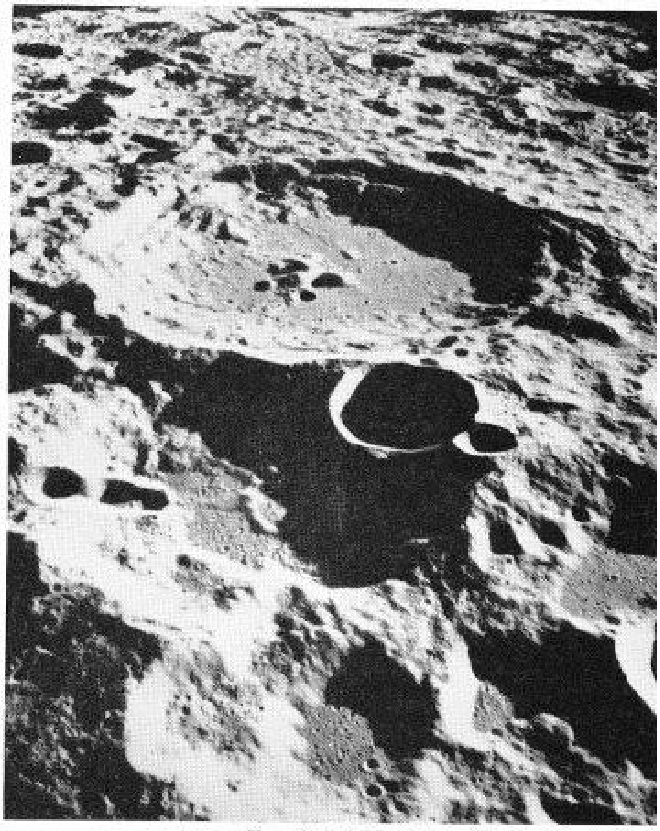
ABOVE: *From take-off to splash-down the astronauts depend on their communications and data systems for all contact with the Earth and each other. This is the Apollo 11 lunar module with Armstrong and Aldrin aboard rising to rejoin the command ship, piloted by Collins, in lunar orbit. Above the Moon's horizon is the half-lighted Earth with whom the Astronauts were able to speak freely*

ABOVE RIGHT: *Landscape on the far side of the Moon photographed by the Apollo 11 team during the ascent from the surface to the command ship. In the centre is International Astronomical Union Crater No. 308*

FROM SPACE

by *Norman Moorcroft*, F.R.A.S., *Baddow*





Photos United States Information Service

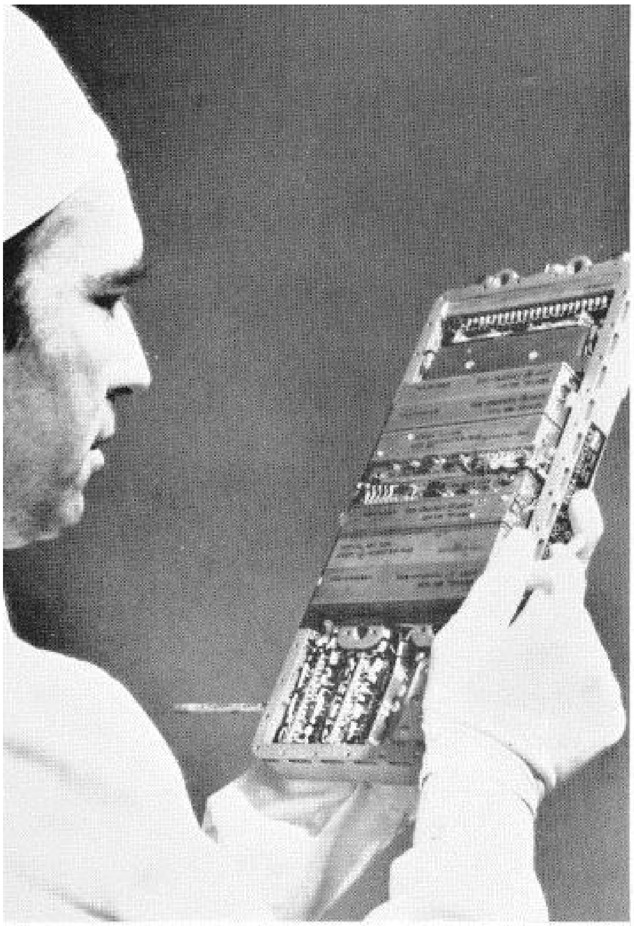
ASTRONAUTS Conrad, Gordon and Bean, with their Apollo 12 spacecraft and its giant Saturn rocket, are now in the final stages of count-down for the next flight to the Moon. Lift off will sever Apollo's umbilical cables and from that moment the astronauts will depend on the vehicle's communications systems for all contact with Earth.

During the two minute, forty-second flight of the first stage of the rocket some 330 measurements, covering fuel consumption, engine ignition, engine cut-offs, and vehicle separation are made and transmitted back to Earth. A further 514 measurements are transmitted during the six and a half minutes' flight of the second stage; 283 during the flight of the third stage with another 221 from the instrument unit. These transmissions are independent of any from the spacecraft itself.

All telemetry during the launch phase and early stages of the flight is transmitted on frequencies around 250 MHz with an additional S-band frequency for the launch vehicle instrument unit.

Communication between the astronauts and ground whilst Apollo is in its initial earth orbit is carried out by means of amplitude modulated V.H.F., but subsequently all communication back to Earth is covered by the unified S-band system. Intercommunication between the astronauts themselves and between the astronauts and the lunar module and command module is carried out on frequencies of 259.7 MHz and 296.8 MHz.

Up to the third stage separation, tracking is accomplished by the use of a C-band transponder in the instrument unit. This provides beacon tracking during the orbital phase and during the lunar trajectory until battery depletion. After battery depletion normal radar tracking is employed until maximum effective range (about 32,000 nautical miles) is reached.



Primary tracking of the command/service module is provided by the unified S-band system, but the C-band system provides support after CSM/S-IVB separation as the secondary tracking system. During re-entry the command module C-band system is used for radar tracking to provide splash-down prediction.

The C-band system used is a high precision monopulse tracking radar designed originally for missile tracking. In the Apollo configuration the system uses a spacecraft-borne transponder and several ground-based stations which can operate in either the 'beacon' or 'skin-track' modes. The latter mode is provided as back-up in case of a failure of the C-band transponder.

The spacecraft carries a C-band transponder, whilst the instrument unit carries an 'Azusa' radar tracking beacon which transmits on 5000 MHz when interrogated by a signal on 5060.194 MHz from the ground, together with a further C-band transponder which similarly transmits on 5765 MHz when interrogated at 5960 MHz.

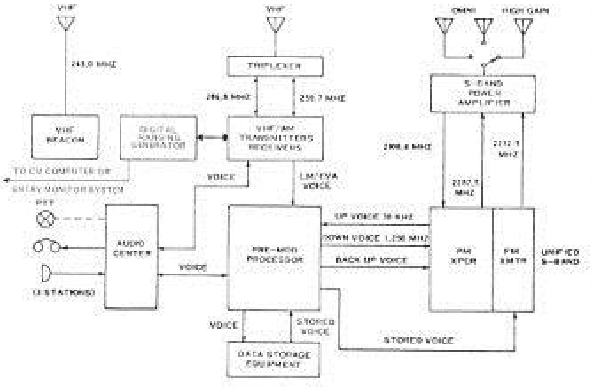
S-band tracking of the instrument unit (and S-IVB rocket stage) is necessary to ensure that the S-IVB stage, which is placed in solar orbit after separation from the spacecraft, is on a correct course and well clear of the spacecraft translunar course.

The unified S-band system is used as the prime 'deep-space' communications and tracking medium between Earth and the spacecraft (i.e. both the lunar module and the command module) and is used throughout the mission.

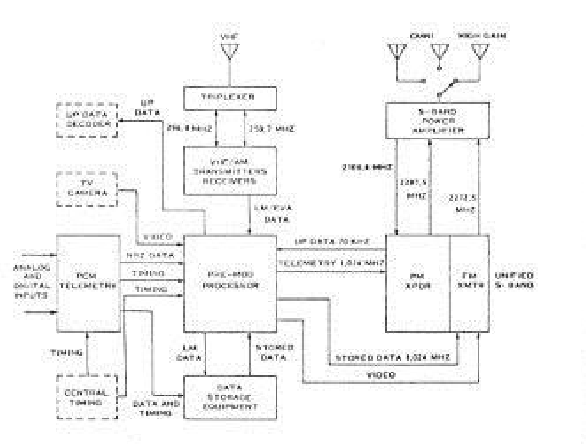
This system uses a single nominal carrier frequency band in each direction to provide both tracking and communications and has the capability to track and provide data communications for both the lunar module and command module simultaneously using a single parabolic aerial.

All 'down-link' telemetry and command control is 'packed' into the frequency band 2270 to 2300 MHz, whilst 'up-link' commands to the spacecraft use the band 2090 to 2120 MHz. Two sets of frequencies, separated by 5 MHz, are used in each 'up-link' and 'down-link' band.

Signals are received on Earth by one of the three 85 ft. 'deep space net' aerials.

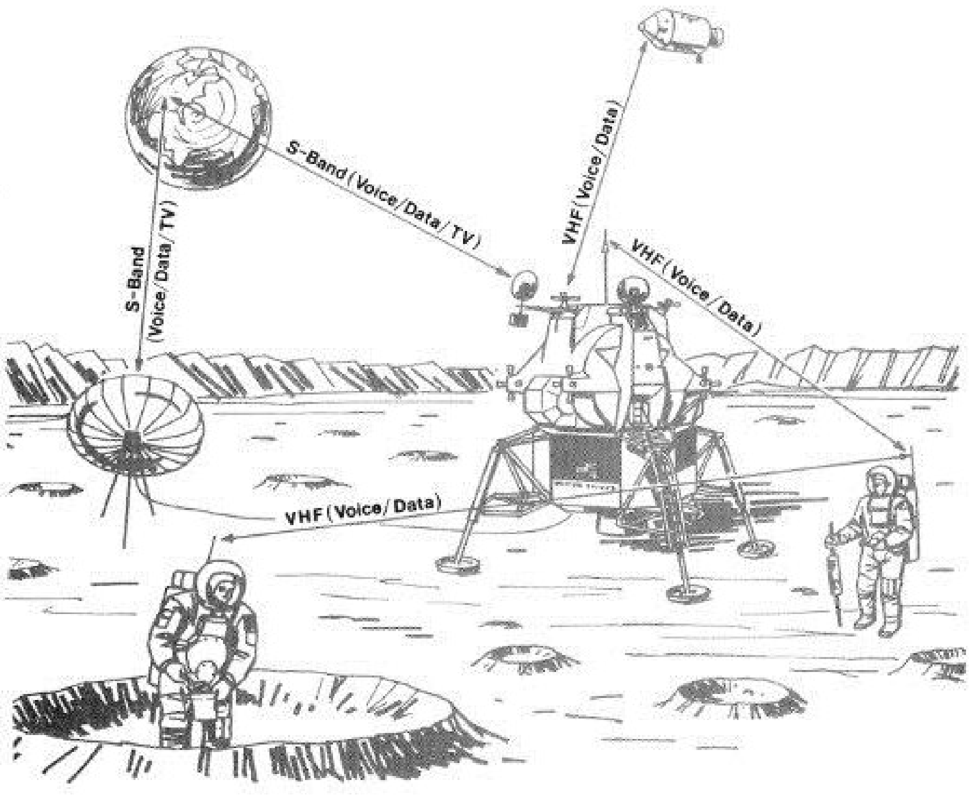


Voice and recovery circuits, functional diagram



Data and video circuits, functional diagram

FAR LEFT: *An RCA technician working on a communications unit for an astronaut's lunar landing back-pack. Hundreds of hours of testing were carried out on these units in varying conditions of heat, cold and vacuum*



RIGHT: *An RCA diagram showing intercommunication between astronauts, landing craft, command ship and Earth. This includes voice, data, and TV* [*RCA*]

The telecommunications system in the command module provides voice, television, telemetry and command data, and tracking and ranging between the spacecraft and Earth; also between the command module and lunar module. In addition it provides communication between the spacecraft and extravehicular astronauts, and intercommunication between the astronauts themselves.

The system comprises:

(a) Pulse code modulated telemetry for relaying data on spacecraft systems and crew condition to MSFN stations.

(b) V.H.F./AM voice communication.

(c) Unified S-band tracking responder, air-to-ground voice communication, onboard TV.

(d) V.H.F. recovery beacon.

A total of ten aerials are mounted around the outside of the spacecraft, comprising two V.H.F. 'blade' recovery aerials (fitted under the forward heat-shield), four flush-mounted S-band omnidirectional aerials and one range tone transfer (RTT) aerial, all mounted on the command module. In addition two 'Scimitar' V.H.F. omnidirectional aerials, mounted 180° apart, and a steerable S-band high-gain aerial are mounted on the service module.

The high-gain aerial (which provides the main deep-space link with Earth) consists of four 31 in. diameter parabolic dishes mounted on a folding boom at the aft end of the service module. Signals from the ground stations can be tracked either automatically or manually by means of the aerial's gimballing system.

Normal S-band voice and uplink–downlink communications are handled by the omnidirectional and high-gain aerials.

Network stations can transmit to the spacecraft such items as updates to the Apollo guidance computer and central timing equipment, together with real-time commands for certain onboard functions.

Later versions of the command module are equipped with a V.H.F. ranging device as back-up to the lunar module rendezvous radar.

The overall weight of the command module system (comprising ten units) is 196 lb. and the average power consumption is 150 watts. The equipment was developed by the Collins Radio Company of Cedar Rapids, Iowa, as sub-contractors to North American Aviation Inc., the prime contractors for the command and service modules.

The equipment carried by the lunar module was developed by RCA for the Grumman Aircraft Engineering Corpn., prime contractors for the lunar module, and is, if anything, even more complex than that in the command module. It consists of two S-band transmitter/receivers, two V.H.F. transmitter/receivers, a signal processing assembly and additional radar equipment.

Crewmen for the Apollo 12 flight scheduled to start on 14 November. Left to right: Charles Conrad, commander; Richard Gordon, command ship pilot; and Alan Bean, landing-craft pilot

Seven aerials are mounted on the ascent stage, comprising a 26 in. diameter parabolic S-band steerable aerial, an X-band rendezvous radar aerial, two V.H.F. 'in-flight' aerials, a V.H.F. extravehicular activity aerial and a landing radar aerial.

In addition an erectable S-band parabolic aerial is carried in the descent stage for possible deployment on the Moon's surface in case of communication difficulties.

The systems are capable of voice transmission and reception, transmission and reception of tracking and ranging data, transmission to Earth of some 270 measurements and also TV signals.

The extravehicular communications units used by the astronauts on the Moon's surface are carried in the portable life support system (PLSS) backpack and measure only 14 in. by 6 in. by $1\frac{1}{4}$ in. and weigh just $6\frac{1}{2}$ lb. They keep the astronauts in two-way contact with each other, with Earth, and with the command module and in addition carry biomedical telemetry to Earth.

On the Moon's surface one set of equipment acts as relay to the lunar module for the other. For instance, during the Apollo 11 flight Aldrin's set transmitted frequency modulated signals (carrying both voice and telemetry) to Armstrong's set. Armstrong's set, in turn, combined his own voice and telemetry with Aldrin's and passed the combined signals by amplitude modulation to the lunar module for relay to Earth by the unified S-band system. The command module is kept in touch through a LM–Earth–CM relay link.

A voice-operated relay system is normally used to leave the astronauts' hands free, but 'push-to-talk' operation can be used by switch selection.

Each set contains five transmitters and receivers plus telemetry instrumentation and voice processing circuits and was developed by RCA. The sets are all solid-state.

The radar section consists of the rendezvous radar which gives CSM range and range-rate together with line-of-sight angles for manoeuvre computation to the LM guidance computer, and the landing radar which provides altitude and velocity data to the LM guidance computer during lunar landing. The rendezvous radar has an operating range from 80 ft. up to 400 nautical miles and both radars operate in X-band. An additional range transfer tone assembly, utilizing V.H.F., is a passive transponder to the CM V.H.F. ranging device which acts as back-up to the rendezvous radar.

With this review of the equipment which will be used to direct the astronauts to their rendezvous and maintain their links with Earth, we would like to wish the Apollo 12 crew a very successful mission.

A Marconi satellite communication system will again play its part in the complex spacecraft tracking operation.

* * *

Television has been a feature of all the manned Apollo flights.

The black-and-white camera of the type used by by Apollo 11 is made by RCA and weighs $4\frac{1}{2}$ lb. It is fitted with an 80° wide-angle lens and a 100 mm. 9° telephoto lens and is attached to a 12 ft. power/video cable. Non-interlaced, 320 line pictures at 10 frames/second are produced.

The colour camera is made by Westinghouse and weighs 12 lb. Fitted with a zoom lens for close-up or wide-angle use it has a 3 in. monitor that can be mounted either on the camera itself or in the command module. This camera produces 525 line, 30 frames/second colour signals by means of a rotating colour wheel.