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APOLLO EXPERIENCE REPORT - COMMUNICATIONS USED DURING RECOVERY OPERATIONS

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16. Abstract

Apollo Program experience in recovery-support communications is reviewed, and the working relationships among NASA, the Department of Defense, and commercial communications facilities are discussed. The organization, facilities, philosophy, and funding of recovery-support communications are described. The relocation of two recovery control centers is discussed, as are the functions of primary and secondary recovery ships, aircraft, and relay satellites. The possibility of using ships of opportunity for recovery operations is considered. Finally, the means by which money, manpower, and resources have been saved and longlines leased are delineated.

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APOLLO EXPERIENCE REPORT

COMMUNICATIONS USED DURING RECOVERY OPERATIONS

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SUMMARY

A dedicated communications network was established to provide the capability for rapid response of the recovery forces in support of the Apollo Program. During the Apollo Program, two recovery control centers were relocated, a new philosophy concerning teletype communications was adopted, and satellites were used to furnish communications between primary recovery ships and the recovery control centers. The use of existing NASA and Department of Defense facilities to the maximum extent possible and the implementation of several other measures resulted in an efficient, reliable communications system at a relatively low cost to NASA.

INTRODUCTION

Before the operational phase of the Apollo Program, a dedicated voice and teletype communications network existed to provide rapid command and control of recovery forces and to keep the staff in the Mission Control Center (MCC) informed of recovery-force activities and status. This network had been established during the Gemini Program because normal common-user Department of Defense (DOD) communications channels were not always responsive enough and, in many cases, did not extend to certain areas of the world where recovery forces would be positioned to provide either contingency or planned landing-area support. During the Apollo Program, the recovery communications network underwent certain modifications as a result of efforts to improve efficiency, to provide greater reliability, and to reduce costs. The most significant communications changes are discussed in this report.

RECOVERY COMMUNICATIONS

Organization

The responsibility of providing recovery support for the Apollo Program was assigned to the DOD as in Project Mercury and in the Gemini Program. The DOD Manager for Manned Space Flight Support Operations, appointed by the Secretary of Defense, coordinated and provided operational control of the various Apollo mission-support operations. The DOD Manned Space Flight Support Office (DDMS) was the focal point for receiving NASA support requests and for administering the plans and policies of the DOD Manager. The responsibility of providing recovery support for specific areas of the world was delegated to various military commands by the Secretary of Defense through the Joint Chiefs of Staff; the type of support and the geographical area of command responsibility were consistent with normal capabilities and theaters of operation.

Facilities

To control and communicate with the recovery forces, the responsible commanders established recovery control centers at appropriate locations. The facility that provided overall direction was the Recovery Operations Control Room (ROCR), located within the MCC at the NASA Lyndon B. Johnson Space Center (JSC) (formerly the Manned Spacecraft Center (MSC)) in Houston, Texas. During a mission, the ROCR is manned by both NASA and DOD recovery personnel. The principal means of communication among the ROCR, the recovery control centers, the recovery ships, and the remote aircraft-staging bases during mission operations are summarized as follows.

Communications link	Method of communication
Between the ROCR and the recovery control centers	Leased longlines and dedicated DOD circuits
Between the recovery control centers and the recovery ships	Satellites and high-frequency radio
Between the recovery control centers and the remote aircraft-staging bases	Combinations of preceding methods

The recovery-communications network in use during a typical lunar-landing mission is shown in figure 1.

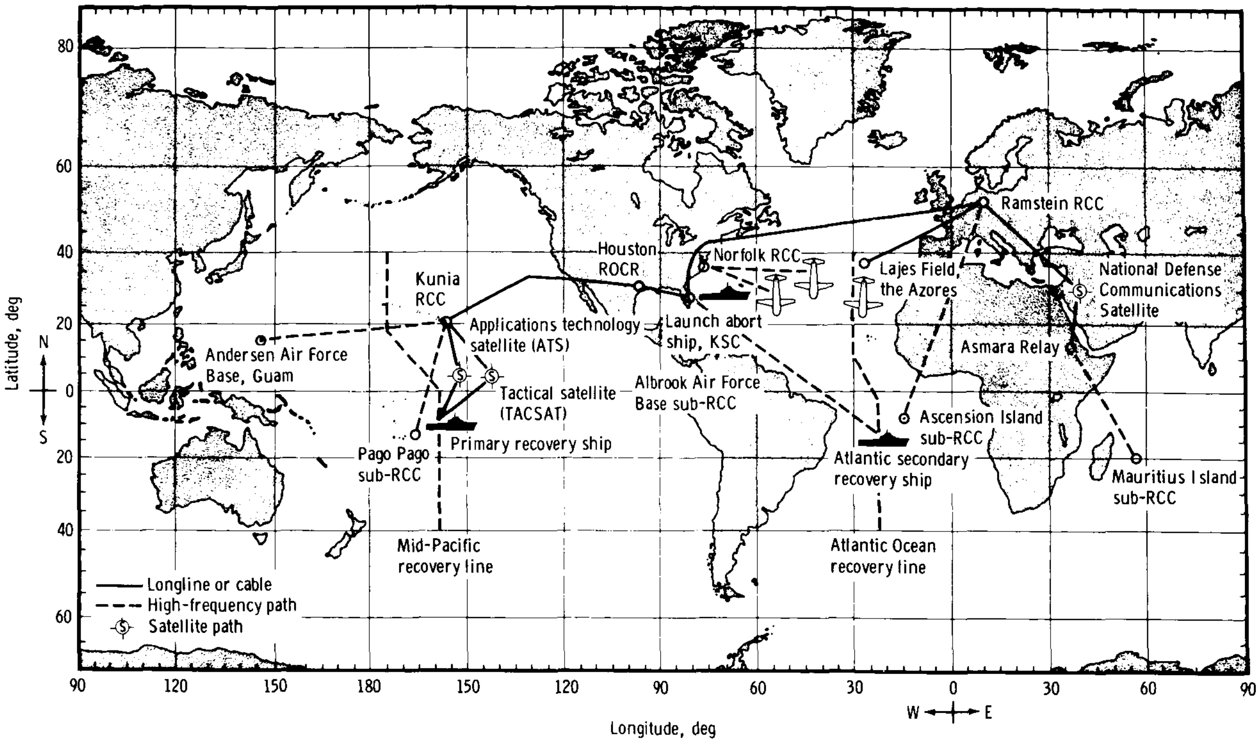

Figure 1.- Functional diagram of recovery communications during a typical lunar-landing mission.

Recovery Control Center Relocations

Atlantic recovery control center.- The Atlantic recovery control center (RCC), serving Commander Task Force 140 (CTF 140), was first located in the Mercury Control Center at the John F. Kennedy Space Center (KSC); this Mercury Control Center was used until 1965 when the MCC at MSC was activated. While the plans for deactivating the Mercury Control Center were being made, a study was conducted to determine the best location for the Atlantic RCC. Several locations were considered, as well as its collocation with the ROCR in Houston. The final decision, however, was to locate the Atlantic RCC in the building occupied by CTF 140 at the Naval Air Station in Norfolk, Virginia. The new RCC was completed in time to conduct an operational checkout during the Apollo 5 mission. In addition to the travel and per diem savings realized by locating the Atlantic RCC in Norfolk, other advantages were gained. The Norfolk Naval Communications Station was able to provide not only additional high-frequency transmitters and receivers for backup to the dedicated high-frequency recovery-communications facilities at KSC, but also a high-frequency circuit for air control of HC-130 rescue aircraft supporting the Atlantic launch abort areas. In addition, personnel for maintenance of RCC teletype and cryptographic equipment were readily available.

Europe/Africa recovery control center. - The Europe/Africa RCC is collocated with the Search and Rescue (SAR) Command Center at Ramstein Air Base, Germany, where the 40th Aerospace Rescue and Recovery Wing (formerly the Atlantic Aerospace Rescue and Recovery Center) was responsible for providing Apollo search and recovery support for contingency landings in Africa and in parts of the Atlantic and Indian Oceans. For recovery operations during the Apollo missions, special Aerospace Rescue and Recovery Service aircraft were positioned at Mauritius Island, at Lajes Field in the Azores, and at Ascension Island. The SAR Command Center for these aircraft was previously located at Moron Air Base in Spain but was moved to Ramstein, Germany, to reduce travel and per diem expenses and to save manpower.

Recovery Ship Communications

Primary recovery ship. - The Apollo Program effected two significant changes to primary recovery ship (PRS) communications — the use of a high-frequency communications relay ship and the use of shipboard communications-relay-satellite terminals to provide ship/shore radio links. Although PRS communications in the Atlantic Ocean had never presented any significant difficulties, communications in the Pacific Ocean were expected to be difficult because of the greater distance involved and the lack of experience in communicating to certain parts of that area of the world.

Because the Apollo 8 recovery was to occur approximately at sunrise (when high-frequency communications are usually of marginal quality), U.S. Navy officials selected the U.S.S. Arlington, a communications relay ship, as the PRS. The time available for testing was brief, however, and the limited capability of the U.S.S. Arlington to perform real-time voice-relay functions was not realized until during the mission. For test purposes and as a secondary backup, Goddard Space Flight Center (GSFC) personnel installed an applications technology satellite (ATS-1) very-high-frequency (vhf) terminal aboard the PRS. Although the terminal had not been designed for efficient shipboard use (e.g., the antenna had to be steered manually), communications from the PRS were very good at times.

Immediately after the Apollo 8 mission, Naval Electronics Laboratory personnel were asked to design and build a shipboard terminal to operate in conjunction with the DOD-sponsored Lincoln Experimental Satellite (LES-6) and the soon-to-be-launched tactical satellite (TACSAT); both satellites were to operate in the 225- to 400-megahertz frequency range. Meanwhile, GSFC personnel redesigned and rebuilt the ATS terminal so that by the time of the Apollo 9 mission both the ATS and the LES-6/TACSAT systems could undergo full-scale checkouts aboard the U.S.S. Guadalcanal, the Atlantic Ocean PRS. These tests, conducted under operational conditions, were very successful; in fact, during a sudden ionospheric disturbance that suppressed all high-frequency communications, the ATS provided the only means of ship/shore communications. The results of the Apollo 9 tests indicated that the ATS and the LES-6 terminal could provide excellent ship/shore recovery communications.

Meanwhile, U.S. Navy officials had modified the U.S.S. Arlington to enable her to provide real-time voice relay, and she was assigned the duty of furnishing command and control communications for the Apollo 10 mission in addition to furnishing satellite communications with the U.S.S. Princeton, the PRS. Communications through the

U.S.S. Arlington during the Apollo 10 mission were greatly improved over those during the Apollo 8 mission. Likewise, the TACSAT performance was successful, and CTF 130 requested satellite support for the Apollo 11 mission.

The PRS designated for the Apollo 11 mission was the U.S.S. Hornet. Favorable high-frequency propagation predictions and the success of satellite communications on the Apollo 10 mission indicated that the ship communications facilities and the TACSAT and ATS could fulfill the communications requirements for this mission. Live television coverage of recovery operations was scheduled, and, because the onboard press pool elected to lease teletype circuits from a commercial carrier which provided the television satellite circuit, the U.S.S. Hornet was relieved of having to provide the customary ship/shore teletype circuit for relaying written press traffic to the Houston News Center at MSC. Although the TACSAT did develop a noise condition during the Apollo 11 mission and some degradation in voice circuits was experienced, satisfactory communications were achieved during recovery by shifting from duplex to simplex modes, adjusting power budgets, and limiting TACSAT use to essential communications.

After the command module (CM) recovery, the PRS circuit was used extensively to coordinate activities such as hardware and experiment data removal, film removal, and postflight medical examinations.

Secondary recovery ship.- Although a secondary recovery ship (SRS) was less likely to be called on for recovery support than a PRS, the requirement for reliable communications still existed. Fewer circuits were required, however. A destroyer was usually designated as an SRS although, in some cases, other ships such as oilers had been used. Because their normal missions did not require it, destroyers and oilers did not have the communications capabilities, either in numbers of circuits or in radiated power output, that ships such as aircraft carriers or helicopter carriers had. When secondary recovery ships had to be several thousand miles from an RCC, special measures were taken to augment the normal communications capabilities, either by the use of remote shore-based transmitters and receivers or by the installation of special equipment on the ships.

Communications in the West Pacific and Mid-Pacific were furnished by naval communications stations in Hawaii and Japan. Because the Pacific RCC, serving CTF 130, was located in Hawaii, a leased undersea cable was required for remote keying of the transmitters at the naval communications station in Japan. Support was also provided by the naval communications station in Guam. The U.S. Air Force Eastern Test Range provided high-frequency transmitters and receivers for use by CTF 140 in communicating with Atlantic secondary recovery ships.

End-of-mission aircraft communications.- Although the accuracy of the Apollo guidance system and live television coverage of recovery did much to lessen the requirement for a real-time narrative of activities from the recovery scene, the need for command and control communications between recovery commanders and their forces still existed. An Apollo range instrumentation aircraft was near the recovery area to relay (to MCC in real time) conversation between the astronauts and the recovery forces being conducted on 296.8 megahertz. In addition, a specially configured helicopter was stationed over the PRS to provide relay of 296.8-megahertz transmission to the PRS if the CM landed out of line-of-sight vhf communications range to the PRS. The PRS then relayed to the RCC, by high frequency, the activities being reported on 296.8 megahertz.

Rescue aircraft, stationed 165 miles up range and down range of the target point to give assistance should the CM land near them, were controlled by the PRS on another circuit, either very high frequency or high frequency.

Ships of opportunity.- A ship of opportunity, such as a merchant vessel, could have been called on had a contingency landing occurred far from a dedicated recovery ship. Although requesting assistance from a ship of opportunity was never necessary, the possibility of doing so was investigated. Information about ships near the area of interest was obtained from the U.S. Coast Guard Automated Merchant Vessel Report Center. Available information included data about U.S. and friendly merchant shipping.

If a U.S.S. or U.S.N.S. vessel had been called on, communications would have been handled through normal Navy channels, such as the fleet broadcast. Merchant vessels presented a greater problem. Although most merchant vessels did not maintain a 24-hour-a-day communications watch, they were required to have automatic-alarm receivers on 500 kilohertz. When an alarm signal was sent by an SAR agency, all ships receiving the signal inquired on that frequency whether assistance was required.

Several test emergencies were simulated to determine the time required for a message to reach merchant vessels in the Atlantic Ocean. Test messages were sent through commercial facilities to selected ships. These exercises indicated that an adequate number of ships was present in each selected area, but the effectiveness of commercial ship/shore telegraphic communications in the areas was considered to be only marginal. A major study effort was undertaken to determine more reliable means of contacting and using merchant shipping in support of recovery operations.

Teletype Communications

During the Apollo Program, a significant change occurred in the philosophy of teletype communications. A dedicated teletype network was originally established to provide record communications and to serve as a backup to the voice communications system. A full-duplex circuit was extended from the MCC to Fort Detrick, Maryland (a major U.S. Army automatic teletype switching center), from which separate circuits were extended to each RCC. Because of the high degree of reliability of voice circuits between the ROCR and each RCC, the teletype backup proved to be of negligible benefit; even when a voice circuit failed, the circuit could usually be restored before a teletype message could be sent and received. For this reason, the dedicated teletype system was replaced by a common-user system to save both manpower and money.

Before the Apollo 6 mission, a plan was developed for conducting tests with the DOD common-user (AUTODIN) system instead of the dedicated system. During the Apollo 6 mission, the dedicated circuits were activated, checked, and then put on standby. All mission teletype messages were then sent over the AUTODIN system. Several delays were noted, but these were attributable to message handling and delivery at the receipt locations. By the time of the Apollo 7 mission, these problems had been identified, and the AUTODIN system was used thereafter. Traffic was handled through the MCC communications center and, during critical or busy periods, an operator manned the ROCR communications center. Had a contingency occurred, the capability existed to establish a direct ROCR-RCC teletype link.

The NASA Worldwide Communication Network Interface

Alternate communications links were identified and checked before a mission in case their usage became necessary. The primary link between the CTF 130 RCC in Hawaii and the SAR aircraft-staging base in Australia was a high-frequency circuit. To provide a backup, local circuits and procedures were established to allow recovery forces to use one of the NASA Worldwide Communication Network (NASCOM) circuits between Hawaii and Australia. This arrangement worked very well, and means were provided to allow the recovery personnel at the staging base to monitor the CM air-to-ground communications on the ground operational support systems (GOSS) circuit.

At other locations near a tracking station or NASCOM switching center, circuits were installed to allow each RCC to monitor the GOSS circuit. These circuits were installed in Bermuda, Moron/Ramstein, Australia, Norfolk, and Hawaii. At Hawaii and Moron/Ramstein, voice-transmission capability was also provided for contingency operations that required additional circuits to the ROCR.

The insertion tracking ship, the U.S.N.S. Vanguard, was chosen to provide launch abort recovery support beginning with the Apollo 7 mission. Procedures were established to allow CTF 140 to communicate with the U.S.N.S. Vanguard if necessary. Already existing circuits among the Norfolk station, the RCC, Cape Kennedy Air Force Station, and GSFC were configured and checked shortly before launch. In case of a launch abort, GSFC personnel would have extended this circuit to the U.S.N.S. Vanguard through one of the Manned Space Flight Network ship/shore links.

COMMUNICATIONS FUNDING

Validation and Approval Procedures

To ensure that NASA realized the greatest value from each dollar spent for communications, validation and approval procedures were established. Before any NASA funds were committed for either leased longlines or communications equipment, existing capabilities were examined to determine whether or not the required element or a suitable alternate was available. If a longline was required, for instance, the Defense Communication Agency (DCA) was tasked to provide the line from the DCA inventory of circuits. If it was necessary to lease the circuit, the DDMS Director requested funding approval from the Chief of the Landing and Recovery Division at MSC. If the request was considered a valid requirement, the expenditure of NASA funds was approved.

Longline Communications

The Defense Commercial Communications Office (DECCO) of the DCA was responsible for all DOD-leased longlines from commercial carriers or other governments and, consequently, had extensive "buying power." When warranted, DECCO officials leased a group of several circuits (called telpak) between two points. Then, as other agencies or commands used the circuits, the cost for these circuits was prorated among the users. The savings were as much as 50 percent as compared to the cost of leasing directly from the commercial carrier. When circuits were not required (e.g., between missions), the circuits could be put on standby and reserved for future use. Thus, only a small monthly fee was paid to ensure that the circuits could be obtained for NASA use at a reduced rate when needed.

CONCLUDING REMARKS

Operational costs were reduced by such actions as relocating two recovery control centers, using existing NASA and Department of Defense facilities where possible, and taking advantage of special rates for leasing longlines. At the same time, ship/shore communications were improved by taking advantage of relay-satellite technology. These measures resulted in an efficient, reliable communications system at a relatively low cost to NASA.

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