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**APOLLO EXPERIENCE REPORT -  
THE AN/ARD-17 DIRECTION-FINDING SYSTEM**

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16. Abstract <p>This report contains a statement of the operational philosophy and requirements leading to the development of the AN/ARD-17 direction-finding system. The technical problems encountered and the solutions devised in the AN/ARD-17 development are discussed. An evaluation of the system under actual operational conditions is included.</p>					
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## APOLLO EXPERIENCE REPORT

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THE AN/ARD-17 DIRECTION-FINDING SYSTEM  
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SUMMARY

Because of the relatively large landing footprint predicted for an Apollo command module returning from a lunar mission, it was determined that rescue aircraft should be equipped with an entry direction-finding system to minimize the search area if a non-nominal landing occurred. In effect, such a system would reduce the size of the recovery force required for rapid location of the command module. Because no system was available at the time, the AN/ARD-17 direction-finding system was developed for this purpose. The system operated by obtaining bearings on signals transmitted from the command module in the S-band frequency range (2200 to 2300 megahertz) and the very-high-frequency range (225 to 300 megahertz) during nonblackout entry periods and during parachute descent and postlanding periods. The landing point then was established by means of triangulation techniques. Although the system performed well during operational testing, several problems that required the incorporation of engineering changes developed during its initial use in the field. These changes have proved to be successful. Nevertheless, a problem that has not been resolved completely is the training of field maintenance personnel to keep the equipment in peak operating condition.

INTRODUCTION

During the latter part of Project Mercury, it became obvious to flight planners and recovery engineers that the possible occurrence of large landing dispersions in the projected Apollo entry and landing profile would prevent timely location and recovery of the command module and crewmembers. These guidance dispersions could cause landing footprints of approximately 9260 kilometers (5000 nautical miles) in length and 1852 kilometers (1000 nautical miles) in width. To locate and recover the Apollo crewmembers and command module within such a landing footprint, many aircraft (more than 10) and several ships would be required in the terminal area. To reduce the cost and number of supporting aircraft and ships, a capability to predict the landing area and to locate the command module without performing an extensive search was required. To minimize the required support, the aircraft normally deployed to provide pararescue support had to be equipped with a direction-finding system that was compatible with signals radiating from the Apollo command module during the entry period. The hardware developed for this purpose was the AN/ARD-17 direction-finding system (ARD-17).

The system procurement, testing, and modification resulting from problems arising during initial operation are discussed in this report.

As an aid to the reader, where necessary the original units of measure have been converted to the equivalent value in the *Système International d'Unités* (SI). The SI units are written first, and the original units are written parenthetically thereafter.

## APPLICABILITY OF ARD-17

The feasibility of using direction-finding equipment in an aircraft to obtain bearings on orbiting spacecraft was demonstrated on the Mercury-Atlas 8 and 9 missions. A U. S. Air Force (USAF) JC-130B aircraft equipped with a very-high-frequency (vhf) direction-finding system, which was designed to locate descending nose cones used in other research and development programs, was used to track the Mercury telemetry signal at line-of-sight ranges (2222 kilometers (1200 nautical miles) with the spacecraft at an altitude of 156 972 meters (515 000 feet) and the aircraft at 7620 meters (25 000 feet)). It was concluded that a similar system having greater sensitivity and better display capability could be used to track the entering Apollo command module using the S-band telemetry signal. A block diagram of the ARD-17 is shown in figure 1.

The entry profile envisioned in 1962 is shown in figure 2. Entry is the part of the flight that begins with atmospheric contact (defined as being at an altitude of 121 920 meters (400 000 feet)) and ends when the command module begins parachute descent to the landing point. The command module normally is tracked by ground-based or ship-based radar to the radiofrequency (rf) blackout altitude (91 440 meters (300 000 feet)). During this initial phase of entry, a pullup maneuver performed by the command module at an altitude of approximately 60 960 meters (200 000 feet) causes the vehicle to skip to an altitude above 91 440 meters (300 000 feet) and to emerge briefly from rf blackout. During the time when the command module is above 91 440 meters (300 000 feet), it is transmitting S-band signals that can be received by an airborne direction-finding system. The command module again reaches the rf blackout altitude and emerges at 45 720 meters (150 000 feet), approximately 370 kilometers (200 nautical miles) from the landing point.

Based on the 1962 entry profile (fig. 2), efforts were initiated to obtain a direction-finding system that would be installed permanently on the USAF HC-130 aircraft (fig. 3) assigned to support the Apollo missions. This system would have to be capable of obtaining accurate bearings on vhf (225 to 300 megahertz) and S-band (2200 to 2300 megahertz) signals from the command module during the nonblackout periods of the entry. For nonnominal entry trajectories (overshoots or undershoots), two or more aircraft stationed along the footprint could obtain fixes for some of the following points by triangulation techniques, and the approximate landing point could then be predicted.

1. Beginning of first blackout
2. End of first blackout

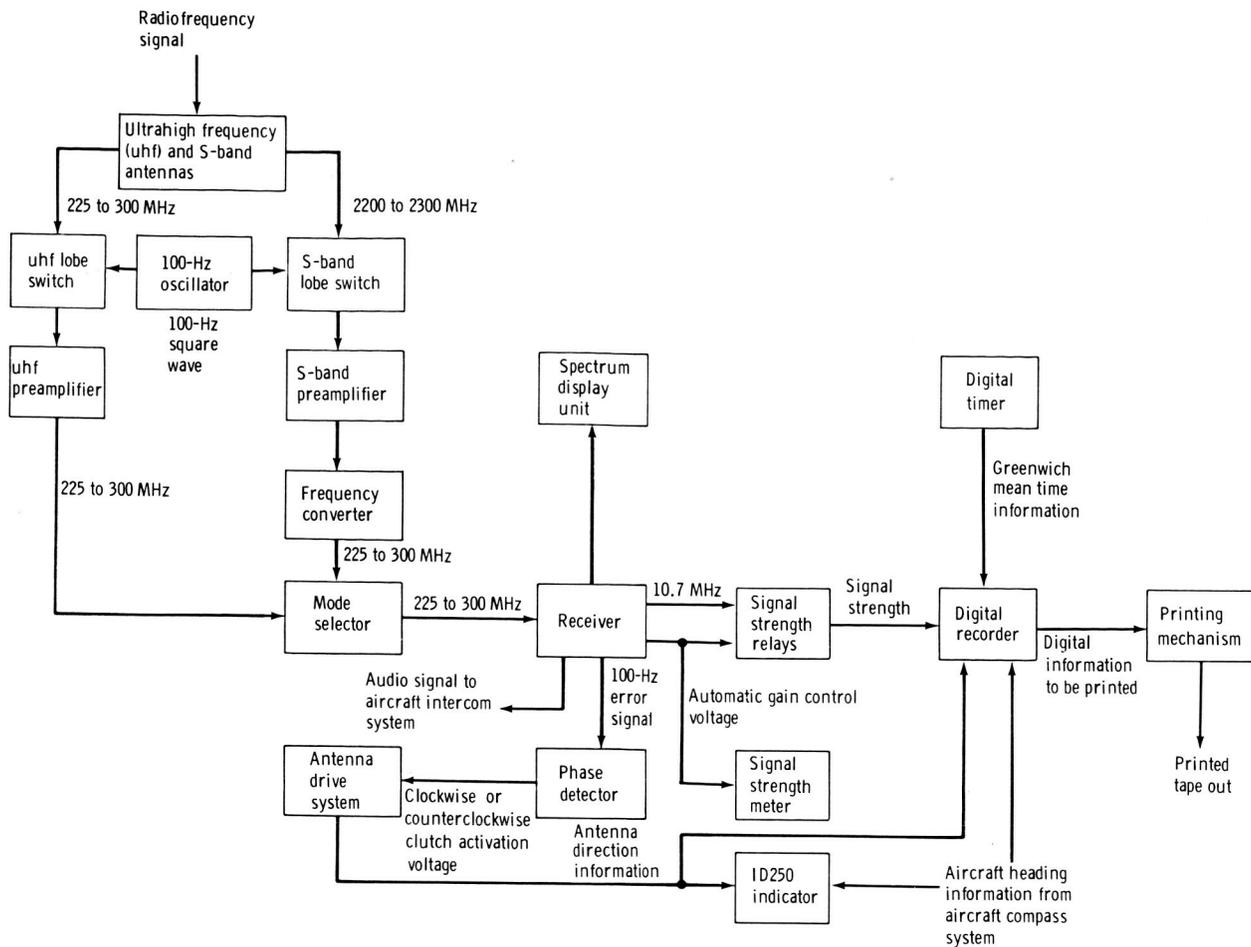


Figure 1. - Block diagram of the AN/ARD-17.

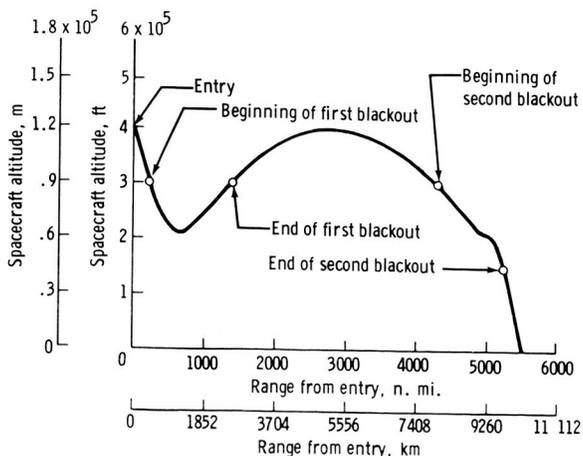


Figure 2. - Apollo entry trajectory (as known in 1962) showing the S-band blackout regions.



Figure 3. - A USAF HC-130 aircraft, showing AN/ARD-17 radome.

3. Beginning of second blackout
4. End of second blackout
5. Recovery-beacon acquisition

Use of this procedure would minimize the search area and the required ship and aircraft support.

## PROCUREMENT OF ARD-17

In the fall of 1963, a team of personnel from the NASA Lyndon B. Johnson Space Center (JSC) (formerly the Manned Spacecraft Center (MSC)) and the Aeronautical Systems Division of the USAF Systems Command prepared a specification for the development and production of sufficient ARD-17 systems and spares to equip 60 USAF HC-130 aircraft. The following capabilities were specified for the AN/ARD-17.

1. Signal detection in both the vhf (225 to 300 megahertz) and S-band (2200 to 2300 megahertz) frequency ranges
2. An antenna having 360° coverage in the azimuth plane and the capability of signal detection above and below the aircraft
3. Manual, search, and track modes of operation (In the manual mode, the antenna is rotated as desired, and the speed and direction are controlled by an antenna slew control knob. In the search mode, the antenna rotates automatically unless a signal of proper frequency and sufficient strength is received; in that event, the antenna locks on and tracks the signal. In the track mode, the antenna automatically tracks the received signal unless overridden by operation of the antenna slew control.)
4. Fixed-frequency and variable-frequency operation
5. Display equipment including a signal-level meter, a spectrum display unit, and an automatic printer that gives an accurate record of the time and the bearing to the target (The provision for accurate time requires a built-in clock that can be reset.)
6. Detection of almost any type of modulated signal within the frequency bands specified
7. System sensitivity of 119 dBm (range 370 kilometers (200 nautical miles)) for the vhf band and 129.5 dBm (range 926 kilometers (500 nautical miles)) for the S-band

The three methods by which this equipment could be procured are as follows.

1. The USAF could procure the system and supply it to the airframe contractor for installation.
2. The NASA could procure the system and supply it to the airframe contractor for installation.
3. The airframe contractor could procure and install the system.

The first alternative, with technical monitoring by both USAF and NASA, was chosen as the optimum method.

## TESTING OF ARD-17

Flight testing of the ARD-17 using a prototype system began in January 1965 at the airframe contractor facility. Sufficient testing was performed to verify that the ARD-17 would track both vhf and S-band signals above and below the aircraft with satisfactory range and bearing accuracies. After the successful completion of this test, a series of tests was initiated in conjunction with spacecraft vhf and S-band transmitters. The first of these tests was performed during the Gemini V mission in 1965. Other vhf tests were concurrent with testing of the Block I Apollo postlanding recovery aids, with the Gemini VI and VII missions, and with the Apollo-Saturn 201 flight. The S-band tests were performed during the Apollo-Saturn 202 flight and the Apollo 4, 5, and 6 missions. The test results indicated the following facts.

1. The vhf recovery beacon had a range of 361 kilometers (195 nautical miles) (line of sight limited); this value was obtained with the command module on the water and the aircraft at an altitude of 7620 meters (25 000 feet).
2. The average orbital vhf range was 2080 kilometers (1123 nautical miles) (line of sight limited), and the average bearing accuracy was  $4.9^\circ$ ; these values were obtained relative to the spacecraft in Earth orbit.
3. The average entry-tracking S-band range was 667 kilometers (360 nautical miles), and the average bearing accuracy was  $4.5^\circ$ ; these values were obtained relative to the entering command module.

The results of flight tests showed that the ARD-17 provides excellent range and satisfactory bearing accuracy in the vhf mode. In the S-band mode, the test results showed that the system provides satisfactory bearing accuracy but less than the desired range of 926 kilometers (500 nautical miles). This range deficiency, which was caused by a combination of less than anticipated radiated power from the spacecraft and lower overall system sensitivity of the direction-finding system, was minimized by the use of one additional aircraft in the landing area.

## MODIFICATION OF ARD-17

After a few months of ARD-17 operational use, several problems developed. Recurrent failures of the two clutches located in the antenna actuator were encountered. Excessive antenna drift occurred, slew switches stuck, and operators had trouble identifying the direction of the signal in the vhf mode because of the presence of two antenna side lobes. To solve these problems, the following engineering changes were made.

1. The antenna actuator clutch seals were wearing out after approximately 20 hours of use, although a minimum requirement of 100 hours of use had been assessed for them. It was determined that the manufacturer could not correct the defect. A reliable unit modified at reasonable cost could not be obtained; therefore, a survey of clutch manufacturers was conducted to obtain replacement clutches having longer life-times. Two candidate clutches that passed a 500-hour life test were selected to replace the original clutches. The manufacturer of the new clutches also certified the units for 1000 hours of operation.

2. A newly designed printed circuit board was installed in the control set to eliminate antenna drift. Basically, this modification permitted an accurate balancing of the clutches that eliminated the antenna drift.

3. The wiring to the slew switches had interfered with the slew switch rotation and caused sticking when the switch was deflected in one direction. Rerouting the wire solved the slew switch problem.

4. The presence of the antenna side lobes when operating in the vhf mode was caused by a radome restriction imposed on the antenna size. Because of this restriction, the side lobes could not be eliminated, but the addition of a manual gain control to the receiver simplified identification of the major lobe. When the manual gain control was switched on, the existing automatic gain control was overridden and the gain of the receiver could be set manually. This change resulted in a greater difference in signal strength between the major lobe and the side lobes and simplified identification of the major lobe.

The four preceding engineering changes were incorporated into the system by use of field modification kits. The changes have proved to be quite successful.

## OPERATIONAL-CONCEPT CHANGES

After the procurement of the ARD-17, the Apollo entry profile changed significantly; that is, reduction of the range from 9260 kilometers (5000 nautical miles) to approximately 4630 kilometers (2500 nautical miles) reduced the number of S-band blackouts to one (fig. 4). Because of the reduced footprint size and the single blackout period, the original requirement for airborne S-band tracking was eliminated. Therefore, the number of HC-130 aircraft required to support a landing was reduced from

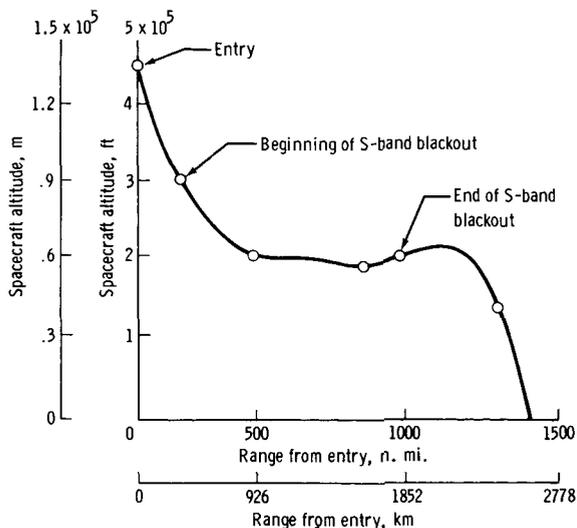


Figure 4. - Final Apollo entry trajectory.

five or six to two or three. If two aircraft are used, they generally are located approximately 370 kilometers (200 nautical miles) up range and down range of the predicted landing point and offset 185 kilometers (100 nautical miles) from the groundtrack. The S-band mode is used from the end of blackout until approximately 1 minute before the predicted main-parachute deployment (vhf recovery-beacon activation) as an aid to determine whether the landing will occur up range or down range of a particular aircraft. At approximately 1 minute before the predicted main-parachute deployment, the ARD-17 is switched from the S-band mode to the vhf mode to attempt reception of the vhf recovery-beacon signal as soon as signal transmission begins at 3048 meters (10 000 feet) altitude. Early signal reception is desirable because the line-of-sight range is approximately 556 kilometers (300 nautical miles) when

the command module is at a 3048-meter (10 000 foot) altitude compared to the 361-kilometer (195 nautical mile) range when the command module is on the water.

## FIELD MAINTENANCE

Since the beginning of the space program, a continuing problem has been equipment maintenance in the field. A rapid turnover of field maintenance personnel occurs, and new personnel are not trained adequately before being assigned to a squadron. Because the Aerospace Rescue and Recovery Service is the only USAF unit equipped with the ARD-17, personnel do not become familiar with the system while assigned to other USAF organizations. Essentially all field maintenance personnel training is accomplished by joint NASA/USAF training teams on a semiannual or annual basis. Although this training method has been moderately successful, the turnover of trained personnel is a constant problem. The first field maintenance facility was operated by the ARD-17 manufacturer for 3.5 years, but this arrangement was not satisfactory because of excessive cost and equipment turnaround time. In July 1968, the field maintenance responsibility was assumed by the USAF Warner Robins Air Material Area. This change resulted in improved field maintenance. The operation and maintenance manuals have been revised and are expected to help eliminate the field maintenance problems. These manuals were initially incomplete, inaccurate, and not easily comprehended by USAF technicians.

## CONCLUDING REMARKS

The AN/ARD-17 direction-finding system has operated satisfactorily since the incorporation of four engineering changes. The only disappointment in performance has been the range obtained on the S-band mode. This deficiency was caused partly by insufficient spacecraft transmitter power, which actually was approximately half the originally stated value for which the AN/ARD-17 performance specifications had been written. Because of the elimination of the S-band entry-tracking requirement, the range deficiency has not impaired the capability of the equipment as currently used. In the very-high-frequency mode, the AN/ARD-17 is the best long-range direction-finding equipment in existence and would have enabled location of the command module if a nonnominal landing had occurred.

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National Aeronautics and Space Administration  
Houston, Texas, October 4, 1974  
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