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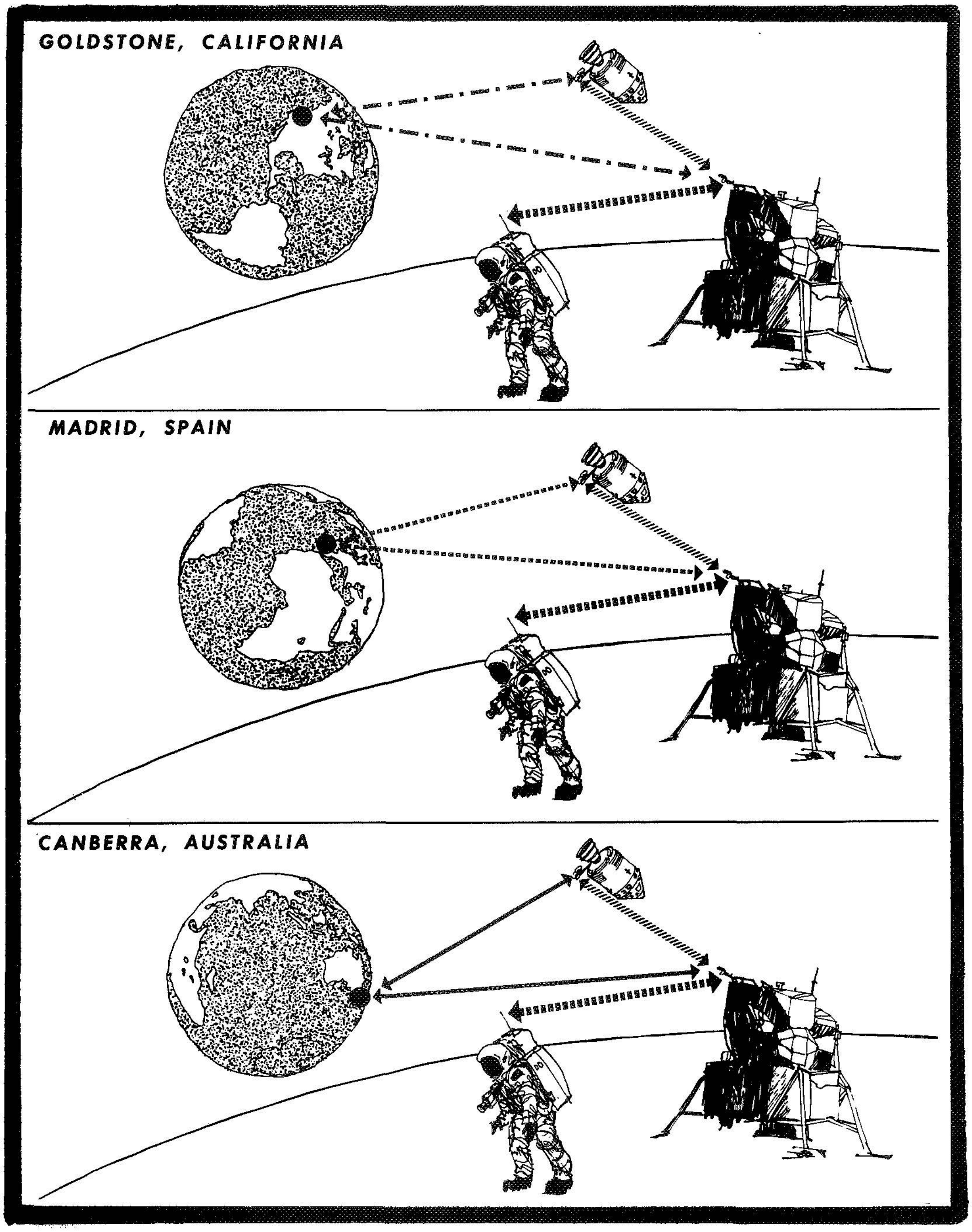

MANNED SPACE FLIGHT NETWORK

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NASA'S MANNED SPACE FLIGHT NETWORK

Tracking, command and communication--Apollo's vital links with the earth--are performed in two broad phases.

For the first phase, the Manned Space Flight Network (MSFN) depends largely on its worldwide chain of stations equipped with 30-foot antennas while Apollo is launched and orbiting near the earth. The second phase begins when the spacecraft moves out more than 10,000 miles above earth, when the 85-foot-diameter antennas bring their greater power and precision into play.

The Network must furnish reliable, instantaneous contact with the astronauts, their launch vehicle and spacecraft, from liftoff through earth orbit, moon landing and lunar takeoff to splashdown in the Pacific Ocean.

The Network consists of 12 ground stations, one ship, and four jet aircraft--all directly or indirectly linked with Mission Control Center in Houston. While the earth turns on its axis, and the moon travels in orbit nearly one-quarter million miles away and the Apollo spacecraft moves between them, ground controllers will be kept in the closest possible contact. Thus, only for some 45 minutes as the spacecraft flies behind the moon in each orbit, is this link with earth out of reach.

All elements of the network get ready early in the countdown. As the Apollo launches from Cape Kennedy, voice and data are transmitted instantaneously to Houston. The data are sent directly through computers for visual display to flight controllers.

Depending on the launch azimuth, the 30-foot antennas keep tabs on Apollo, beginning with the station at Merritt Island, Fla., thence Bermuda; the tracking ship Vanguard; the Canary Islands; Tananarive, Madagascar; Carnarvon, Australia; Guam; Hawaii; and Corpus Christi, Texas.

To inject Apollo into translunar flight path, Mission Control sends a signal through one of the land stations. As the spacecraft heads for the moon, the engine burn is monitored by the ground stations and an Apollo range instrumentation aircraft (ARIA). The ARIA provides a relay for the astronauts' voices and data communication with Houston.

When the spacecraft reaches an altitude of 10,000 miles the more powerful 85-foot antennas join in for primary support of the flight, although the 30-foot "dishes" continue to track and record data. The 85-foot antennas are located about 120 degrees apart at Madrid, Spain; Goldstone, Calif.; and Canberra, Australia.

With the 120-degree spacing around the earth, at least one of the large antennas always has the moon "in view." As the earth revolves from west to east, one 85-foot station hands over control to the next 85-foot station as it moves into view of the spacecraft. In this way data and communication flow is continuous.

Data are always relayed back through the large antennas and transmitted via the NASA Communications Network (NASCOM)--a two-million mile hookup of landlines, undersea cables, radio circuits and communication satellites--to Houston. This information is fed into computers for visual display in Mission Control--for example, a display of the precise position of the spacecraft on a large map. Or, returning data may indicate a drop in power or some other difficulty in a spacecraft system, which would energize a red light to alert a flight controller to action.

Returning data flowing through the earth stations give the necessary information for commanding midcourse maneuvers to keep Apollo in a proper trajectory for orbiting the moon. While Apollo is in the vicinity of the moon, these data indicate the amount of retro burn necessary for the service module engine to place the spacecraft in lunar orbit.

Once the lunar module separates from the command module and goes into a separate lunar orbit, the MSFN is required to keep track of both spacecraft at once, and provide two-way communication and telemetry between them and the earth. The prime antenna at each of the three 85-foot tracking stations handles one spacecraft while a wing, or backup, antenna at the same site handles the other spacecraft during each pass.

Tracking and acquisition of data between earth and the two spacecraft provide support for the rendezvous and docking maneuvers. The information also is used to determine the time and duration of the service module into a precise trajectory for reentering the earth's atmosphere at the planned location.

As the spacecraft comes toward earth at high speed--more than 25,000 miles per hour--it must reenter at the proper angle. To make an accurate reentry, information from the tracking aircraft and stations is fed into the MCC computers where flight controllers make decisions that will provide the Apollo crew with the necessary information.

Appropriate network stations and aircraft in the Pacific are on hand to provide support during the reentry. An ARIA aircraft relays astronaut voice communications to MCC, and antennas on reentry ships follow the spacecraft.

Through the journey to the moon and return, television is received from the spacecraft at the Goldstone, Madrid, and Canberra 85-foot antennas. In addition, 210-foot-diameter antennas in California and Australia are used to augment the television coverage while the Apollo is near and on the moon. Scan converters at the stations permit immediate transmission of commercial quality TV via NASCOM to Houston, where it is then released to TV networks.

NASA Communications Network

The NASA Communications Network (NASCOM) consists of several systems of diversely routed communications channels leased on communications satellites, common carrier systems and high frequency radio facilities where necessary to provide the access links.

The system includes both narrow and wideband channels, and some TV channels. Among these are a variety of telegraph, voice, and data systems (digital and analog) with several digital data rates. Alternate routes or redundancy provide added reliability.

A primary switching center and intermediate switching and control points provide centralized facility and technical control, and switching operations under direct NASA control. The primary switching center is at the Goddard Space Flight Center, Greenbelt, Md. Intermediate centers are located at Canberra, Madrid, London, Honolulu, Guam, and Kennedy Space Center.

The Kennedy Space Center is connected directly to the Mission Control Center, Houston, via the Apollo Launch Data System and to the Marshall Space Flight Center, Huntsville, Ala., by a Launch Information Exchange Facility.

After launch, all network tracking and telemetry data hubs at GSFC for transmission to MCC Houston via two 50,000 bits-per-second circuits used for redundancy and in case of data overflow.

Two Intelsat communications satellites are used for Apollo. The Atlantic satellite services the Ascension Island unified S-band (USB) station, the Atlantic Ocean ship and the Canary Islands site.

The second Apollo Intelsat communications satellite over the mid-Pacific services the Carnarvon, Australia, USB site. These stations transmit simultaneously through the satellite to Houston via Brewster Flats, Wash., and the Goddard Space Flight Center.

Network Computers

At fraction-of-a-second intervals, the network's digital data processing systems, with NASA's Manned Spacecraft Center as the focal point, "talk" to each other or to the spacecraft. Highspeed computers at the remote site (tracking ships included) issue commands or "up-link" data on such matters as control of cabin pressure, orbital guidance commands, or "go-no-go" indications to perform certain functions.

When information originates from Houston, the computers refer to their pre-programmed information for validity before transmitting the required data to the spacecraft.

Such "up-link" information is communications by ultra-high-frequency radio at about 1,200 bits-per-second. Communication between remote ground sites, via high-speed communications links, occurs at about the same rate. Houston reads information from these ground sites at 2,400 bits-per-second, as well as from remote sites at 100 words-per-minute.

The computer systems perform many other functions, such as:

- Assuring the quality of the transmission lines by continually exercising data paths.

- Verifying accuracy of the messages by repetitive operations.

- Constantly updating the flight status.

For "down link" data, sensors built into the spacecraft continually sample cabin temperature, pressure, physical information on the astronauts such as heartbeat and respiration, among other items. These data are transmitted to the ground stations at 51.2 kilobits (12,800 binary digits) per second.

At MCC the computers:

- Detect and select changes or deviations, compare with their stored programs, and indicate the problem areas or pertinent data to the flight controllers.

- Provide displays to mission personnel.

- Assemble output data in proper formats.

- Log data on magnetic tape for replay for the flight controllers.

- Keep time.

The Apollo Ship and Aircraft

The mission is supported by one instrumentation ship operating as an integral station of the Manned Space Flight Network (MSFN) to provide coverage in areas beyond the range of land stations, and four instrumented jet aircraft on station over the South Pacific.

The ship, USNS Vanguard, performs tracking, telemetry, and communication functions for the launch phase, and earth-orbit insertion.

Vanguard is stations about 1,000 miles southeast of Bermuda (25 degrees N., 49 degrees W.) to bridge the Bermuda-Ascension Island gap during earth-orbit insertion. Vanguard also functions as part of the Atlantic recovery fleet in the event of a launch phase contingency. In the event the launch date slips, the ship normally moves in a northeastward direction to cover the changing translunar injection location.

The Apollo ship was developed jointly by NASA and the Department of Defense. The DOD operates the ship in support of Apollo and other NASA and DOD missions on a non-interference basis with Apollo requirements.

Management of the Apollo ship is the responsibility of the Military Sea Transport Service, with maritime crews and the Federal Electric Corp., International Telephone and Telegraph, under contract providing the technical instrumentation crews.

The technical crews operate in accordance with joint NASA-DOD standards and specifications which are compatible with MSFN operational procedures.

The Apollo Range Instrumentation Aircraft or ARIA, are used primarily to fill coverage gaps between Australia and Hawaii during the translunar injection interval. Prior to and during the burn, the ARIA record telemetry data from Apollo and provide real-time voice communication between the astronauts and the Mission Control Center at Houston.

Four aircraft participate, operating from Pacific, Australian, and Indian Ocean air fields in positions under the orbital track of the spacecraft and launch vehicle. The aircraft are deployed in a northwestward direction in the event of launch day slips.

For reentry, two ARIA are deployed to the landing area to continue communications between Apollo and Mission Control at Houston and provide position information on the spacecraft after the blackout phase of reentry has passed.

The total ARIA fleet for Apollo missions consists of four EC-135A (Boeing 707) jets equipped specifically to meet mission needs. They carry seven-foot parabolic antennas in the nose section, giving them a large, bulbous look.

The aircraft, as well as flight and instrumentation crews, provided by the Air Force, are equipped through joint Air Force-NASA contract action to operate in accordance with MSFN procedures.

Mission Control Center

The Mission Control Center at the Manned Spacecraft Center, Houston, is the focal point for Apollo flight control activities. The center receives tracking and telemetry data from the Manned Space Flight Network, processes data through the Mission Control Center Real-Time Computer Complex and displays the data to the flight controllers and engineers in the Mission Operations Control Room and staff support rooms.

The Manned Space Flight Network tracking and data acquisition stations link the flight controllers at the center to the spacecraft.

For Apollo all network stations are remote sites, that is, without flight control teams. All up-link commands and voice communications originate from Houston, and telemetry data are sent back to Houston at high speed rates (2,400 bits-per-second), on two separate data lines. They can be either real time or playback information.

Signal flow for voice circuits between Houston and the remote sites is via commercial carrier, usually satellite, wherever possible using leased lines which are part of the NASA Communications Network.

Commands are sent from Houston to NASA's Goddard Space Flight Center, Greenbelt, Md., on lines which link computers at the two points. The Goddard communication computers provide automatic switching facilities and speed buffering for the command data. Data are transferred from Goddard to remote sites on high speed (2,400 bits-per-second) lines. Command loads also can be sent by teletype from Houston to the remote sites at 100 word per minute. Again, Goddard computers provide storage and switching functions.

Telemetry data at the remote site are received by the RF receivers, processed by the pulse code modulation ground stations, and transferred to the 642B remote-site telemetry computer for storage. Depending on the format selected by the telemetry controller at Houston, the 642B sends the desired format through a 2010 data transmission unit which provides parallel to serial conversion, and drives a 2,400 bit-per-second mode.

The data mode converts the digital serial data to phase-shifted keyed tones which are fed to the high speed data lines of the communications network.

Tracking data are sent from the sites in a low speed (100 words) teletype format and a 240-bit block high speed (2,400 bits) format. Data rates are one sample--6 seconds for teletype and ten samples (frames) per second for high speed data.

All high-speed data, whether tracking or telemetry, which originate at a remote site are sent to Goddard on high-speed lines. Goddard reformats the data when necessary and sends them to Houston in 600-bit blocks at a 40,800 bits-per-second rate. Of the 600-bit block, 480 bits are reserved for data, the other 120 bits for address, sync, intercomputer instructions, and polynominal error encoding.

All wideband 40,800 bits-per-second data originating at Houston are converted to high speed (2,400 bits-per-second) data at Goddard before being transferred to the designated remote site.

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