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~~FINAL REPORT~~, OPERATIONAL EVALUATION

OF

AIRBORNE EW RECONNAISSANCE SYSTEM

(A/R) ~~(U)~~

(Job 33-56-0023)

EW SYSTEMS TEST

USAEPG-3

PHASE II

EQUIPMENT TEST

AND EVALUATION

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FINAL REPORT
OPERATIONAL EVALUATION
OF THE
AIRBORNE EW RECONNAISSANCE SYSTEM (A/R) (U)

(Job 33-56-0023)

February 1957

Electronic Warfare Department
UNITED STATES ARMY ELECTRONIC PROVING GROUND
Fort Huachuca, Arizona

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FOREWORD

This report on the operational evaluation of the Airborne EW Reconnaissance System (A/R), as a combination direction finder and search intercept equipment, was prepared by the Electronic Warfare Department as a part of Job 33-56-0023 (USAEPG-3 EW Systems Test) of the United States Army Electronic Proving Ground Technical Program. The report is based on field tests conducted at Fort Huachuca, Arizona, during the period of 25 September 1956 to 22 October 1956.

ABSTRACT

Tests were designed and conducted to evaluate the feasibility of airborne electronic reconnaissance in support of EW operations of the field army. The equipment evaluated by the tests here reported is the Airborne EW Reconnaissance System (A/R System), a combination direction-finding and search-intercept device formerly designated as the QRR-4 (Quick Reaction Requirement Four).

The A/R System was installed in a modified L-20 army aircraft. Intercept frequency coverage is from 30 to 10,750 Mc/s with D/F capability from 140 to 10,750 Mc/s.

The system consists of the modified aircraft, a Receiver AN/APR-9, Receiver AN/APR-14, Direction Finder AN/APA-69, Signal Analyzer AN/APA-74, Oscilloscope Camera KD-2, and a Sound Recorder RO-28 (XN-1)/UN.

The feasibility of airborne electronic reconnaissance for the EW operations of the field army is substantiated.

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Section I. Summary

Tests were designed and conducted to evaluate the feasibility of employing the Airborne EW Reconnaissance System to support the Electronic Warfare (EW) operations of the field army. The intercept and direction-finding capabilities were tested against the following:

1. Surveillance Radars: Both L-band and S-band, sweeping 360 degrees.
2. Tracking Radars: X-band, and medium and short range S-band.
3. Cw Jammers: Both X-band and L-band.

Test results indicate that individual D/F readings made with the A/R System are likely to be in error by several degrees. However, the average of several D/F readings made above a well-defined check point yields a D/F error of approximately two degrees.

Human engineering tests revealed an impairment in effective operation because of inadequate workspace, inefficient arrangement of controls, improper lighting for operation at any time of day, safety hazards, and an awkward antenna-changing mechanism.

Because of the weight of the A/R System, the L-20 aircraft used as the airborne platform must sacrifice some fuel capacity, maneuverability, and duration of flight.

The feasibility of airborne electronic reconnaissance for the field army has been substantiated, and the limitations of the present interim A/R System have been determined.

Section II. Introduction

1. *BACKGROUND*

The Airborne EW Reconnaissance System resulted from Signal Corps requirements for a highly mobile, widely useful search-intercept and direction-finding system to support the EW operations of the army in the field. Such a system is required for intercept of enemy line-of-sight signals when ground intercept is denied by the situation or terrain.

An interim airborne reconnaissance system was assembled, using equipments which were immediately available, so that the feasibility of employing such a system could be evaluated. The component equipments were obtained and installed in a modified L-20 aircraft. Responsibility for testing the proposed system was assigned to the Electronic Warfare Department, United States Army Electronic Proving Ground, Fort Huachuca, Arizona. The tests necessary to evaluate the operational performance of the A/R System were performed as part of the USAEPG-3 Systems Test program.

2. *PURPOSE*

The purpose of the tests was to obtain the data necessary to evaluate the operational performance of the A/R System and to determine the feasibility of airborne electronic reconnaissance.

Section III. Description of Airborne EW Reconnaissance System (A/R System)

3. *GENERAL*

The A/R System installed in a modified L-20 aircraft consists of two independent receiving systems, signal analyzer, a direction finder, tape recorder, camera, and dual purpose antennas for searching and also direction finding. The major components of the system are: (a) Receiver AN/APR-14, (b) Receiver AN/APR-9, (c) Signal Analyzer AN/APA-74, (d) Direction Finder Group AN/APA-69, (e) Oscilloscope Camera KD-2, and (f) Sound Recorder RO-28(XN-1)/UN. The equipment weighs approximately 600 pounds.

Fig. 1 shows the operating console and equipment mounted in its special rack, fig. 2 is a close-up view of the program controls, and fig. 3 is a diagram of equipment placement.

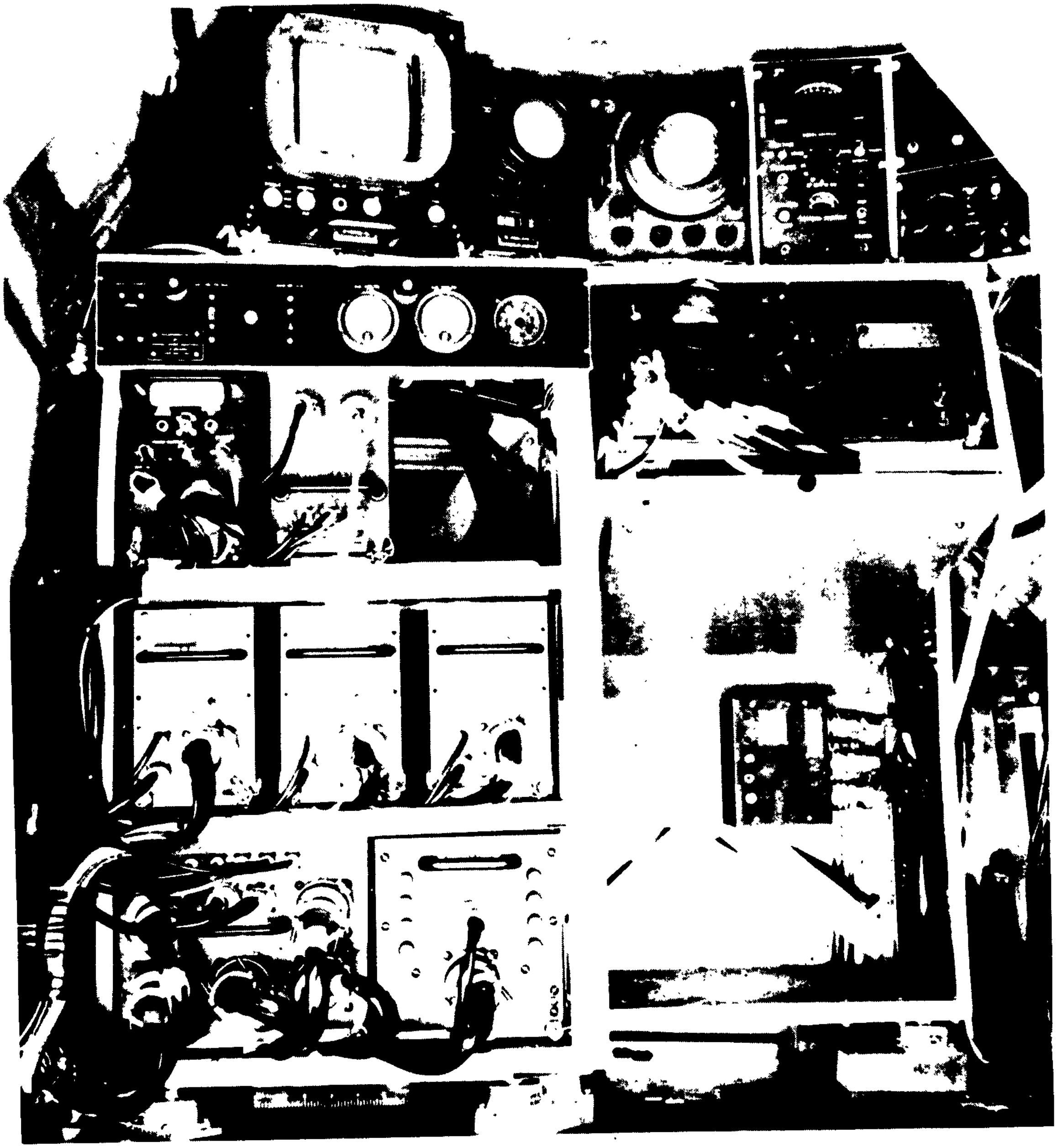

Fig. 1. Operating Console and Equipment Rack

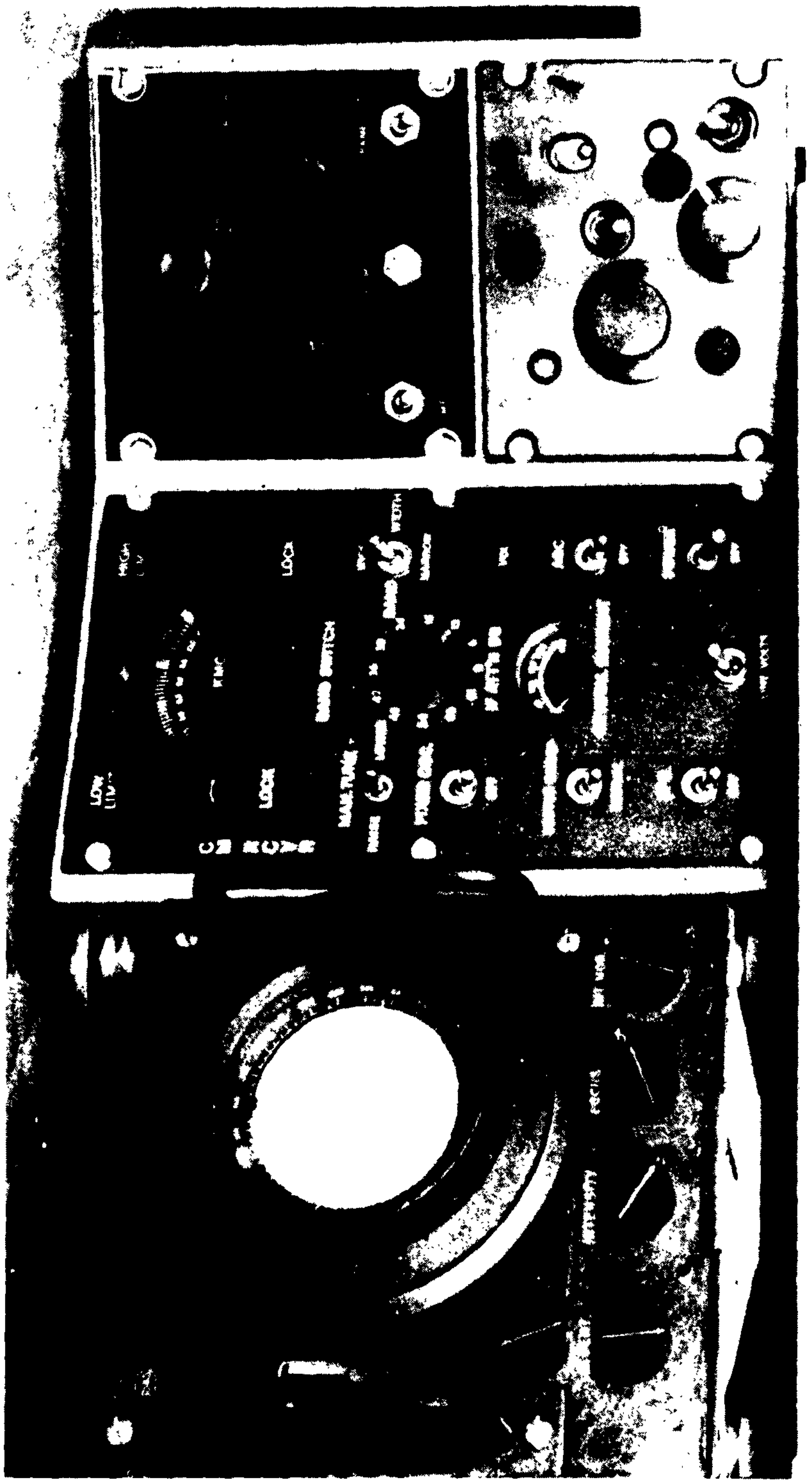

Fig. 2. Program Controls

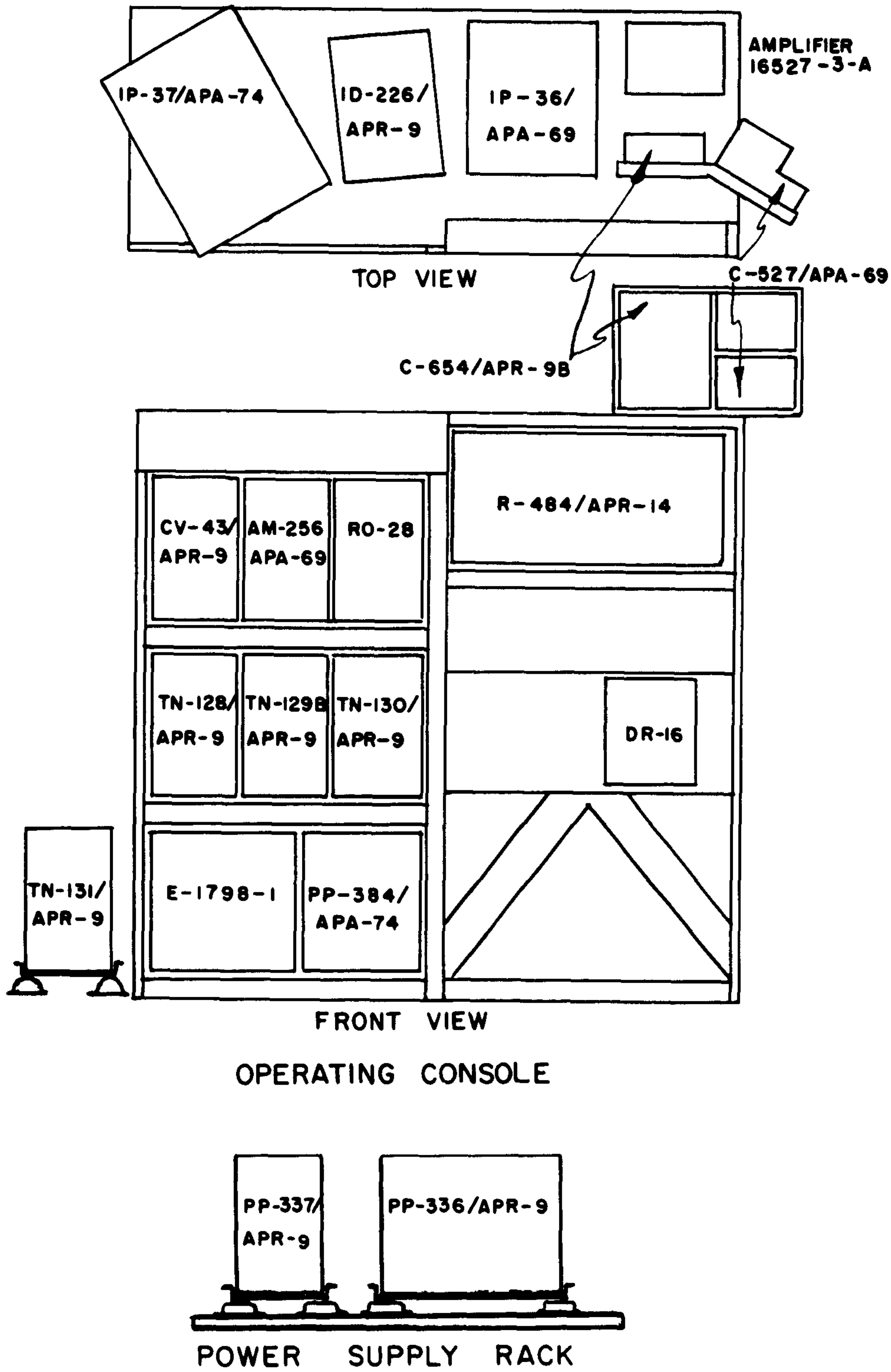

Fig. 3. Equipment Layout

4. *FUNCTIONAL DESCRIPTION*

a. *Antenna System*

The antenna system consists of two stub antennas and the three antenna assemblies of the AN/APA-69 group. Antenna nomenclature and frequency coverage are as follows:

AT-43/APT (Stubs)	30 to 140 Mc/s
AS-435/APA-69	140 to 1,800 Mc/s
AS-434/APA-69	1,000 to 5,000 Mc/s
AS-436/APA-69	5,000 to 10,750 Mc/s

The stub antennas are mounted to the sides of the L-20 and are capable of receiving either horizontally or vertically polarized signals. Since these stubs are omnidirectional, the reconnaissance system has only a search capability from 30 to 140 Mc/s. Both of these stubs are connected directly to the AN/APR-14 receiver.

The AN/APA-69 antenna assemblies have directional antenna patterns and are rotated at high rates of speed so that they function as search and direction-finding antennas for the system from 140 to 10,750 Mc/s. The output of these antennas may be fed to either of the two search receivers by means of a remotely controlled coaxial switch.

b. *Receivers*

The receiver AN/APR-14 receives and panoramically displays signals from 30 to 1000 Mc/s in three bands, and the AN/APR-9 receives and panoramically displays signals from 1,000 to 10.750 Mc/s in four bands. The video output of either receiver is selected by means of remotely operated coaxial switches and is fed to both the Direction Finder AN/APA-69 and the Signal Analyzer AN/APA-74.

c. *Direction Finder*

The Direction Finder Group AN/APA-69 consists of the antennas, antenna drive mechanisms, amplifier, and an indicator. The video output from the functioning receiver is fed to the direction finder along with resolver data from the antenna drive mechanism. The received signal is displayed on the directional indicator, and the true bearing of the signal is indicated by a circular azimuth scale which is driven by a Flux Gate Compass.

d. *Signal Analyzer*

The AN/APA-74 analyzes the video signals received from either receiver. A five-gun cathode ray tube displays pulse repetition frequency, pulse width, and rise time of the intercepted signal. The limits on pulse repetition frequency are 20 cps to 4,000 cps, while any pulse width of 0.2 to 50 usec can be displayed.

e. *Tape Recorder and Camera*

A Tape Recorder RO-28(XN-1)/UN is provided for recording signal frequency, as derived by the audio circuits of the two receivers. Oscilloscope camera KD-2 is provided for photographic recording of time of intercept, and signal characteristics as displayed by the Signal Analyzer AN/APA-74. Because of power requirements, either the tape recorder or the camera can be used at any one time, but they cannot operate simultaneously. These recording media are used as assigned on individual missions.

f. *Flux Gate Compass*

Although the flux gate compass is not a part of the A/R System, it is necessary as an input to the direction finder for display of true bearing of received signals.

g. *Power*

The primary dc power required by the aircraft and the electronic components of the reconnaissance system is supplied by a 100-ampere, 28-volt dc generator which replaced the standard generator supplied with the aircraft. This generator supplies the aircraft load of 10 amperes, the dc requirements of the A/R System, and the input to the inverter which converts the primary dc power to the 115-volt, 400-cycle power required by the reconnaissance system.

5. *TECHNICAL CHARACTERISTICS*

Characteristics of the A/R System components are shown in the following table.

Components	Characteristics
AN/APR-14 Intercept Receiver	30 to 1000 Mc/s, any signals. Panoramic display, audio and video outputs. 3 bands.
AN/APR-9 Intercept Receiver	1000 to 10,750 Mc/s, any signals. Panoramic display, audio and video outputs. 4 tuning units.
AN/APA-69 Direction Finder Group	140 to 10,750 Mc/s, any signals. Cathode ray tube display of bearing. 4 antennas.
AN/APA-74 Signal Analyzer	Pulse repetition frequency: 20 to 40,000 cps. Pulse width: 0.2 to 50 usec. Five-gun cathode ray tube display.
KD-2 Oscilloscope Camera	Photographs AN/APA-74 display, time of intercept (clock), material on adjacent writing surface.
RO-28(XN-1)/UN Tape Recorder	Dual-track record only tape recorder, fed from audio output of receivers.
Flux Gate Compass	Provides servo input to AN/APA-69 for true bearing indication.

Section IV. Performance Against Surveillance Type Radars

This group of tests was conducted to evaluate the performance of the A/R System against surveillance type radars in the L-band and S-band.

Preliminary flights to check the equipment pointed up several necessary changes in procedure. The operator of the A/R System knew the location and frequency of the radar. Under these conditions, signal analysis was not recorded by the informed operator. Thus the test data is almost exclusively D/F readings.

It was recognized that subsequent tests of the A/R System's capability in signal analysis were to be performed in the laboratory, using the training device 15-X-7 for signal sources. The 15-X-7 is a radar training device including rf and fm oscillators, pulse and noise modulators, and antenna simulators, combined into a system that can produce a wide variety of radar signals to be fed into search and analysis equipment for the training of operators. The equipment has been operationally evaluated at USAEPG and is the subject of a forthcoming report. Conclusions drawn from the results of these tests are included in para 15, Test 10.

The preliminary flights also indicated the improbability of establishing the ground point above which the aircraft was located at the instant that S/N was marginal. In this connection, it was also revealed that radar output measurements would be difficult to obtain. It was decided that the radial flight called for by the test plan would not add sufficient additional data to warrant the flight.

6. *TEST 1, PERFORMANCE AGAINST THE AN/TPS-1D*

The purpose of this test was to evaluate the D/F performance of the A/R System against a surveillance-type radar operating in the L-band.

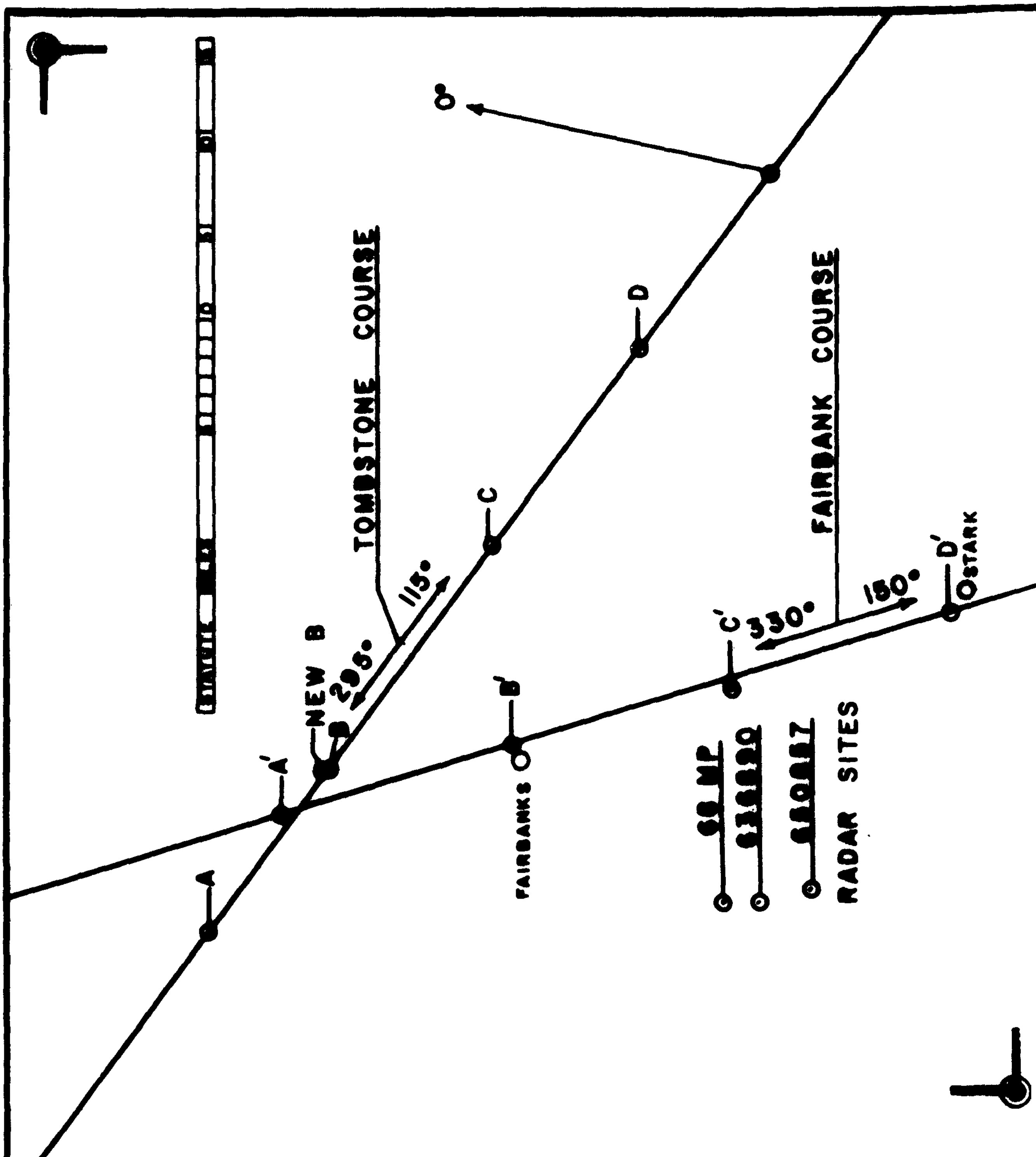

Fig. 4a. Geometry of Test Situations

Insert Nr. 1

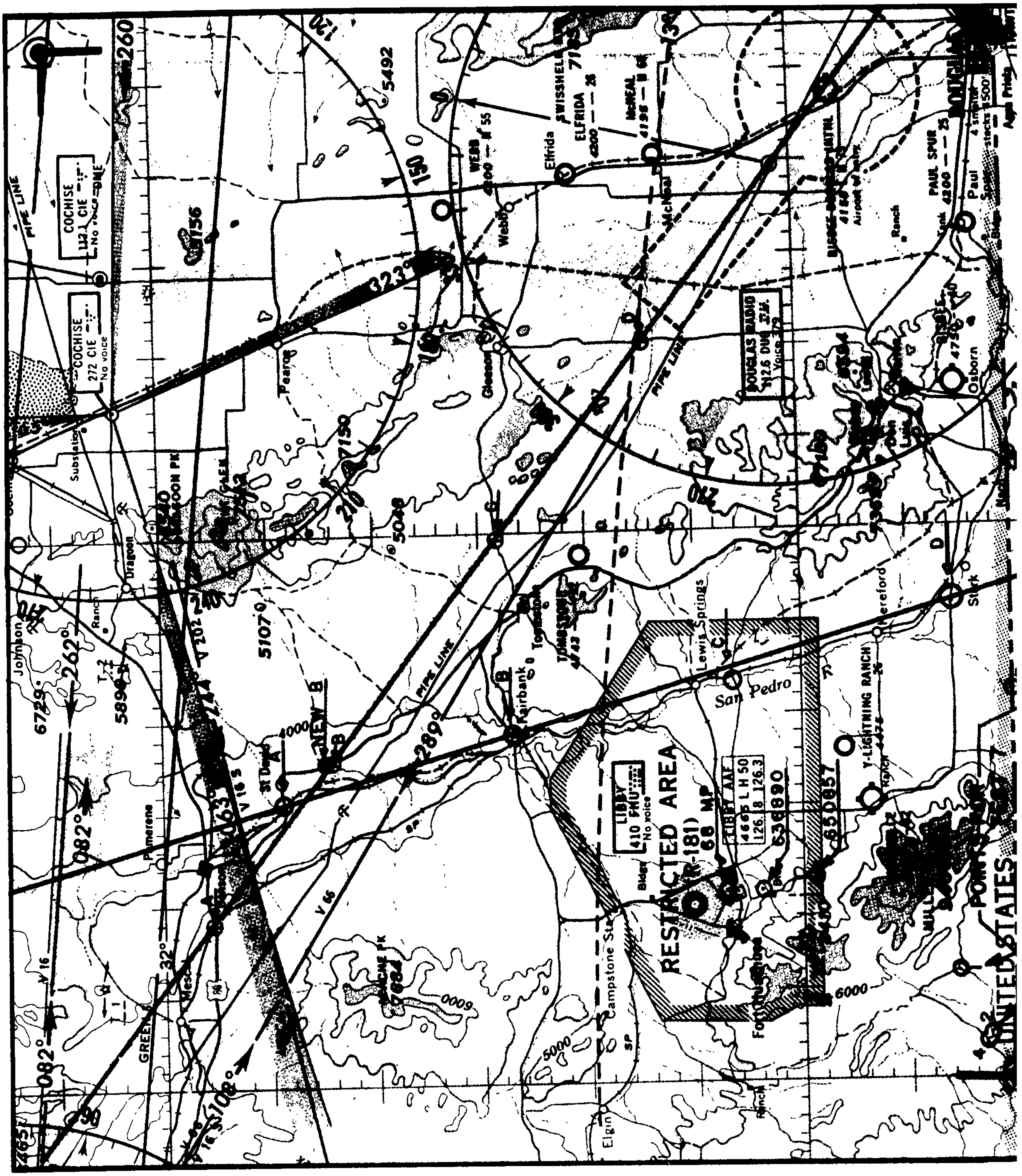

Fig. 4b. Geometry of Test Situations

An AN/TPS-1D radar was sited on Hill 636890 as shown in fig. 4 and put into search operation, searching 360 degrees in azimuth.

The A/R System aircraft flew a total of five flights. One flight was made along the Fairbanks flight path of fig. 4, and the other four flights were made along the Tombstone flight path. The results are shown in the following table:

Position	Range	A/R System Bearing	Standard Bearing	D/F Error	Average Error
	Yards	Degrees	Degrees	Degrees	Degrees
A'	46,000	166	177	-11	
B' Fairbanks	27,000	181	199	-18	-6
C'	19,000	264	253	+11	
D'	33,000	---	292	--	
A	52,000	165	165	0	
B Tombstone	43,000	184	185	- 1	+4
C	42,000	222	221	+ 1	
D	53,000	262	246	+16	
A	52,000	162	165	- 3	
B Tombstone	43,000	181	185	- 4	-1.3
C	42,000	224	221	+ 3	
D	53,000	245	246	- 1	
A	52,000	147	165	-18	
B Tombstone	43,000	185	185	0	-2.8
C	42,000	226	221	+ 5	
D	53,000	248	246	+ 2	
A	52,000	156	165	- 9	
B Tombstone	43,000	178	185	- 7	-5.8
C	42,000	212	221	- 9	
D	53,000	248	246	+ 2	

These results indicate that repeated D/F readings on a target signal from each of several positions yield grand average D/F accuracy of about -2.2 degrees.

7. *TEST 2, PERFORMANCE AGAINST THE M-33 (ACQUISITION)*

The purpose of this test was to determine the D/F performance of the A/R System against a surveillance radar operating in the S-band.

The M-33 radar was set up on Hill 636890 and the acquisition portion put into operation, in normal search through 360 degrees.

A flight was made along the Tombstone flight path, yielding data as follows:

Position	Range	A/R System Bearing	Standard Bearing	D/F Error	Average Error
	Yards	Degrees	Degrees	Degrees	Degrees
A	52,000	157	165	- 8	
B Tombstone	43,000	196	185	+11	+3.3
C	42,000	223	221	+ 2	
D	53,000	254	246	+ 8	

It might be noted that the operator reported that D/F readings were difficult to obtain because of lobe splitting.

Section V. Performance Against Tracking Type Radars

The general conditions of testing for Section IV above hold true also for this section, so that the data are almost entirely D/F readings.

8. *TEST* 3, *PERFORMANCE AGAINST THE M*-33 (*TRACKING*)

The purpose of this test was to determine the D/F performance of the A/R System against a tracking-type radar operating in the X-band.

The M-33 was placed at Hill 636890 with the antenna set at 600 mils magnetic azimuth and 50 mils elevation. Four flights were run; all using the Tombstone flight path. Flight conditions were bad because of air turbulence, and the operator found this very disturbing. He was affected to such a degree that two flights yielded data from some radar other than the desired one. Thus, only seven significant readings were obtained, as follows:

Position	Range	A/R System Bearing	Standard Bearing	D/F Error	Average Error
	Yards	Degrees	Degrees	Degrees	Degrees
A	52,000	166	165	+ 1	
B Tombstone	43,000	192	185	+ 7	+2.3
C	42,000	---	221	-	
D	53,000	245	246	- 1	
A	52,000	158	165	- 7	
B Tombstone	43,000	184	185	- 1	-4
C	42,000	220	221	- 1	
D	53,000	239	246	- 7	

Here the grand average D/F error for seven readings is -1.3 degrees.

9. *TEST* 4, *PERFORMANCE AGAINST THE AN/MPQ*-16

The purpose of this test was to determine the D/F performance of the A/R System against a medium-range S-band tracking radar.

The AN/MPQ-16 was set up on Hill 633918 and the tracking portion placed in operation with the antenna set at 600 mils magnetic azimuth and 50 mils elevation.

One check flight was made generally along the Fairbanks flight path, and two data flights along the Tombstone flight path. The results obtained are as follows:

Position	Range	A/R System Bearing	Standard Bearing	D/F Error	Average Error
	Yards	Degrees	Degrees	Degrees	Degrees
Special	19,000	258	261	-3	
Special	26,000	291	289	+2	-1
D' Fairbanks	35,000	294	296	-2	
A	49,000	162	165	-3	
B Tombstone	40,000	185	187	-2	-2.5
C	40,000	224	226	-2	
D	52,000	246	249	-3	
A	49,000	165	165	0	
B Tombstone	40,000	190	187	+3	+1.3
C	40,000	226	226	0	
D	52,000	251	249	+2	

The resulting grand average for 11 readings is -0.7 deg.

10. *TEST* 5, *PERFORMANCE AGAINST THE AN/MPQ*-10

The purpose of this test was to determine the D/F performance of the A/R System against a short-range S-band tracking-type radar.

The AN/MPQ-10 was placed on Hill 650857, and placed in operation scanning a sector of 800 mils in the general direction of the Tombstone flight path.

One flight was made along the Fairbanks flight path; D/F readings indicated that some radar other than the intended target was operating at the time. The observed pulse repetition frequency and pulse width did not agree with the known signal characteristics of the AN/MPQ-10.

Two flights were made along the Tombstone flight path with the following results:

Position	Range	A/R System Bearing	Standard Bearing	D/F Error	Average Error
	Yards	Degrees	Degrees	Degrees	Degrees
A	57,000	154	164	-10	
B Tombstone	47,000	179	181	- 2	-1.5
C	44,000	217	215	+ 2	
D	53,000	244	240	+ 4	
A	57,000	---	164	--	
B Tombstone	47,000	168	181	-13	-1.7
C	44,000	216	215	+ 1	
D	53,000	247	240	+ 7	

The resulting grand average error of -1.6 deg. is surprisingly good considering the presence of several simultaneous radar signals. The project officer commented:

> "A suggestion was made that the A/R System work against a signal which is one of several at a ground site. It is assumed that all the signals will be within the display band-width of the receiver used, that is, 20 Mc/s or 1 Mc/s for the AN/APR-9.
>
> "During several test runs this condition did exist. In one case three radar signals were received and each one presented a D/F indication on the AN/APA-69 indicator. Each radar had approximately the same PRF so that this characteristic could not be used to separate the various signals. The AN/APR-9 band-width was left in the wide position. The D/F indications were very clear but could not be tagged [*sic*]. In the narrow band-width position, however, only the one signal to which the AN/APR-9 is tuned will be presented on the D/F display.
>
> "At another time two signals were present on very nearly the same frequency, but the two signals could be separated because of their different characteristics. One signal was of the M-33 acquisition type while the other was of the conical scan type. A good search and intercept operator would have little trouble in D/F."

Section VI. Performance Against Jammers

This section presents results of tests against the AN/TPQ-8, operating first in flat and then in mountainous terrain, and against the AN/MRT-4. In these three tests, the data are again largely confined to D/F readings.

11. *TEST* 6, *PERFORMANCE AGAINST THE AN/TPQ*-8

This test was performed to determine the D/F performance of the QRR-4 against an X-band noise-modulated jammer. The jammer was located to assure line-of-sight conditions throughout the test.

The AN/TPQ-8 jammer was sited on Hill 636890 with the antenna set at 600 mils magnetic azimuth and 50 mils elevation. This orientation causes the jammer beam to lieathwart the flight paths.

Two flights were made along the Fairbanks flight path. During both flights, the AN/TPQ-8 signal, which is noise-modulated, was very difficult to identify and separate from the inherent display of noise. It was also found that the jammer beam is so narrow that the S/N ratio above points A' and D' was too low to afford D/F readings.

One special D/F reading was made near the center of the jammer beam at a radial range of approximately 148,000 yards. This reading was possible because of an existing check point consisting of an intersection of a highway and a course from a radio range.

The data from this test is summarized as follows:

Position	Range	A/R System Bearing	Standard Bearing	D/F Error	Average Error
	Yards	Degrees	Degrees	Degrees	Degrees
A' B' Fairbanks C' D'	46,000 27,000 19,000 33,000	--- 198 248 ---	177 199 253 292	-- -1 -5 --	-3
A' B' Fairbanks C' D'	46,000 27,000 19,000 33,000	--- 196 258 ---	177 199 253 292	-- -3 +5 --	+1
Special	148,000	189	193	-4	-4

This indicates a grand average D/F accuracy of -1.6 degrees, for five readings. The weighting of the Fairbanks readings is justified by their smaller range.

12. *TEST 7, PERFORMANCE AGAINST THE AN/TPQ-8 IN MOUNTAINOUS TERRAIN*

The purpose of this test was to determine the D/F performance of the A/R System against an AN/TPQ-8 located in mountainous terrain.

The AN/TPQ-8 was again sited on Hill 636890 but with its antenna pointed toward a pass in the Huachuca Mountains south of the site. The antenna elevation was set so that the beam just cleared the pass saddle; for this setting the pedestal indications were 3300 mils magnetic azimuth and 50 mils elevation.

The aircraft bearing the A/R System was flown in the area south and west of the Huachuca Mountains (see fig. 4). The presence of the AN/TPQ-8 signal could not be detected unless line-of-sight conditions existed. The operator of the A/R System discounted the possibility of beam bending or refraction. The minimum altitude at which the signal could be received while flying southwest of Miller Peak was 9,000 feet, and the signal was alternately present and absent while flying at this level along a north to south flight path west of the mountain range. The situation was aggravated by the lack of usable check points when the signal was present.

Four D/F readings were obtained, above the ground points indicated for Test 7 on fig. 4. The readings above these points were as follows:

Position	Range	A/R System Bearing	Standard Bearing	D/F Error	Average Error
	Yards	Degrees	Degrees	Degrees	Degrees
1 2 3 4	21,000 26,000 30,000 26,000	352 12 306 309	9 18 310 20	-17 - 6 - 4 -71	- 9 (for 1, 2, 3) -24.5 (all)

The large error is most probably caused by multiple reflection of the AN/TPQ-8 signal under these test conditions. The most accurate D/F reading was obtained from a side lobe but with line-of-sight conditions. The extreme error of the fourth reading was almost certainly due to a reflection of the AN TPQ-8 signal.

13. *TEST* 8, *PERFORMANCE AGAINST THE AN/MRT*-4

The purpose of this test was to determine the D/F performance of the A/R System against a cw jammer operating in the L-band.

The AN/MRT-4 was set up on Hill 636890, operating on a frequency of 226 Mc/s and radiating at an azimuth of 60 mils magnetic and at 50 mils elevation.

The A/R System aircraft used a flight path which was closer than either the Tombstone or Fairbanks paths. D/F readings were taken above prominent landmarks which were athwart the main lobe of the AN/MRT-4. Four readings were made at approximately horizontal ranges of 18,000, 14,000, 7,700, and 3,400 yards from the AN/MRT-4. The results were, in the A/R System operator's words:

> "The D/F reading is more an estimate on the part of the operator than actual readings. The approximate bearing of the MRT-4 was a burst covering 90 deg. and the target bearing D/F was determined by estimating the center of the burst."

Another run was conducted on the following day with a different operator for the A/R System, who stated that:

> "The MRT-4 was . . . . operational for about 25 minutes and then the magnetron developed trouble. . . . It was not possible to D/F the MRT-4. The signal on the Pan scope gave no indication of direction. The scope presentation indicated that the signals were arriving from a full 360°."

Section VII. Additional Tests

Although not listed in the test plan, a test of the human engineering applied to the A/R System was performed. The results are presented in this section, and are relevant to the feasibility of airborne electronic reconnaissance generally as well as to the A/R System specifically.

This section also presents results of laboratory tests on the signal analysis capability of the A/R System.

14. *TEST* 9, *OPERATOR-MACHINE RELATIONSHIPS*

The purpose of this test was to evaluate the man-machine relationship of the A/R System and its operator.

After preliminary, firsthand familiarization with the A/R System and its capabilities, psychologists devised an Interview Record Form and an Observer's Record Form as instruments for obtaining information on the man-machine relationship of the equipment and its operator. The Interview Record Form used was semistructured to insure systematic preplanned inquiry on the part of the interviewer of all aspects of the man-machine relationship while at the same time permitting the interviewee conversational freedom. The Observer's Record Form consisted of a preplanned record sheet for noting various aspects of operator behavior.

Methodology of the test consisted of executing the Observer's Record Form during mock operation of the A/R System by each of the two operators utilized during other tests referred to in this report. Space and loading restrictions precluded observation of operation during actual flight of the aircraft. Following observation each operator was interviewed separately regarding operation of the equipment, and comments were recorded directly on the Interview Record Form.

The following paragraphs comprise the evaluation of the man-machine relationship and suggest remedies to unsatisfactory aspects of that relationship. In reporting this study, it is recognized that production facilities and supplies and other considerations may be found to preclude adherence to some of the findings made herein; e.g., racks may not be available which permit certain recommended equipment rearrangements. It is felt, however, that recommendations made are soundly based when considered strictly from the standpoint of the man-machine relationship. Moreover, the attempt has been made in many cases to describe the general redesign principles which need to be effected.

Evaluation of the man-machine relationship during operation of the A/S System is as follows:

a. *General Comments on the Workspace*

Effective operation of equipment is seriously jeopardized by an undesirable positioning of the operator with regard to equipment. There are many facets of this deficiency:

(1) There is insufficient leg and knee room with the arrangement of equipment as presently constituted. Operators are freer of the distractions of physical tension and can operate more effectively when there is sufficient leg room to permit changes of leg position from time to time and when the knees are not pressed upon by surfaces above them such as the present slanting panel. This deficiency should be corrected to provide a *minimum* rectangular leg area for the seated operator of 24" (height) X 24" (width) X 18" (depth), instead of the narrow irregular area provided at present. Although space is limited within the aircraft, it is sufficient for achieving this change, especially in view of the equipment rearrangement suggested in subsequent paragraphs of this report.

(2) The operator is too close to many of the control surfaces to permit easy manipulation of some knobs and switches, particularly those of the AN/APR-14. The present arrangement of equipment has necessitated placement of the operator with the back of his chair flush with one of the workspace walls. He cannot be placed further from the equipment than he is now under the present arrangement. The operator's chest should, however, be no closer than 1' 2" from any control surface. It should be noted in this connection that the parachute, which will be between the operator and the back of his seat, is 5-1/2" in thickness, and distance of equipment from the operator's chest should be planned with this in mind.

(3) The operator's seat should face forward, and equipment should therefore be rearranged accordingly. Although the present arrangement of equipment in the aircraft provided a fairly good centering of control surfaces in front of the observer if he faced the equipment (sidewise of the direction of flight), both operators felt strongly that facing forward was more desirable in spite of the extreme awkwardness of such a position at present. The operators, after trying the present facing during early flights, quickly decided they preferred to face forward in spite of the fact this required them to maintain their torsos in a twisted position with legs toward the front of the aircraft and upper portions of the body turned sidewise toward the equipment. There were several reasons for this:

1. Operators felt a strong desire for more leg and knee room (see 1-a above) even at the expense of strain to the torso.

2. Operators found it would be extremely difficult to get out of the presently intended position quickly in case of an emergency.

3. There was a strong subjective feeling of greater safety when operators were facing the direction of flight rather than sideways to it. There was a feeling, whether facts substantiate its reasonableness or not, that since the craft was in rapid motion forward any severe change in the operator's equilibrium would come along the front-rear axis and that facing forward permitted a stance braced by the legs and supplemented by muscle groups of greater strength than those which limit sideways lurching. The reasonableness of this attitude is relatively unimportant; tension in the operator *is* induced by the sideways position.

(4) The AN/APA-74 is placed too far from the operator. At those times when it is necessary for the operator to view the screen through the rubber hood, he must lean far forward for several minutes in a severely strained position. The AN/APA-74 should be placed in such a position that the operator has a shorter distance to lean but should still allow for sufficient safe clearance during rough air conditions when the KD-2 camera is attached. (For comment on the KD-2 as a safety hazard see d-(1)-4 below.)

Elimination of the shortcomings of the workspace which are noted above is thus desirable from the standpoint of reducing physical and emotional tensions in the operator which tend to limit unnecessarily his ability to perform his operational duties.

b. *Excluding Daylight from the Work Area.*

Means of excluding light from the operator's work area are unsatisfactory. Effective operation of the A/R System requires almost total darkness, particularly for reading scopes, and the seven light-admitting areas need attention in this regard.

(1) The two, small, circular windows to the rear of the compartment, one on each side of the aircraft, should be permanently covered with some opaque substance. Light from these windows is not needed at any time either during operation of the A/R System or at other times during flight or while the aircraft is on the ground for maintenance.

(2) The two overhead windows are presently equipped with roller shades which admit a great deal of light at the shade edges. Panels which slide on a light-sealing track are suggested.

(3) Windows in the doors on the operator's compartment are presently equipped with snap-on, flexible material which leaks light through numerous gaps around the edges. It is necessary that an improved light-sealing panel which may be easily removed on the operator's side be provided. The operator must be able at times to have access to daylight from this window and be able to observe conditions outside the aircraft. A panel which slides on a track from a secured blackout position to a position at the bottom of the door and flush with it is suggested. For reasons of safety the panel should not be so designed that it will be loose in the aircraft when not in blackout position. On the side of the aircraft away from the operator the present window may be covered with some nonremovable opaque substance.

(4) The vertical curtain between the pilot's compartment and the operator's compartment also admits much light. It is suggested that the curtain be attached around its entire periphery to walls, ceiling, and floor by one or more zippers instead of by the present sporadic fasteners. Consideration should also be given to providing a small zippered flap behind the pilot to enable him to make a quick visual check on conditions in the operator's compartment if the situation demands.

c. *Antennas and Related Mechanisms.*

If tactical usage will require change of antennas during flight, the present method of changing them should be greatly revised. Replacement during flight is very time-consuming, is dangerous to the operator under rough flight conditions, and is extremely awkward and fatiguing. Even for ground changes it is unnecessarily time-consuming and awkward.

From the standpoint of compartment arrangement the aircraft housing is probably located in the best position in the aircraft as presently placed, but the time- and space-consuming mechanism for raising and lowering an antenna in and out of its operating position in the bubble by means of the screw arrangement does not appear to be necessary, especially since no fine height adjustments are demanded during operation. Furthermore, in order to change antennas the operator has to assume numerous restrictive positions. In particular, to remove a raised antenna from its housing the antenna must be tipped toward the operator, who is sitting on the floor, at an angle of 90 degrees from its operating axis; due to lack of space the antenna can barely be removed by pulling it toward the operator. If the antenna and its housing could be rotated to 135 degrees instead of 90 degrees, the antenna could be satisfactorily lifted up and over the operator since it is light in weight. If the screw arrangement is not absolutely necessary, however, the method for changing antennas should be radically redesigned to permit the use of quick bolting to a housing which can then be lowered into operating position in the bubble with speed and a minimum of effort. The danger to the operator under rough, bumpy flight conditions should also be kept in mind and a minimum of projecting surfaces utilized.

d. *Potential Hazards to Operator and Equipment.*

Hazards in addition to those which are implicit in considerations noted above are:

(1) Numerous sharp, projecting objects in the operator's compartment. Their existence in the work area is a needless producer of tension in the operator as well as a real hazard. Operators are aware that under normal flying conditions many of these

objects pose little hazard, but they exhibit considerable anxiety that in occasional unusual situations, such as rough flying weather or emergency landings on rough terrain, the hard-surfaced projections would be quite dangerous. For example, the operator must occasionally check the frequency counter on the APR-9 against the frequency counter on one of the tuners near the floor. Due to the small size of the numbers on the latter the operator must lean forward off-balance and place his head within a few inches of the tuner. A sudden lurch by the aircraft could result in a severe head injury from the cable connector on the tuner. (Legibility of the frequency counter is discussed in f-(4) below.) Specific conditions posing a hazard are the following:

1. The air vent directly over the operator's head is irregular in shape and projects downward from the compartment ceiling. Operators have bumped this numerous times. The vent should be relocated at another accessible position.

2. The numerous cable connectors on tuners and other components provide too many sharp edges. Operators commented several times on this. Rearrangement of the A/R System components should provide for recessing of tuners and other components with sharp edges or covering them with smooth panels which have apertures for exit of cables and for viewing frequency counters.

3. Other miscellaneous sharp edges such as cabinet corners at head level should be made safe by padding.

4. The KD-2 camera, when mounted on the AN/APA-74, presents an extreme hazard and one which is not easily surmounted since the AN/APA-74 must be close enough to the operator's head that when the camera is detached he does not have to assume a strained position while using the rubber viewing hood. If the AN/APA-74 were on a sliding track permitting locking in a near position for use with the hood and a far position for use with the camera, this problem would be solved. For the KD-2 camera a thick protective mask of resilient rubber with apertures for vital adjustments and for viewing scope and scales is also suggested.

(2) More important as a hazard to the equipment itself then to the operator is the fact that the operator often leans on the cables which come out of the face of the AN/APR-14. While this is comfortable for the operator at times, it is a misuse of the cables which might eventually cause breakage, short-circuiting, or possible injury to the operator. Probably no amount of written or verbal regulation would end this practice in a tactical situation. The cables should be covered with a smooth, rounded metal shield.

e. *Night Lighting.*

Night lighting is satisfactory in general, but there are a few aspects of it which can be improved:

(1) Adaptation of the eye to the low-intensity stimulus from luminous markings on control panels is slow enough after continuous viewing of the relatively brighter scopes that these markings cannot be seen quickly. Adjustments making use of these markings are not frequently used, but when they are used the operator must wait several seconds until his eyes have adapted to the new stimulus. Though luminous surfaces may be satisfactory when new, over a period of weeks perspiration, dirt, and grime dull the effectiveness of these manually contacted surfaces. Very dim panel lights as on other control surfaces would eliminate this deficiency.

(2) Frequency counters on tuners cannot be read easily at night. Very dim lights are needed here also, especially if counters are to be viewed through apertures in a safety panel (as suggested in d-(1)-2 above).

(3) Operators reported that the AN/APA-74 scope, of all the scopes, was the one which should have a sharp clear picture; yet it was, they believed, unnecessarily obstructed by the orange filter provided. Necessity for this filter is questioned.

f. *Miscellaneous.*

The following miscellaneous factors in the man-machine relationship are worthy of note:

(1) When the operator of the A/R System wants to use audio outlets of one of the various receivers he must get up from his seat, unplug the earphones from an out-

let near the pilot's compartment, and replug it in the desired receiver. He should be provided with a nearby communications junction box with a switch which will permit him to tap into the aircraft intercom system or into any receiver quickly and effortlessly. The microphone jack should be located in the same place.

(2) The hand microphone furnished with this equipment denies use of one hand at times. Activities of the operators were impaired by this, and it is suggested that a throat or lip microphone be furnished instead.

(3) The TN-131/APR-9 tuner is placed on the floor behind the pilot's compartment and forward of the rest of the equipment of the A/R System. To read its frequency counter the operator must assume a nearly prone position on the floor. This unit must in any future rearrangement of equipment be placed in a more accessible position.

(4) Tuner frequency counter numbers are somewhat small for easy reading even if they are to be lighted. If the tuners were to be placed as close to the operator as the principal control surfaces now are they might be easily readable, but the feasibility of this is in doubt because of space limitations. Larger figures on larger counter discs are needed.

(5) The frequency counter set control cover which contains a list of frequency settings cannot be opened downward far enough for the operator to read the low-frequency settings listed. Re-design of the cover to permit it to open to 180 degrees from its closed position is desirable.

(6) The pull-out writing shelf provided for use in data taking is unusable because the operator is so close he cannot pull it out. This present limitation should be kept in mind in any future rearrangement of components of the A/R System. It should be placed directly in front of the operator at a height of about 1' 1" above the level of the seat of the operator's chair.

(7) Two padded armrests about 1" (thick) X 2-1/2" (wide) X 12" long should be provided, one to the right and one to the left of the writing shelf and mounted horizontally along the face of the equipment stand in front of the operator so he can rest his elbows while manipulating controls.

15. *TEST* 10, *TEST OF SIGNAL ANALYSIS CAPABILITY*

Signals were generated within the Training Device 15-X-7 and introduced into the A R System equipment. The search-intercept operator was asked to analyze these signals and to record their principal features.

The frequency of the signals was read consistently within the expected accuracy of the combination of the AN/APR-9 and the 15-X-7. There is a possibility of misreading the frequency as presented to the A/R System operator and this actually happened several times during the test.

Operators of the A/R System confuse noise and FM signals. This frequently happened during these tests.

The operator was usually able to determine pulse width and repetition rate quite accurately, provided he was allowed plenty of time for the determination. In some cases errors were made which were attributable to the design of the scales on the IP-37 APA-74. In other cases the errors were partially attributable to the fact that the sweeps on the IP-37/APA-74 were not adjusted to start coincidentally with the scales. When these errors are taken into account the operator was always able to determine the pulse width and repetition rate within the accuracy of the 15-X-7.

Section VIII. Conclusions

Since the tests were performed according to three large categories, the conclusions are presented in that order.

16. *DIRECTION-FINDING CAPABILITY*

a. There is no trend of D/F accuracy as a function of range.

b. There is no trend of D/F accuracy as a function of S/N ratio, provided that a minimum ratio of approximately 1.5 to 1 is exceeded.

c. There is no trend of D/F accuracy as a function of frequency.

d. Several independent readings from each of several independent well-defined check points must be made to achieve acceptable D/F accuracy. When this has been accomplished, the error of the average D/F reading from each point is approximately 2 degrees.

e. The accuracy of single airborne D/F readings is sufficient for either the control of jamming or the launching of homing missiles.

f. Single D/F readings taken from an aircraft are likely to be less accurate than single readings from a ground-based D/F station. However, line-of-sight conditions exist more often for airborne D/F operation. Airborne equipment is therefore more versatile.

17. *OPERATOR-MACHINE RELATIONSHIP*

a. There is insuffcient leg and knee room for the operator. This deficiency should be corrected to provide a minimum rectangular leg area of 24" (height) x 24" (width) x 18 " (depth).

b. The operator is too close to many of the control surfaces to permit easy manipulation of some knobs and switches, particularly those of the AN/APR-14. The operator's chest should be no closer than 1' 2" from any control surface.

c. The operator's seat should face forward, and equipment should therefore be rearranged accordingly.

d. The AN/APA-74 is placed too far from the operator except for those times when the KD-2 camera will be attached. If the AN/APA-74 were on a sliding track permitting locking in a near position for use with the hood and a far position for use with the camera, this problem would be solved.

e. Facilities for excluding daylight from the operator's compartment are unsatisfactory. Redesign of these facilities is needed.

f. If tactical usage will require change of antennas during flight, the present method of changing them should be greatly revised since the current mechanism is unnecessarily time-consuming, awkward to use, and a safety hazard in rough weather. Replacement of the screw device with one which is less bulky, less time-consuming to operate, and from which the antenna can be removed more simply is suggested.

g. There are numerous sharp, projecting objects in the operator's work area which should be relocated, redesigned, or padded.

h. Lighting of control surfaces, while satisfactory in general, needs to be extended to a few other areas.

i. The operator should be provided with a nearby communications junction box with a switch which will permit him to tap into the aircraft intercom system or into any receiver quickly and effortlessly.

j. The pull-out writing shelf is unusable because the operator is too close for it to be drawn out.

k. Padded armrests are needed so the operator can rest his elbows while manipulating controls.

18. *SIGNAL ANALYSIS CAPABILITY*

a. Frequency of target signals can be determined acceptably, but there is a possibility of misreading the present scales.

b. The type of target signal is often incorrectly identified by operators of the present A/R System.

c. It is extremely difficult to determine polarization of target signals with the present equipment.

d. Pulse width and repetition rate can be determined quite accurately, but only after a long period of time.

e. The five-gun trace of the IP-37/APA-74 requires improvement in linearity of sweep and coincidence of sweep trace with the scales.

19. *GENERAL CONCLUSIONS*

a. The feasibility of airborne electronic reconnaissance has been substantiated.

b. Extensive modification of present equipment for use in airborne electronic reconnaissance for the field army is necessary.

c. The system weight reduces fuel capacity, maneuverability, and duration of flight of the L-20 in which it is mounted.