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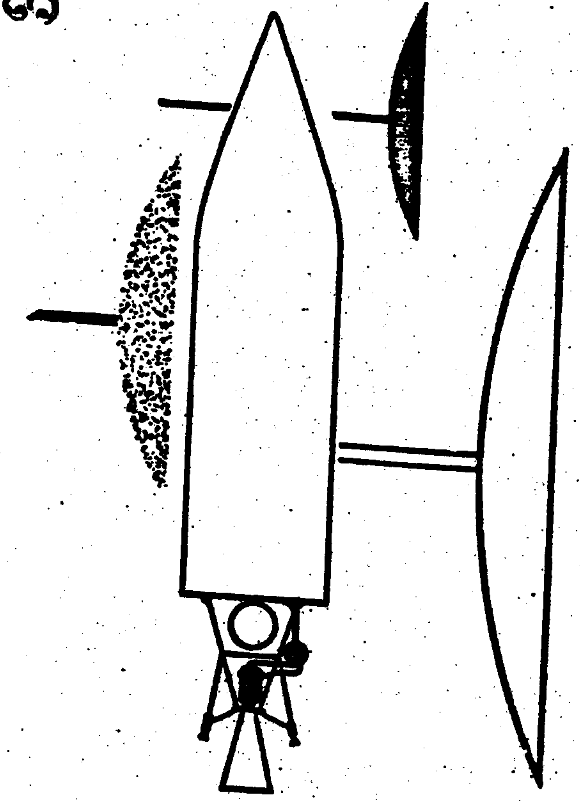

Pied Piper
DEVELOPMENT PLAN

VOL. II SUB-SYSTEM PLAN

F. Electronic Reconnaissance (S)

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LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION
VAN NUYS, CALIFORNIA

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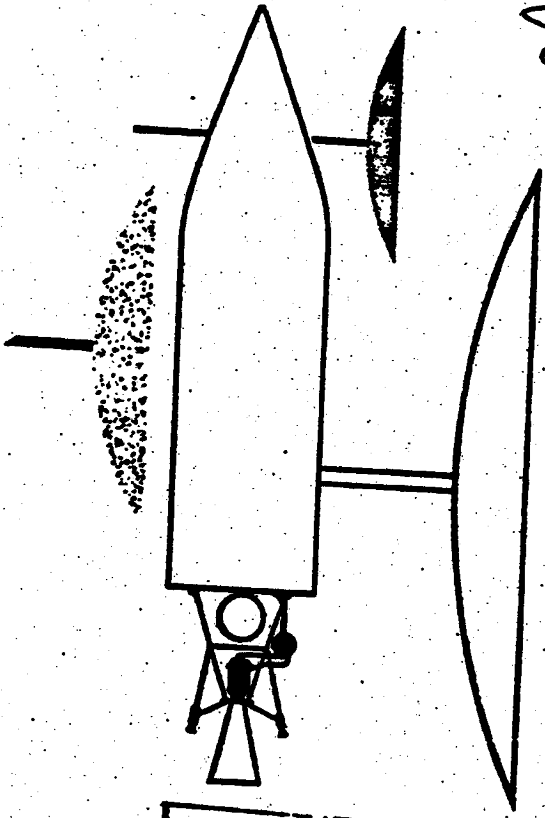

Pied Piper DEVELOPMENT PLAN

VOL. II SUB-SYSTEM PLAN

F. Electronic Reconnaissance

DOWNGRADED AT 12 YEAR INTERVALS;
NOT AUTOMATICALLY DECLASSIFIED
DOD DIR 5200.10

Title Secret

CLASSIFICATION CHANGED
IN ACCORDANCE WITH
AUTH # S35-913
DATE 6-12-61
INITIALS

LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION
VAN NUYS, CALIFORNIA

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FOREWORD

The Advanced Reconnaissance System (ARS) consists of a satellite vehicle containing equipment to perform visual, ferret, and infrared reconnaissance, together with the necessary system of ground stations and data processing centers.

This Development Plan for the accomplishment of the ARS was prepared by the Missile Systems Division, Lockheed Aircraft Corporation and its subcontractors, CBS Laboratories and Eastman Kodak Company. The specifications for the system were determined in the course of a one-year study now being conducted for the United States Air Force under contract AF 33(616)-3105. The plan is presented in two parts; Volume I, System Plan, and Volume II, Subsystem Plan. The subsystems are described in separate books, Volume II-A through II-L.

PIED PIPER DEVELOPMENT PLAN

CONTENTS

Subsystem F Electronic Reconnaissance

~~SECRET~~
~~SECURITY CLASSIFICATION~~

RDB PROJECT CARD

TYPE OF REPORT

REPORTS CONTROL SYMBOL DD-RDB(A)48

1. PROJECT TITLE
ELECTRONIC RECONNAISSANCE SUBSYSTEM
~~FOR ADVANCED RECONNAISSANCE SYSTEM~~
(UNCLASSIFIED)

(PIED PIPER)

2. SECURITY ~~Secret~~

3. PROJECT NUMBER 1115

4. INDEX NUMBER

5. REPORT DATE 1 March 1956

6. BASIC FIELD OR SUBJECT

7. SUBFIELD OR SUBJECT SUBGROUP

7A. TECH. OBJ.

8. COGNIZANT AGENCY

9. DIRECTING AGENCY

OFFICE SYMBOL

TELEPHONE NO.

10. REQUESTING AGENCY

11. PARTICIPATION, COORDINATION, INTEREST

12. CONTRACTOR AND/OR LABORATORY
Lockheed Missile
Systems Division

CONTRACT/W.O. NO. AF33(616)-3105

13. RELATED PROJECTS

14. DATE APPROVED

15. PRIORITY Maximum

16.

17. EST. COMPL. DATES

RES.	
DEV.	
TEST	
OP. EVAL.	
18. FY	FISCAL ESTS. (M $)

19.

20. REQUIREMENT AND/OR JUSTIFICATION

a. This subsystem is needed for the satellite since no comparable system is available, or in development. All prior systems involve reconnaissance from aircraft, and are concerned with problems of range, numbers of radars illuminated by and illuminating the vehicle, and physical environment, at orders of magnitude smaller than those of the satellite environment.

b. The reconnaissance capabilities will be of interest to SAC and ATIC. It also promises information of interest in the area of Electronic Countermeasures and strategic warning.

c. The ARS will provide knowledge of enemy military build-up, preparedness, capability, and possible intent. It will also provide a measure of enemy military and technolcgical progress.

22. RDB	SM	CM	IC & P	X.	I.	C.

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MISSILE SYSTEMS DIVISION

~~SECRET~~
~~SECURITY CLASSIFICATION~~

LOCKHEED AIRCRAFT CORPORATION

R&D PROJECT CARD
CONTINUATION SHEET

SECURITY CLASSIFICATION SECRET

1. PROJECT TITLE ELECTRONIC RECONNAISSANCE SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) (PIED PIPER)	2. SECURITY OF PROJECT ~~Secret~~	3. PROJECT NUMBER 1115
	4.	5. REPORT DATE 1 March 1956

21 a. Brief and Operational Characteristics

The Pioneer ferret equipment will provide a measure of electronic activity in the various enemy frequency bands. It identifies the approximate location, frequency, and prf of radar intercepts. It thereby delivers reconnaissance data on deployment of enemy radars (and associated military forces, airbases, weapons systems) for use by SAC, ATIC, and ECM people.

The Advanced reconnaissance equipment provides a measure or radar activity in greater detail than the pioneer system. It measures frequency, prf, and pulse width of each intercept with an order of magnitude greater accuracy, and provides a more accurate estimate of enemy electronic capabilities and deployment. The advanced system has greater resolving power, and can correctly classify radar intercepts with 75 to 90 per cent accuracy.

The continuous surveillance equipment has improved accuracy and resolution over the advance system, plus additional capability in the analysis of special signals, such as coded pulses. Wide band video signals can also be recorded directly for detailed study. It has great flexibility and can be programmed from the ground.

21 b. Approach

The ferret data acquisition in this system differs significantly from electromagnetic reconnaissance from aircraft. The latter is usually carried out at such an altitude and slant range that: (1) several orders of magnitude fewer radars are within line-of-sight from the vehicle, (2) the vehicle velocity is sufficiently slow to take several direction finding "cuts" which locate the radar within a small circle of confusion. In addition, ferret reconnaissance aircraft can have a much greater payload capability, a human operator to monitor the equipment, and frequent maintenance.

The major difficulties to be overcome in designing a satellite ferret system include: (1) obtaining long life and reliability, (2) the hazards of cosmic and nuclear radiation damage, (3) those aspects of gravitationless environment which effect operation of mechanical units, (4) reliable operation at extremes in temperature, and in the presence of occluded ionized gases, (5) shock and vibration during launch, and (6) the determination of interrelationships among vehicle stability, radar environment, antenna patterns, system bandwidths, and satellite-borne data reduction.

21 c. Subsystem Tasks

1. a. Pioneer Ferret Reconnaissance Equipment

b. Contractor: CBS

c. Characteristics

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R&D PROJECT CARD
CONTINUATION SHEET

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SECURITY CLASSIFICATION

MSD 1536

1. PROJECT TITLE ELECTRONIC RECONNAISSANCE SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) (PIED PIPER)	2. SECURITY OF PROJECT ~~Secret~~	3. PROJECT NUMBER 1115
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(1) Antennas from 50 to 18,000 mc, each antenna with approximately one octave coverage.

(2) 26 adjacent channel crystal video receivers to cover the above band; operation as programmed or commanded through communication channel.

(3) Data processing to identify the location, frequency, and prf of each signal. Integration-type of prf analysis.

(4) Narrow band magnetic tape recorder, to store the reconnaissance data.

(5) Playback and transmission of the data when commanded through the command link from a satellite control station.

(6) Flexibility of adding advanced reconnaissance receivers for "fine-tuning" in selected bands where detailed data is particularly desirable.

2. a. Advanced Ferret Reconnaissance Equipment

b. Contractor: CBS

c. Characteristics

(1) Antennas from 50 to 30,000 mc, with wider bandwidth antennas. Special antenna systems for accurate direction sensing from the satellite to improve directive resolution at long ranges.

(2) Scanning superhetrodyne receivers to cover approximately one octave each in frequency. Special receivers for pulse by pulse direction sensing from the satellite.

(3) Accurate prf, pulse width, and frequency analysis, and correlation with intercept location.

(4) Narrow band magnetic tape storage of processed data.

(5) Read-out to ground when commanded by satellite control station.

3. a. Continuous Surveillance Reconnaissance Equipment

b. Contractor: CBS

c. Characteristics

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(1) Progression to super-broadband antennas.

(2) Flexibility in receiver programming, as commanded by satellite control station, to cover different frequency bands, or for parallel operation in a single band.

(3) Data analysis capability extended to special signals, frequency modulation, pulse width, or pulse code modulation, etc.

(4) Wide band data recording.

(5) Transmission of wide band video data to satellite control station aided by vehicle-borne high gain servo-controlled antenna, similar to visual reconnaissance data link antenna, for tracking satellite control station.

21 d. Other Information

Although all work involving airborne ferret reconnaissance may be considered collateral activities, the unusual environmental and operational conditions involved in reconnaissance from a satellite are not met by presently available equipment.

21 e. Statement of Effects

All equipment will be contractor maintained; operating personnel will be contractor trained.

21 f. Background History

Project Beacon Hill* concluded that approximate frequency and location constitute up to 90% of the intelligence that can be derived from a signal intercept. Pied Piper Study Contract AF33(616)-3105 has shown the feasibility of obtaining this data (plus prf and pulse width) on radars in the USSR, China, and the satellite countries by means of electronic intercept equipment carried aboard an orbiting satellite.

21 g. References

1. Final Report, Project Beacon Hill, 15 June 1952
2. Appendix to this volume
3. Pied Piper Monthly and Quarterly Report

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R&D PROJECT CARD
CONTINUATION SHEET

SECRET
SECURITY CLASSIFICATION

1. PROJECT TITLE ELECTRONIC RECONNAISSANCE SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) (PIED PIPER)	2. SECURITY OF PROJECT ~~Secret~~	3. PROJECT NUMBER [illegible]
	4.	5. REPORT DATE 1 March 19[illegible]

21 h. Future Plans

It is planned to continue the studies already initiated and to develop equipment which will result in a military system at the earliest possible time commensurate with the intelligence needs and state-of-the-art, and with a logical progression from that point to more sophisticated equipments.

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Pied Piper

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TABS

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Subsystem F - ELECTRONIC RECONNAISSANCE

Tab 1 - General Design Specification

1. GENERAL

A. Statement of the Problem

The problem in Pied Piper ferret reconnaissance development is to design electromagnetic intercept equipment to be carried in an orbiting satellite vehicle, which will gather radar intercept data, process and record the data, and retransmit the information when the satellite is in communication with friendly satellite control stations.

The ARS requirements which establish the objectives are:

1. Continuous ferret reconnaissance of the USSR and satellite nations. Timeliness of the receipt of the intelligence information is essential.
2. Electronic reconnaissance capabilities should extend from 50 to above 10,000 mc. The modulation characteristics should be determined, and correlated with the frequency data in order to identify the signal source types.
3. The location of ground signal sources should be determined in a manner suitable for this unique application.
4. A minimum useful military system shall be made available at the earliest possible time, and the improved system capabilities shall be evolved in a logical and efficient manner.

B. Approach

Due to our limited present knowledge of the USSR radar environment, and the maze of electronic signals to be expected, the ferret reconnaissance program will begin with equipment capable of signal density analysis with detailed signal analysis equipment added in succeeding flights.

The planning has been divided into the following programs:

1. Equipment for pioneer ferret reconnaissance
2. Equipment for advanced ferret reconnaissance
    a. General reconnaissance
    b. Special Purpose reconnaissance
3. Equipment for continuous surveillance

The sub-system progression is from simple, low resolution, to more sophisticated equipments; the superposition of data gathered by each equipment leads to a realistic detailed synthesis of the enemy radar network. A preliminary analysis of the confidence limits and an investigation of the intelligence parameters is presented in the appendix.

Subtasks in the sub-system development will be the design and selection of components, with a logical progression to more sophisticated designs. The component subtasks are:

1. Antennas
2. Ferret Receivers
3. Data Processing Equipment
4. Data Recording Equipment
5. Data Transmission Equipment

C. Solutions and Recommendations

1. Operational Ranges

Each task will result in an operational military equipment; the operational capability of each equipment is given as follows:

1. Pioneer Ferret Reconnaissance Equipment. Measures coarse frequency, location, and prf of each intercept; approximate radar count by type and development; low resolution of intercepts (up to 50 percent).

2. Advanced Ferret Reconnaissance Equipment

   2.1 General. Measures accurate frequency, prf, and pulse width of each intercept; more accurate location of each target; 75 to 90 percent correct classification of radar intercepts.

   2.2 Special Purpose. Detection, identification and location of selected radar types, or detailed analysis of intercepted signals, including special signals (e.g., PCM, or PTM); high intercept probability and classification accuracy.

3. Continuous Surveillance Reconnaissance Equipment. The resolving power and analysis capability of the most sophisticated advanced reconnaissance equipment, plus wide band video recording and transmitting to enable the processing of special signals. Completely flexible data gathering and processing, and capable of programming from the ground.

Subtasks of the subsystem are:

1. Estimated antenna typical bandwidths for early equipments are one octave. Later equipments will use special antenna configurations. Super-broadbanding will be a goal in advanced reconnaissance equipment. (See appendix)

2. Receivers

   2.1. Pioneer. 26 adjacent channel receivers for continuous coverage of 50-18,000 mc; low resolving power. (See appendix)

   2.2 Advanced. Nine (9) scanning superheterodyne receivers which cover the range from 50-30,000 mc; good resolving power. (The operational characteristics and design criteria are described in the appendix.)

   2.3 Continuous Surveillance. Receivers with large capability in analyzing signal intercepts; very good resolution, high intercept probability, and up to 90 percent correct classification of intercepts even in dense signal environments. Flexible operation which can be programmed from the ground.

3. Data Processing Systems

3.1 Pioneer. The Pioneer data processing equipment will integrate incoming prf's between 50-10,000 pps with an accuracy of ± 100 pps. Provision will be made for recording up to 26 channels of integrated prf's on a magnetic tape transport operating at 15 inches per second by means of commutation and pulse width recording. The individual techniques for accomplishing the above are present state of the art.

3.2 Advanced. The advanced data processing equipment will measure prf by the cycle counting technique with an accuracy ranging as high as 1% for the higher prf's. Pulse width will be measured by integration - boxcar technique to an accuracy of ± 20%. The prf indications will be stored as binary bits on magnetic tape, the pulse width signal will be stored as an analogue signal. The same tape transport will be used as in the Pioneer System. Four receiver outputs can be recorded on one magnetic track. Parallel tracks will be used to accommodate additional receivers.

3.3 Continuous Surveillance. The Continuous Surveillance equipment will be a modified version of the Pioneer and advanced equipment set up to select the desired signals for recording by the wide band tape recorder will be available.

4. Data Recording Systems

4.1 Pioneer. A tape transport mechanism must be developed capable of operating at 15 inches per second under the expected environmental conditions.

4.2 Advanced. The same mechanism will be used as for the Pioneer, however, provision will be made for multiple track recording to accommodate the increased amount of information which will be gathered.

4.3 Continuous Surveillance. A wide band video tape recorder capable of recording 1 mc signals must be developed by extending presently known techniques an order of magnitude.

5. Data Transmission Systems

5.1 Pioneer. A standard telemetering 50 watt transmitter must be modified to operate for long periods of time in the expected environment.

5.2 Advanced. A standard telemetering 50 watt transmitter must be modified to operate over long periods of time in the expected environment.

5.3 Continuous Surveillance. A video transmitter capable of 1-mc modulation and 10 watts output must be developed for transmitting the output of the wide band recorder to the ground intercept station.

2. State-of-the-Art

The present state-of-the-art as applicable to the tasks of the subsystem are:

1. Pioneer. The pioneer equipment is within the state-of-the-art, and uses mostly off-the-shelf components. It is based on present estimates of the operational and physical environment.

2. Advanced. The advanced equipment is also within the present state-of-the-art. Although some components are not yet shelf-items, no difficulty is anticipated for the intended operational period. The present estimate of subsystem capability is based on usage of currently available, or soon-to-be available reliable components.

3. Continuous Surveillance. Progression to the most sophisticated equipment relies on foreseeable component developments, such as:

   3.1 Wide Band Video Recorders

   3.2 Miniaturized Wide Band R-F Amplifiers

   3.3 Super-broadband Antennas

   3.4 Improved Component Reliability

3. Unusual Environmental Conditions

The most unusual environmental conditions will be nuclear and cosmic rays, and zero gravitational field.

Other environmental conditions are different only in severity from conditions to which military equipments are currently subjected. These are low temperature, partial vacuum and occluded ionized gases, and shock and vibration during launching.

4. Special Tests Prior to Freezing Design

1. Propagation tests to determine atmospheric effects and probable reliability of vehicle to ground communication.
2. Airborne tests to measure typical ground radar elevation patterns in typical terrains.
3. Ground tests to determine electrical characteristics of each unit separately.
4. Ground tests to determine electrical characteristics under simulated environmental conditions, such as low temperature, vibration, shock, and nuclear radiation tests; operation of units in every orientation to simulate operation in gravitationless environment.
5. Ground tests to determine subsystem characteristics under simulated operational environment. Use of special test devices to simulate multiple radar intercepts and evaluate reliability of operational analysis.
6. Accelerated life tests of components.
7. Tied-down launching tests of subsystems.
8. Airborne tests to determine operational characteristics of each unit separately.
9. Airborne tests to determine operational characteristics of complete subsystem.

5. The vehicle structural design cannot be frozen until all antenna designs are firm.- The antenna designs in turn cannot be frozen until tests indicated in item 4 are performed.

6. A preliminary estimate of the pioneer sub-system reliability based on currently available components is a few hundred hours. The critical nature of major components is indicated in tabular form below.

Item	Expected Life	Notes
Commutators	Min: 50; Max: several hundred hours	Spares will be included with provision for automatic switching
Traveling Wave Tubes	1000 to 5000 hours	
Transmitting Tubes	1000 to 5000 hours	
Tape Transport Mechanism of Recorder	MIN. 1000 hours	

Based on these values, an expected life during the intended operational period of the pioneer sub-system should be 500 to 5000 hours. For the operational duty cycle anticipated, this should permit a year's operation.

The surveillance sub-system should be an order of magnitude better due to the industry wide effort to improve component reliability, and as a result of experience gained during the development of the pioneer sub-system.

7. The equipments should be mounted as follows:

Subject to least vibration

Maximum accessibility

Maximum shielding from radiation by nuclear power unit -- special protection for most critical components.

8. In order to complete airborne tests, the following GFE items will be required:

1. Domah: Helicopter for typical radiation patterns and propagation tests.

2. B-50 Bomber for operational tests of sub-system.

9. None

10. Based on estimated size, weight, and power, and sophistication of each stage of the ferret reconnaissance sub-system (pioneer, advanced, and continuous surveillance) is compatible with:

1. Anticipated vehicle payload capacity during the intended operational period of each ferret stage.
2. The development from one stage to the next is an orderly progression from simple to more complex, from present to foreseeable state-of-the-art, and from lesser to greater reconnaissance capability.
3. Operational characteristics of each stage of ferret development is geared to anticipated intelligence needs.

Subsystem F - ELECTRONIC RECONNAISSANCE

Tab 2 Summary - Subsystem Milestones

Pioneer Ferret Recon. Payload

Design & Fabrication of First Experimental Model Begins

Delivery for Environmental Test

Flight Test in Manned Aircraft

Delivery for First STV Flight Test

Delivery for First PTV Flight Test

Delivery for First OTV Flight Test

Advanced Ferret Recon. Payload

Design and Fabrication of First Experimental Model Begins

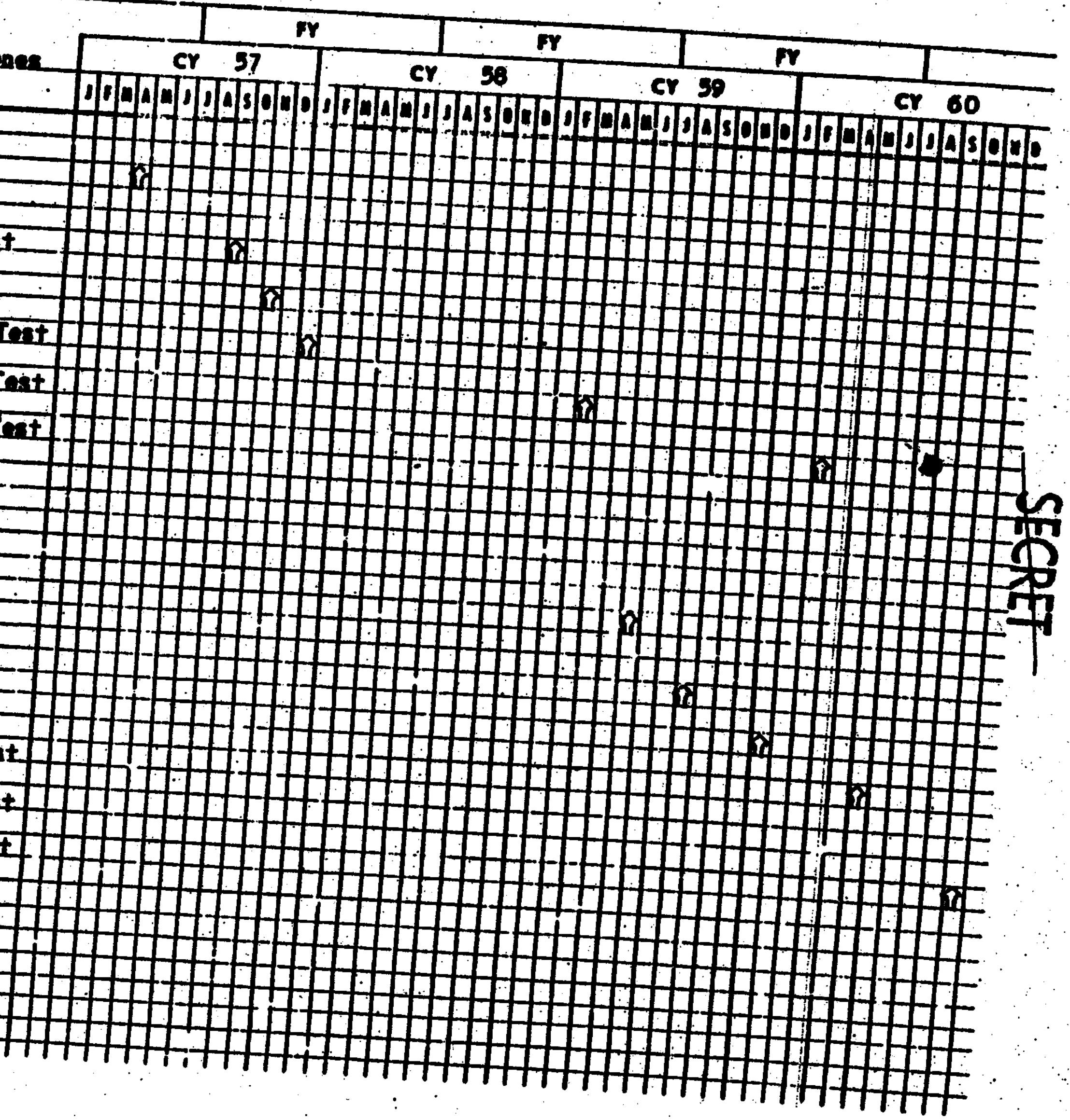
Delivery for Environmental Test

Flight Test in Manned Aircraft

Delivery for First STV Flight Test

Delivery for first PTV Flight Test

De'ivery for First OTV Flight Test



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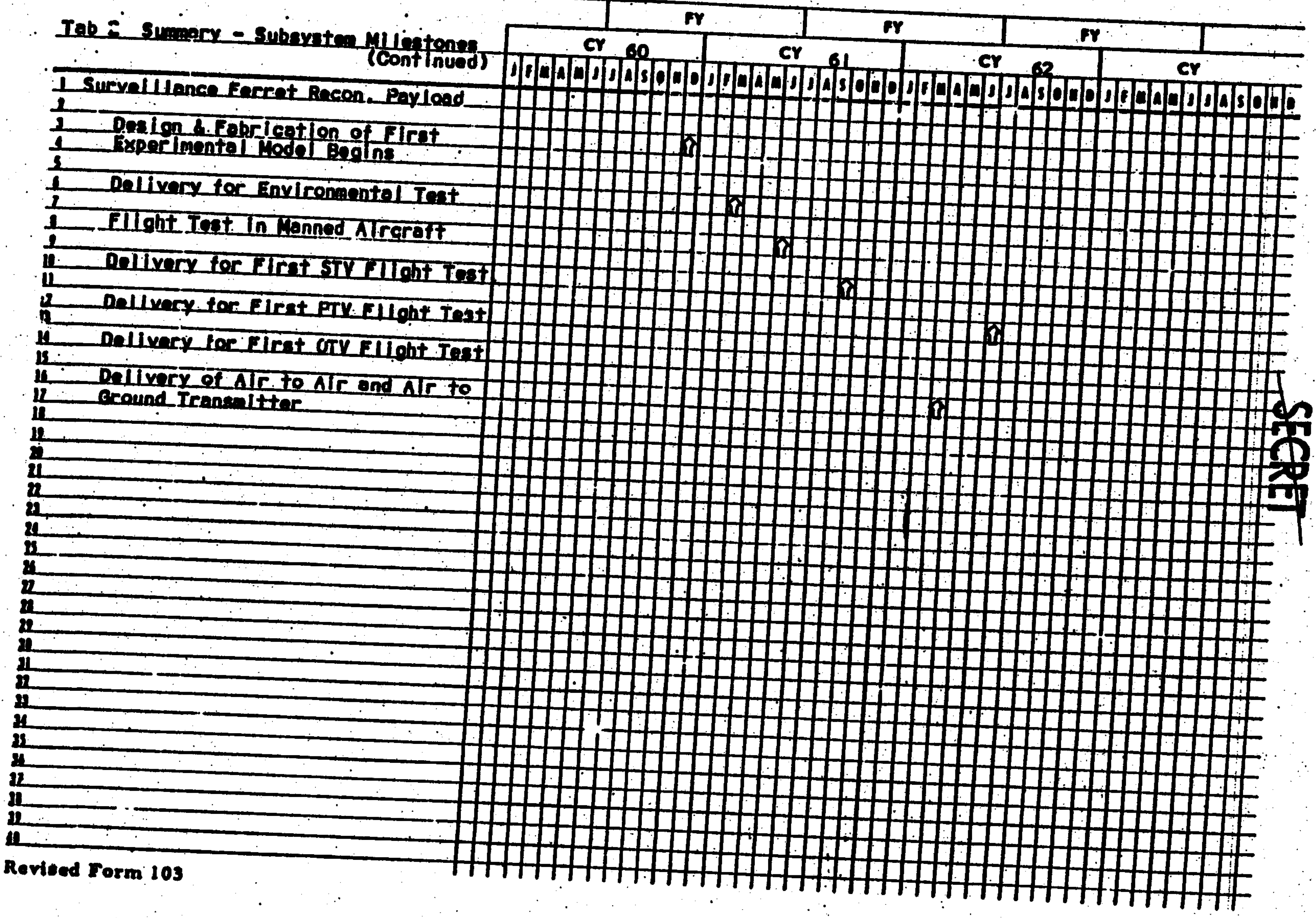
Subsystem F - ELECTRONIC RECONNAISSANCE

Tab 2 Summary - Subsystem Milestones (Continued)



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Subsystem F - ELECTRONIC RECONNAISSANCE

Tab 2 Summary - Hardware Delivery

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Subsystem F - ELECTRONIC RECONNAISSANCE

	Tab 2 Summary - Hardware Delivery (Continued)							FY 62												FY 63												FY																	
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Subsystem F - ELECTRONIC RECONNAISSANCE

Tab 2 Summary - Subsystem Test Schedule

1
2 Pioneer Ferret Recon. Payload
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4 Environmental Test
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6 Compatability Test with Nuclear APU
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8 Helicoptar Antenna Pattern Measurements
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10 Flight Test in Manned Aircraft
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12 STV Flight Tests
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14 PTV Flight Tests
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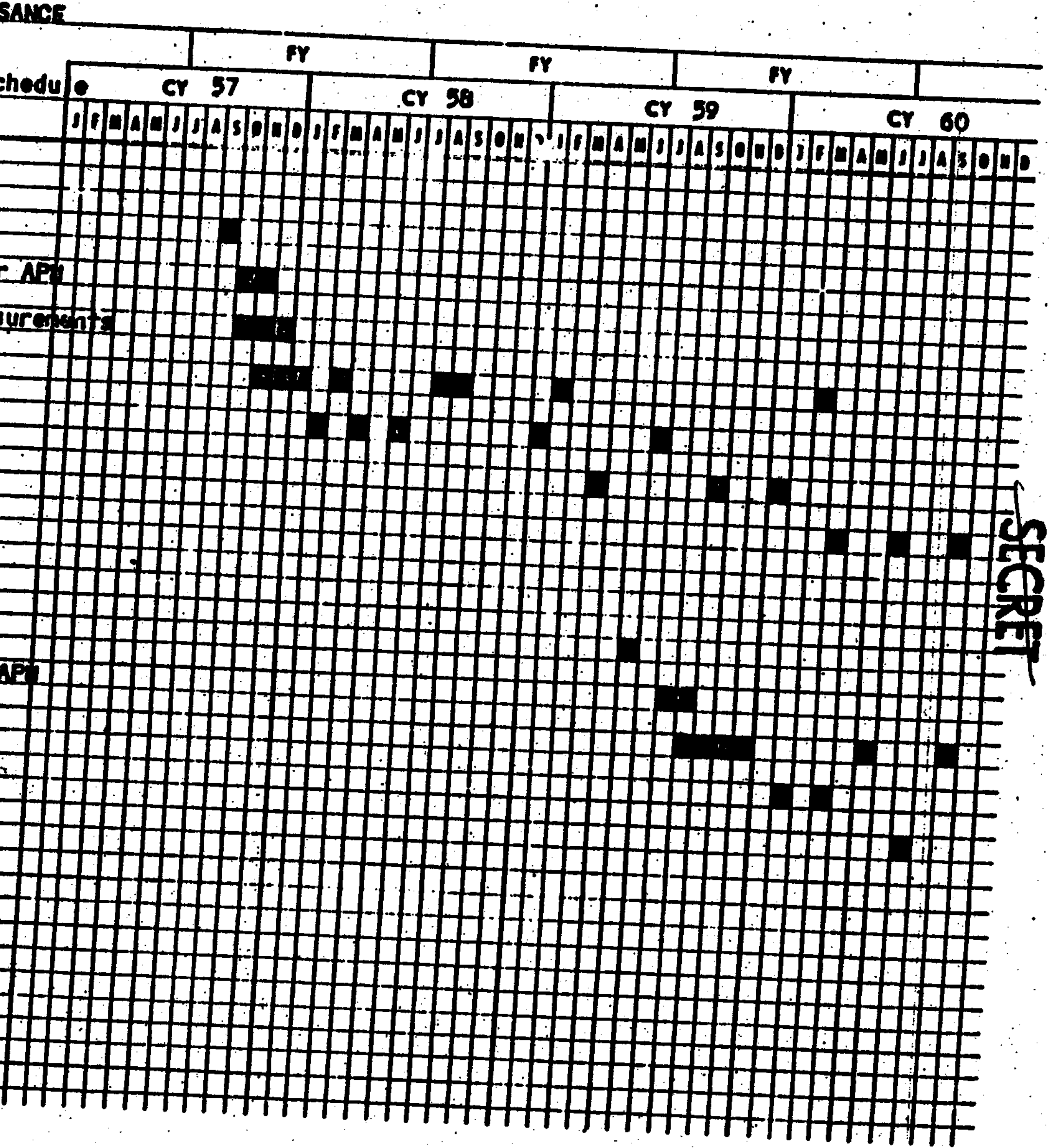

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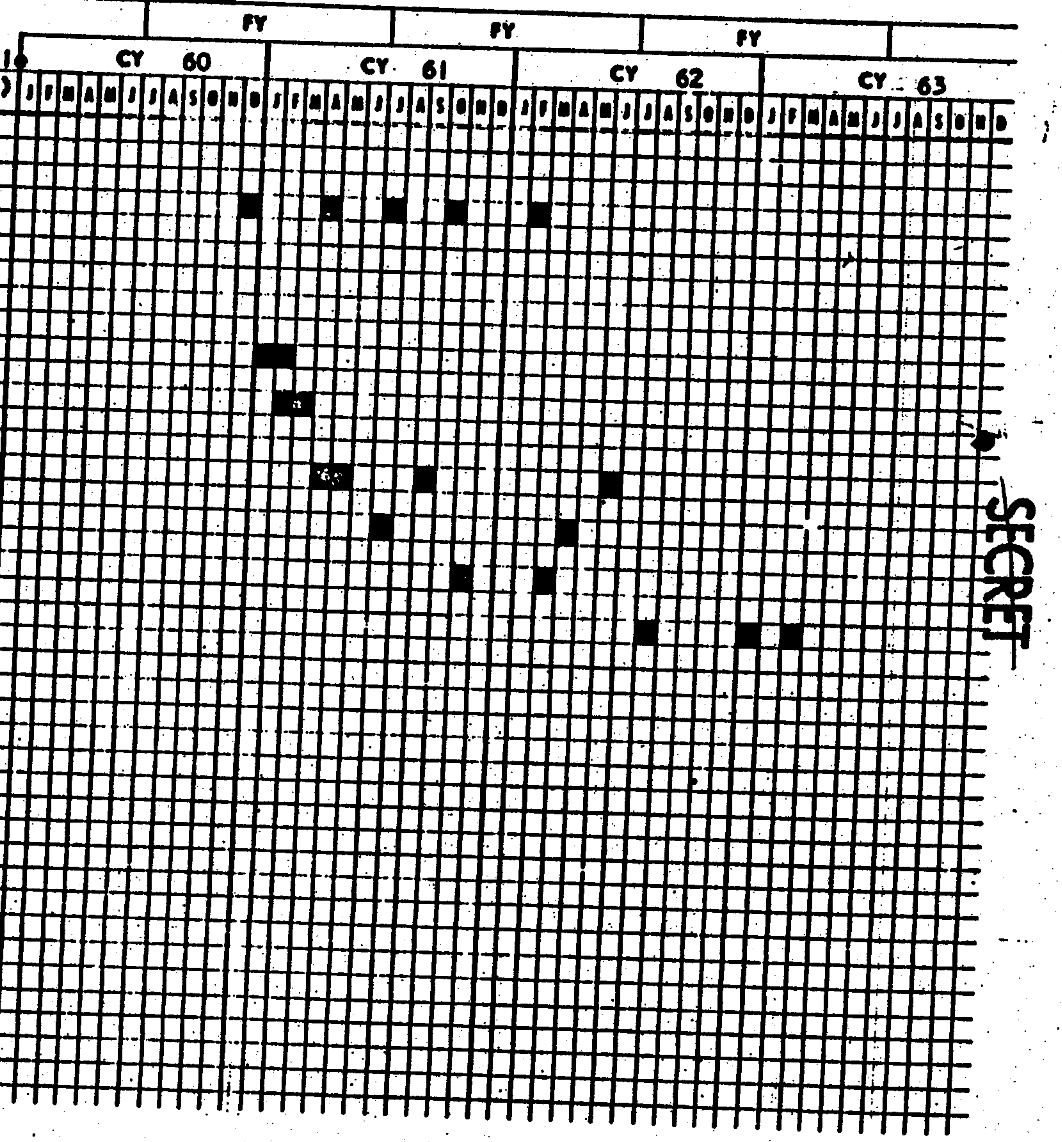
Subsystem F - ELECTRONIC RECONNAISSANCE

Tab 2 Summary - Subsystem Test Schedule
(Continued)



1
2 Advanced Ferret Recon. Payload
3
4 OTV Flight Tests
5
6
7
8 Surveillance Ferret Recon. Payload
9
10 Environmental Test
11
12 Compatability Test with Nuclear
13 APU
14
15 Flight Test in Manned Aircraft
16
17 STV Flight Tests
18
19 PTV Flight Tests
20
21 OTV Flight Tests
22
23
24
25
26
27
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38
39
40

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Subsystem F - ELECTRONIC RECONNAISSANCE

Tab 2 Summary - R & D Schedule

System

System Engineering Begins (Continuing Study)

Research & Development Begins

Pioneer Ferret Recon. Payload

Preparation of Design Specifications for First Experimental Model

Design & Fabrication of First Experimental Model Begins

Testing of First Experimental Mode

Delivery for Environmental Test (Tiedown 1 and 2)

Compatability Test with Nuclear APU

Flight Test in Manned Aircraft

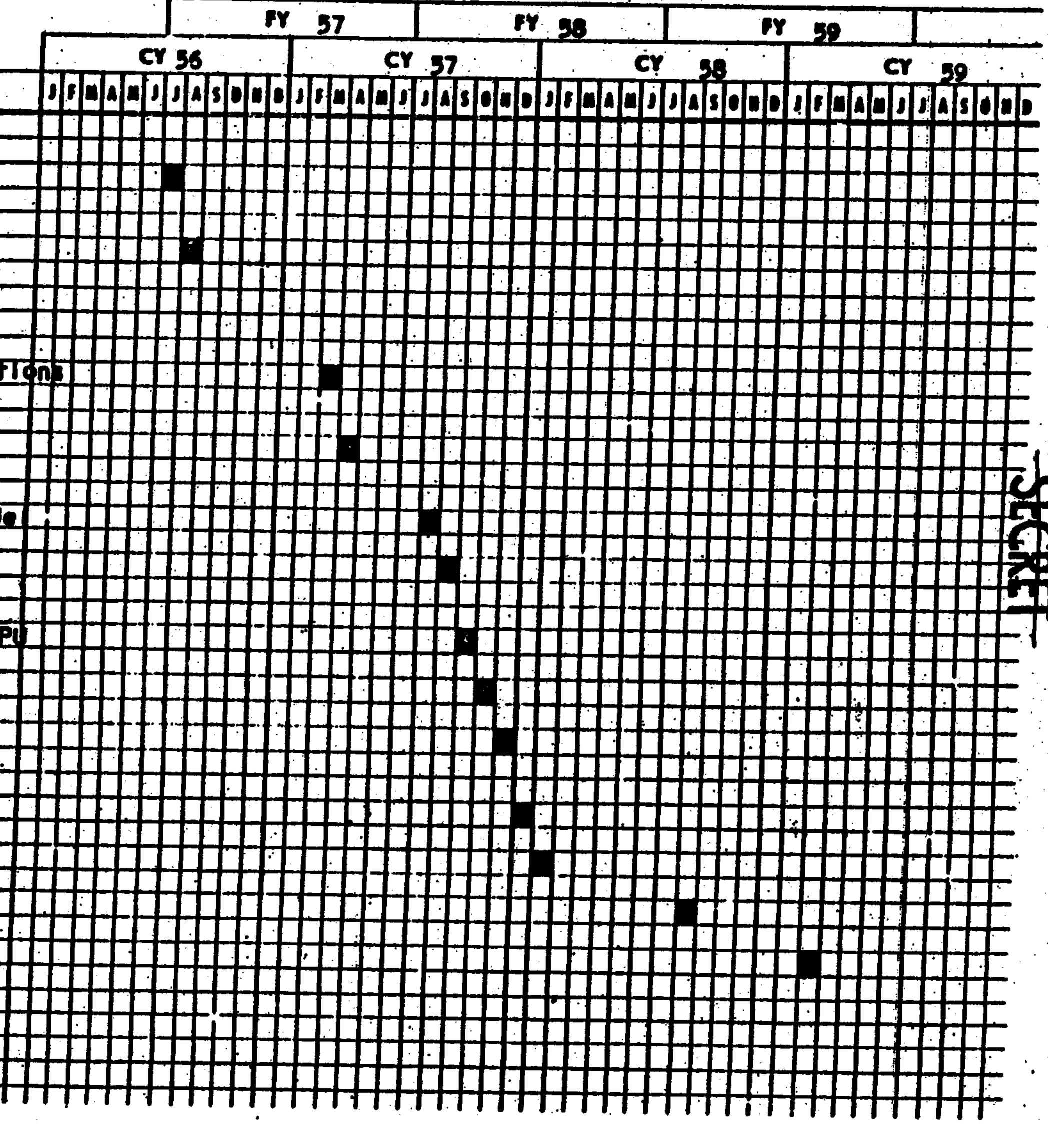
Design & Fabrication of Sweeping Receiver

Delivery for STV Flight Test

Redesign for PTV

Fabrication for PTV & OTV (6)

Delivery for PTV Flight Test



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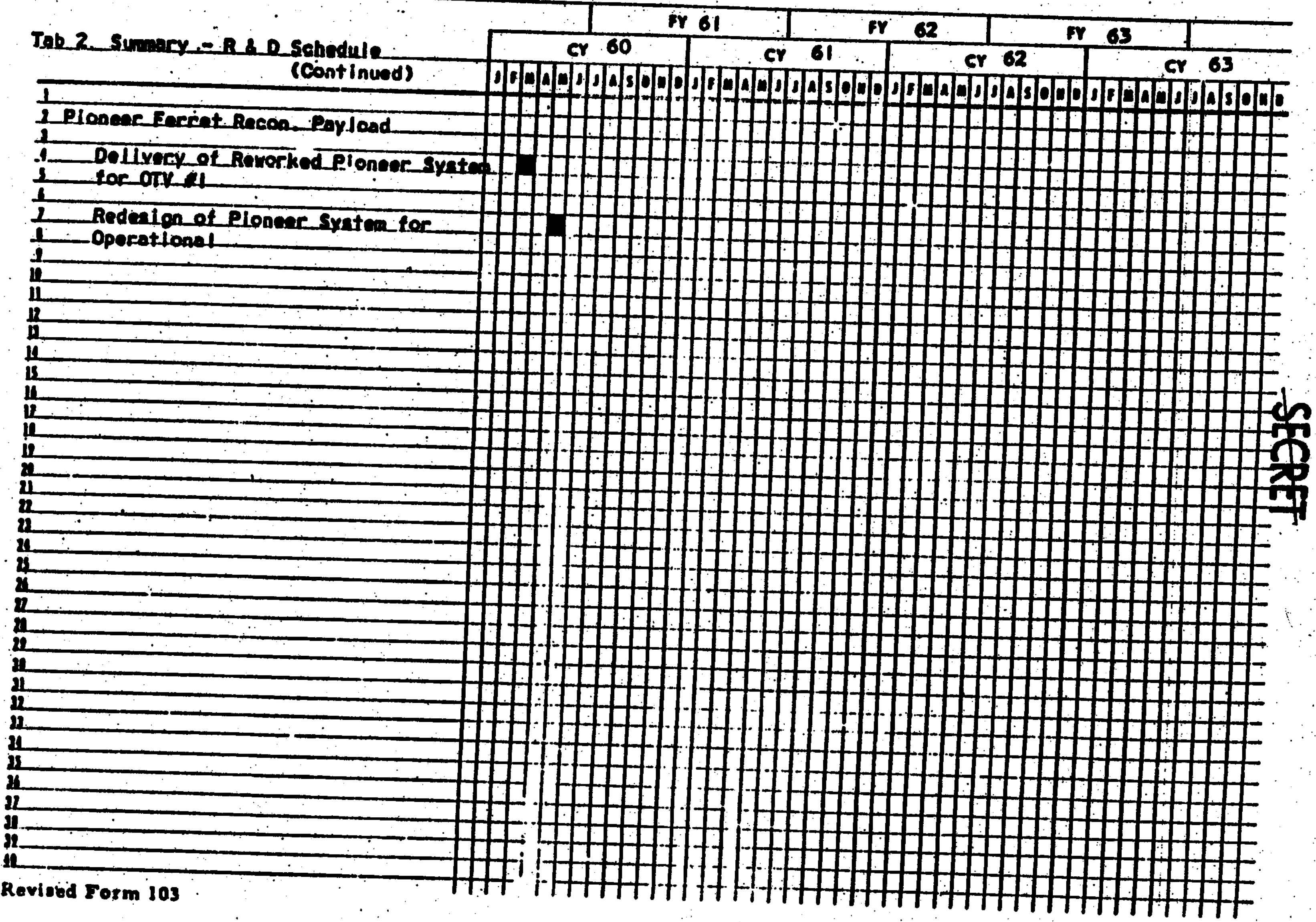
Subsystem F - ELECTRONIC RECONNAISSANCE



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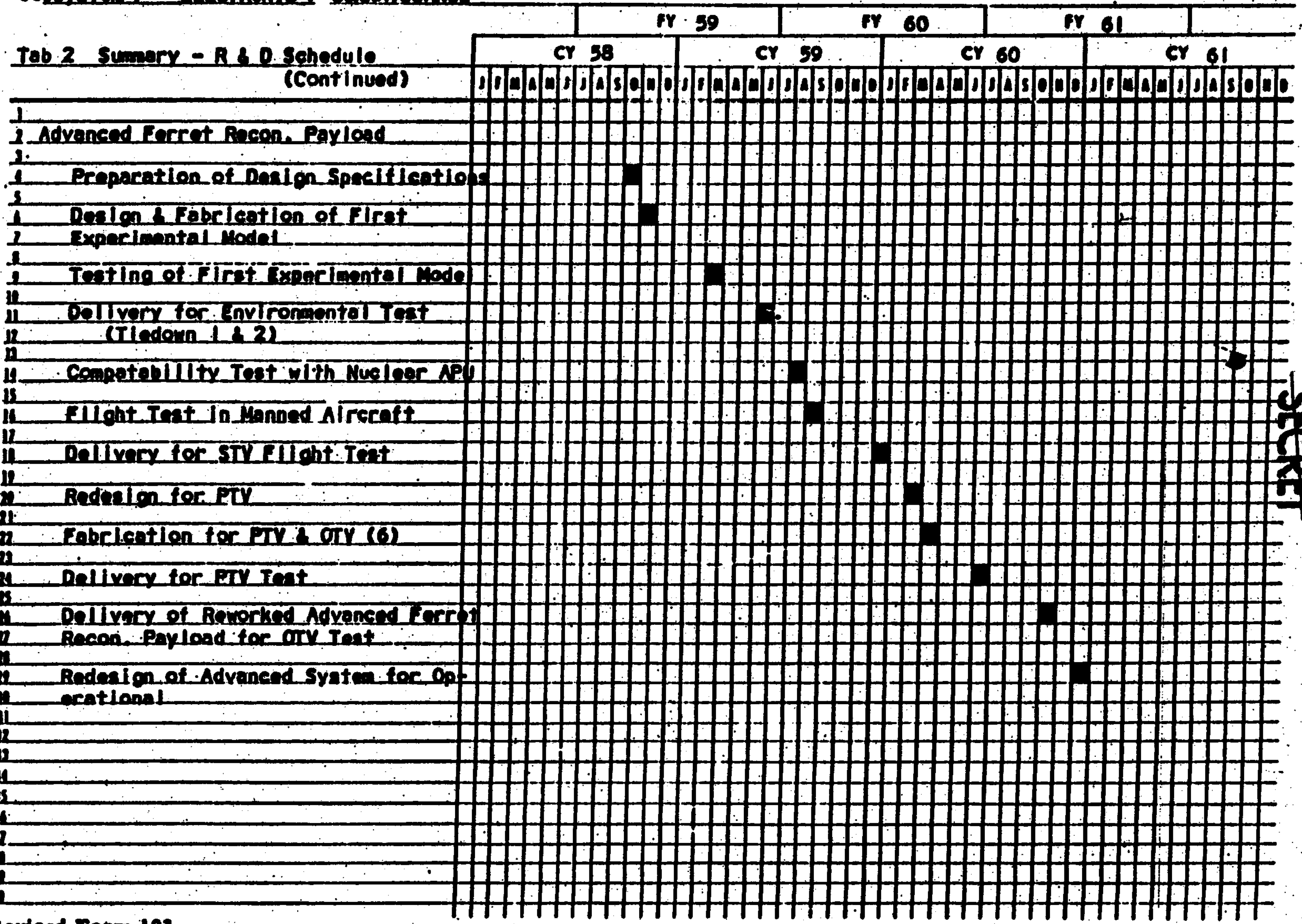
Subsystem F - ELECTRONIC RECONNAISSANCE

Tab 2 Summary - R & D Schedule (Continued)



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Subsystem F - ELECTRONIC RECONNAISSANCE

Tab 2 Summary - R & D Schedule (Continued)

								FY												FY												FY																	
		CY 59												CY 60												CY 61												CY 62											
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1	Surveillance Ferret Recon. Payload																																																
2																																																	
3	Preparation of Design Specifications															■																																	
4																																																	
5	Design & Fabrication of First																	■																															
6	Experimental Model																																																
7																																																	
8	Testing of First Experimental Model																					■																											
9																																																	
10	Delivery for Environmental Test																								■																								
11	(Tiedown 1 & 2)																																																
12																																																	
13	Compatability Test with Nuclear AP																										■																						
14																																																	
15	Flight Test in Manned Aircraft																											■																					
16																																																	
17	Delivery for STV Flight Test																														■																		
18																																																	
19	Redesign for PTV																															■																	
20																																																	
21	Fabrication for PTV & OTV (5)																																■																
22																																																	
23	Delivery for PTV test																																		■														
24																																																	
25	Delivery of Reworked Advanced Ferret																																																
26	Recon. Payload for OTV Test																																											■					
27																																																	
28	Redesign of Advanced System for																																																
29	Operational																																													■			
30																																																	
31	Delivery of Air-to-Air & Air-to-																																																
32	Ground Transmitter																																								■								
33																																																	
34																																																	
35																																																	
36																																																	
37																																																	
38																																																	
39																																																	
40																																																	

Revised Form 103

1\.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2\. REPORTS CONTROL SYMBOL

PAGE 1 OF 7 PAGES

3\. DATE

4\. TITLE

Subsystem F - ELECTRONIC RECONNAISSANCE

5\. INITIAL ☒ CHANGE

6\. NUMBER

7\. RESP CENTER

8\. PROJECT OFFICER

9\. SUPPORTS (Sys or Proj)

10\. CONTRACTOR

11\. CONTR NR

12\. PRIORITY AND PREC

13\. SECURITY

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RDD TEST COMPL DATE
1	Pioneer Ferret Recon Payload Less Data Recording	STV Flight Test of Pioneer System Less Data Recorder, Modified as Result of Manned Flight Tests	AFMTC	Jan 1958	Mar 1958
2	Pioneer Ferret Recon Payload (Model 1)	STV Flight Tests of Pioneer System (Model 1)	AFMTC	Mar 1958	May 1958
3	Pioneer Ferret Recon Payload (Model 1)	STV Flight Test of Pioneer System (Model 1)	AFMTC	May 1958	Jul 1958
4	Pioneer Ferret Recon Payload (Model 1 - Mod. 1)	STV of Flight Test of Pioneer Ferret	AFMTC	Dec 1958	Feb 1959
5	Pioneer Ferret Recon Payload (Model 1 - Mod. 2)	PTV Flight Test and Propagation Test	AFMTC	Mar 1959	May 1959
6	Pioneer Ferret Recon Payload (Model 1 - Mod. 3)	STV Flight Test of Equipment On Modified as Result of 1st PTV Test	AFMTC	Jul 1959	Aug 1959

TEST CENTER APPROVAL

20\. NAME | ORGANIZATION | DATE

21\. NAME | ORGANIZATION | DATE

RESPONSIBLE CENTER APPROVAL

22\. NAME | ORGANIZATION | DATE

ARDC FORM 1 JUL 55 105 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

1\.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2\. REPORTS CONTROL SYMBOL

PAGE 2 OF 7 PAGES

3\. DATE

4\. TITLE

Subsystem F - ELECTRONIC RECONNAISSANCE

5\. INITIAL ☒ CHANGE

6\. NUMBER

7\. RESP CENTER

8\. PROJECT OFFICER

9\. SUPPORTS (Sys or Proj)

10\. CONTRACTOR

11\. CONTR NR

12\. PRIORITY AND PREC

13\. SECURITY

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
7	Pioneer Ferret Recon Payload (Model I - Mod. 3)	PTV Flight Test and Isotope Closed Cycle Test	AFMTC	Sep 1959	Nov 1959
8	Pioneer Ferret Recon Payload (Model I - Mod. 3)	Second PTV Flight Test and Nuclear APU Test	AFMTC	Dec 1959	Feb 1960
9	Pioneer Ferret Recon System	First Orbital Flight Test Chemical - APU Version	GFF*	Mar 1960	**
10	Pioneer Ferret Recon System	Second Orbital Flight Test Chemical - APU Version	GFF*	Jun 1960	**
11	Pioneer Ferret Recon System	Third Orbital Flight Test Chemical - APU Version	GFF*	Sep 1960	**
12	Advanced Ferret Recon System (Model I)	First STV Flight Test	AFMTC	Jan 1960	Feb 1960
**	For useful life of vehicle and payload.				
*	To be determined at a later date.				

TEST CENTER APPROVAL

20\. NAME ORGANIZATION DATE

21\. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22\. NAME ORGANIZATION DATE

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 3 OF 7 PAGES

3. DATE

4. TITLE Subsystem F - ELECTRONIC RECONNAISSANCE

5. INITIAL ☒ CHANGE

6. NUMBER

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj)

10. CONTRACTOR

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
13	Advanced Ferret Recon System (Model I - Mod. I)	First STV Flight Test	AFMTC	Mar 1960	May 1960
14	Advanced Ferret Recon System (Model I - Mod. I)	First FTV Flight Test and Calibration over known Targets	AFMTC	Jul 1960	Sep 1960
15	Advanced Ferret Recon Payload (Model I - Mod. I)	First OTV Flight Test - NAPU	AFMTC	Nov 1960	*
16	Advanced Ferret Recon Payload (Model I - Mod. I)	Second OTV Flight Test - NAPU	AFMTC	Mar 1961	*
17	Advanced Ferret Recon Payload (Model I - Mod. I)	Third OTV Flight Test - NAPU	AFMTC	Jun 1961	*
18	Advanced Ferret Recon Payload (Model I - Mod. I)	Fourth OTV Flight Test - NAPU	AFMTC	Sep 1961	*
19	Advanced Ferret Recon Payload (Model I - Mod. I)	Fifth OTV Flight Test - NAPU	AFMTC	Jan 1962	*
20	Surveillance Ferret Recon System (Model I)	First STV Flight Test	AFMTC	Jun 1961	Aug 1961

* For useful life of vehicle and payload.

TEST CENTER APPROVAL

20. NAME ORGANIZATION DATE

21. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

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MSD 1536

1\.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2\. REPORTS CONTROL SYMBOL

PAGE 4 OF 7 PAGES

3\. DATE

4\. TITLE Subsystem F - ELECTRONIC RECONNAISSANCE

5\. INITIAL ☒ CHANGE

6\. NUMBER

7\. RESP CENTER

8\. PROJECT OFFICER

9\. SUPPORTS (Sys or Proj)

10\. CONTRACTOR

11\. CONTR NR

12\. PRIORITY AND PREC

13\. SECURITY

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
21	Surveillance Ferret Recon Payload (Model I)	Checkout in Manned Aircraft Prior to First PTV	AFMTC	Aug 1961	Oct 1961
22	Surveillance Ferret Recon System (Model I)	First PTV Flight Test	AFMTC	Oct 1961	Dec 1961
23	Surveillance Ferret Recon System (Model I)	Second PTV Flight Tast	AFMTC	Feb 1962	Apr 1962
24	Surveillance Ferret Recon System (Model I - Mod. I)	First STV Flight Test	AFMTC	Mar 1962	May 1962
25	Surveillance Ferret Recon System (Model I - Mod. I)	First OTV Flight Test	GFF*	Jul 1962	**
26	Surveillance Ferret Recon System (Model I - Mod. I)	Second OTV Flight Test	GFF*	Dec 1962	**
*	To be determined at a later date.				
**	For useful life of vehicle and payload.				

TEST CENTER APPROVAL

20\. NAME ORGANIZATION DATE

21\. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22\. NAME ORGANIZATION DATE

ARDC FORM 1 JUL 58 105 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

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1\.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2\. REPORTS CONTROL SYMBOL

PAGE 5 OF 7 PAGES

3\. DATE

4\. TITLE Subsystem F - ELECTRONIC RECONNAISSANCE

5\. INITIAL ☒ CHANGE

6\. NUMBER

7\. RESP CENTER

8\. PROJECT OFFICER

9\. SUPPORTS (Sys or Proj)

10\. CONTRACTOR

11\. CONTR NR

12\. PRIORITY AND PREC

13\. SECURITY

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RDD TEST COMPL DATE
27	Surveillance Ferret Recon System (Model I - Mod. 1)	Third OTV Flight Test	GFF*	Feb 1963	**
28	Pioneer Ferret Recon Payload	Tests in Captive Test Vehicle	LAC MSD Sunnyvale	Aug 1957	Oct 1957
29	Pioneer Ferret Recon Payload	Compatibility Test with Nuclear APU	LAC MSD Sunnyvale	Sep 1957	Dec 1957
30	Radar Side Lobe Test	Test of Side Lobe Response of Typical Radars	LAC MSD Sunnyvale	Sep 1957	Jan 1958
31	Pioneer Ferret Recon Payload Less Data Recording	Flight Test in Manned Aircraft	LAC MSD Sunnyvale	Sep 1957	Jan 1958
32	Pioneer Ferret Recon Payload (Model 1)	Flight Tests in Manned Aircraft of Complete Pioneer Ferret Recon Payload	LAC MSD Sunnyvale	Feb 1958	Apr 1958

* To be determined at a later date.

** For useful life of vehicle and payload.

TEST CENTER APPROVAL

20\. NAME ORGANIZATION DATE

21\. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22\. NAME ORGANIZATION DATE

ARDC FORM 105 1 JUL 55 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

1.

R & D TEST ANNEX

☐ STEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 6 OF 7 PAGES

3. DATE

4. TITLE Subsystem F - ELECTRONIC RECONNAISSANCE

5. INITIAL ☒ CHANGE

6. NUMBER

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj)

10. CONTRACTOR

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RDD TEST COMPL DATE
33	Pioneer Ferret Recon Payload (Model I - Mod. 1)	Flight Tests in Manned Aircraft	LAC MSD Sunnyva e	Jul 1958	Oct 1958
34	Pioneer Ferret Recon Payload (Model I - Mod. 2)	Flight Test in Manned Aircraft	LAC MSD Sunnyvale	Jan 1959	Mar 1959
35	Pioneer Ferret Recon Payload (Model I - Mod. 3)	Checkout Flight Test in Manned Aircraft	LAC MSD Sunnyvale	Feb 1960	Mar 1960
36	Advanced Ferret Recon Payload	Environmental Test in Captive Test Vehicle	LAC MSD Sunnyvale	May 1959	Jul 1959
37	Advanced Ferret Recon Payload	Compatibility Test with Nuclear APU	LAC MSD Sunnyvale	Jul 1959	Oct 1959
38	Advanced Ferret Recon Payload (Model I)	Flight Test in Manned Aircraft	LAC MSD Sunnyvale	Aug 1959	Jan 1960

TEST CENTER APPROVAL

20. NAME ORGANIZATION DATE

21. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

ARDC FORM 1 JUL 55 105 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 7 OF 7 PAGES

3. DATE

4. TITLE Subsystem F - ELECTRONIC RECONNAISSANCE

5. INITIAL ☒ CHANGE

6. NUMBER

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj)

10. CONTRACTOR

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
39	Advanced Ferret Recon Payload (Model I - Mod. I)	Checkout in Flight Test Prior to First PTV Flight	LAC MSD Sunnyvale	May 1960	Jul 1960
40.	Advanced Ferret Recon Payload (Model I - Mod. I)	Checkout in Flight Test Prior to First OTV Flight Test	LAC MSD Sunnyvale	Sep 1960	Nov 1960
41	Surveillance Ferret Recon Payload	Environmental Test in Captive Test Vehicle	LAC MSD Sunnyvale	Dec 1960	Mar 1961
42	Surveillance Ferret Recon Payload	Compatibility Test with Nuclear APU	LAC MSD Sunnyvale	Jan 1961	Apr 1961
43	Surveillance Ferret Recon Payload	Flight Test in Manned Aircraft	LAC MSD Sunnyvale	Mar 1961	Jun 1961
44	Surveillance Ferret Recon Payload (Model I - Mod. I)	Checkout in Manned Flight Test Prior to First OTV Test	LAC MSD Sunnyvale	May 1962	Jun 1962

TEST CENTER APPROVAL

20. NAME ORGANIZATION DATE

21. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

ARDC FORM 1 JUL 56 185 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

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MSD 1536

1.

R & D TEST AND TEST SUPPORT AIRCRAFT ANNEX

☐ SYSTEM ☐ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 1 PAGES

3. DATE 1 Mar 56

4. TITLE Subsystem F - ELECTRONIC RECONNAISSANCE

5. INITIAL ☒ CHANGE

6. NUMBER

7. ITEM NUMBER	8. AIRCRAFT REQUIRED QTY	TYPE, MODEL AND SERIES	SERIAL NUMBER	9. ASG CODE	10. [illegible]	11. DATE REQD AND LOCATION	12. ESTIMATED RELEASE DATE	13. RECOMMENDED DISPOSITION	14. [illegible]	15. [illegible]
1	1	B-50								
2	1	Doman Helicopter			*	Aug. 1956 Sunnyvale Calif.	Jan. 1957		500	

* Aircraft for Electronics Reconnaissance is same as that requested in Subsystem H.

** The extent of modification required is not known now, but will be indicated in the bailment agreement.

ARDC FORM 1 JUL 55 186 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

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1\.

R & D MATERIEL ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2\. REPORTS CONTROL SYMBOL

PAGE 1 OF 1 PAGES

3\. DATE 1 March 1956

4\. TITLE Subsystem F - ELECTRONIC RECONNAISSANCE

5\. INITIAL ☒ CHANGE

6\. NUMBER

7\. MATERIEL REQUIREMENTS (Indicate Items in Columnar Form using Columns as cited in Examples)

R and D requirements are listed as part of Tab 5 - Subsystem J - Vehicle Intercept and Control Ground Station.

Other specialized equipment will be listed at a later date.

ARDC FORM 1 JUL 55 107 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

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SUBSYSTEM F - ELECTRONIC RECONNAISSANCE

DATE 1 March 1956

SYSTEM TEST FACILITY *
ITEM: AFMTC *
INTERCEPT, CONTROL AND DATA ACQUISITION STATION *
USING AGENCY: LOCKHEED MSD, CBS LABORATORIES, EASTMAN KODAK CO.

LOCATION:
BUDGET CONTROL ESTIMATE:
NEED DATE:

SCHEDULE:

1956						1957												1958												1959											
J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D

DESCRIPTION AND UTILIZATION:

* Complete description of these facilities are given in Tab 6 - Subsystem L - Vehicle Ground Support

REMARKS:

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Tab 7

R & D Contract Funds

Subsystem F - Electronic Reconnaissance

Subsystem F. ELECTRONIC RECONNAISSANCE

Tab 7. R & D Contract Funds (in thousands of dollars).

	FY 57				FY 58				FY 59				FY 60	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
LAC														
(1) Research and Engineering	10	20	26	32	42	42	46	46	41	56	70	85	105	125
CBS	131	151	172	212	267	331	308	467	547	657	772	876	902	942
Sub Total	141	172	198	244	309	373	354	513	588	713	842	959	1007	1065
Fee	14	17	20	24	31	37	35	51	53	71	84	96	101	107
TOTAL*	155	189	217	268	340	411	390	564	647	785	926	1055	1107	1173
Total Fiscal Year				829				1705				3413		

*Difference in totals due to rounding

F-Tab 7, p 2

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Subsystem F. ELECTRONIC RECONNAISSANCE

Tab 7. R & D Contract Funds (in thousands of dollars) (Cont'd)

	FY 60				FY 61				FY 62				FY 63		
LAC	15	16	17	18	19	20	21	22	23	24	25	26	27		TOTALS
(1) Research and Engineering	155	170	170	180	190	210	215	215	216	141	116	91	106		2,879
CPS	924	859	747	560	714	1007	1227	1309	1309	1029	867	662	492		18,440
Sub Total	1079	1029	917	739	904	1217	1442	1524	1526	1170	983	753	598		21,320
Fee	108	103	92	74	90	122	144	152	153	117	98	75	96		2,132
TOTALS*	1187	1132	1009	813	995	1338	1586	1676	1678	1287	1081	828	694		23,452
Total Fiscal Year		4539			4155				6828			2523			23,452

*Difference in Totals due to rounding

Tab 8

Estimate of Manpower Requirements

Subsystem F - Electronic Reconnaissance

Subsystem F. ELECTRONIC RECONNAISSANCE

Tab 5. Estimate of Manpower Requirements

WORK ITEM	Type of Manpower	QUARTERS													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
LAC - Research and Development	1-2-3*	2	4	5	6	8	8	9	9	8	11	14	17	21	25
LAC - Fabrication and Assembly (Airframe)	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub Total		2	4	5	6	8	8	9	9	8	11	14	17	21	25
CBS - Scientific and Engineering	1	8	9	10	12	14	17	19	24	27	31	35	40	39	41
CPS - Engineering Support	2	13	16	19	23	29	36	25	48	52	61	71	80	81	83
CBS - Manufacturing	4	4	4	4	6	6	8	11	14	17	24	31	32	41	44
Sub Total		25	29	33	41	49	61	55	86	96	116	137	152	161	168
Total		27	33	38	47	57	69	64	95	104	127	151	172	182	193
*Average:															
40% Type 1 Scientific & Technical															
50% Type 2 Engineering Support															
10% Type 3 Management & Administration															

Subsystem F - ELECTRONIC RECONNAISSANCE

Tab 8. Estimate of Manpower Requirements (Cont'd)

WORK ITEM	Type of Manpower	QUARTERS 15	16	17	18	19	20	21	22	23	24	25	26	27	28	Total Man Quarters
LAC - Research and Development	1-2-3 *	31	34	34	36	38	42	43	43	43	28	23	18	13	573	573
LAC - Fabrication and Assembly (Airframe)	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Sub-Total		31	34	34	36	38	42	43	43	43	28	23	18	13	573	573
CBS - Scientific & Engineering	1	40	36	31	22	30	45	55	60	60	48	41	31	23	848	848
CBS - Engineering Support	2	80	74	63	46	61	89	113	120	120	97	81	62	47	1690	1690
CBS - Manufacturing	4	45	44	40	33	37	45	50	52	52	37	31	24	17	756	756
Sub-Total		165	154	134	101	128	179	218	232	232	182	153	117	87	3294	3294
Total		196	188	168	137	166	221	261	275	275	210	176	135	100	3867	3867

* Average:

40% Type 1 Scientific & Technical

50% Type 2 Engineering Support

10% Type 3 Management & Administration

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Pied Piper

MSD 1536

LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION

APPENDIX

~~SECRET~~

SUBSYSTEM F

ELECTRONIC RECONNAISSANCE

APPENDIX

1. INTRODUCTION

1.1 General

The primary purpose of the Pied Piper ferret reconnaissance mission is to carry the intercept equipment over the interior of the USSR and the satellite countries for mapping of the electromagnetic activity in that area. Since this data is required at the earliest possible time, the electronic design will rely on present state-of-art components, while keeping in mind vehicle limitations on size, weight, and period of operation.

Because of the maze of electronic signals to be expected, a reconnaissance mission will be composed of several information flights, each capable of contributing information to the mapping problem. Initial missions will supply a priori information for subsequent special purpose flights, so as to require the minimum number of ferret flights.

It has been estimated that 75 to 90 percent of the intercepted radars can be identified with four equipment parameters. These are:

1. Frequency
2. PRF
3. Pulse width
4. Direction of signal relative to vehicle.

While increased accuracy can be obtained by determining such radar parameters as signal level, antenna scan, and polarization, these characteristics and other possible ones can be obtained only with the aid of more complex equipment. The additional space, weight, and power requirements will place too high a load on the early vehicles.

1.2 Pioneer Reconnaissance

The crystal video receivers being proposed for pioneer reconnaissance have the following characteristics:

1. Continuous frequency coverage from 50 to 18,000 cps
2. -60 dbm sensitivity
3. Average channel bandwidth 25 percent of center frequency (Less in crowded frequency bands)
4. Pulse Analysis: prf measuring accuracy of 200 pps from 50 to 10,000 prf
5. Measures coarse location of radar intercepts
6. Operation against target radar antenna major radiation lobe in order to take advantage of the non-coherence of radar antenna scanning characteristics for resolution of individual signal intercepts.

Based on these characteristics, it is estimated that perhaps 50 percent of radar intercepts can be correctly identified. This capability will yield the following reconnaissance information:

1. Frequency bands in use
2. Relative importance of each frequency band (this is important for decisions in the area of electronic counter-measures and subsequent reconnaissance missions.)
3. As a corollary of (2) above, the discovery of signals in previously unused frequency bands as protection against technological surprise
4. Approximate geographic deployment of the radar network
5. Activity levels in the various frequency bands (electromagnetic activity is a very useful indicator of military buildup, preparedness, and industrial capability and of the size of forces in being)
6. Changes in deployment or signal activity (this intelligence is very important for the evaluation of possible enemy intent, military and industrial build-up, and the military state of readiness)
7. Electromagnetic activities in new areas for the discovery of enemy interest.

1.3 Advanced Reconnaissance

The frequency scanning superheterodyne receivers which will be used for advanced reconnaissance have much greater frequency resolving power than the simple receivers used for pioneer missions. These receivers as presently conceived will use present state-of-the-art components. They achieve a greater analysis capability and, based on the following characteristics, can achieve approximately 75 to 90 percent correct classification of radar intercepts:

1. Frequency coverage from 50 to 30,000 mc
2. Sensitivity of -85 to -90 dbm
3. Frequency measurement accuracy of 1 to 2 percent
4. Pulse analysis: prf accuracy of 1 percent at 10,000 pps and 25 percent at 50 pps; pulse width accuracy of 20 percent
5. Due to the increased sensitivity of these receivers, they can detect the side and back radiation of most strategically important radars and, as presently conceived, may operate with the ferret antennas pointed at the nadir; (if used with the same ferret antennas as the pioneer receivers the advanced reconnaissance will permit better resolution of radar intercepts)
6. Better than 1 percent frequency resolution of radar intercepts.

Based on these characteristics, the advance reconnaissance receivers will yield the following intelligence information:

(a) An accurate count of specific radars or radar types. (This implies a statistical distribution with respect to the number of passes by the satellite over the same area.)

(b) Location and identification of radar types within the specified signal parameter ranges with an accuracy of approximately 75 to 90 per cent.

(c) More accurate location and geographical distribution of the specific radar equipments.

(d) As implied by the above performance, signal activity per frequency band.

(e) Accurate radar signal data analysis for ECM and technological evaluations and as a measure of military electronic progress and capability. At the low frequency end of the range, the physical limitations to the size of the antennas result in relatively broad-beamed patterns. In special reconnaissance missions at these frequencies, direction sensing will be accomplished by means of lobe comparison techniques.

The advanced reconnaissance capabilities, superimposed on the pioneer data gathering ability, will therefore yield a more fine-grained picture of the activity level, frequencies, and deployment of the radar network. In addition, this system has sufficient resolving power to detect and classify a larger number of strategic targets, such as weapons systems and strategic air bases, by correctly identifying the associated radar system emissions.

1.4 Direction Sensing Advanced Reconnaissance

During the advanced reconnaissance phase of Pied Piper, the accurate location of strategic targets will be of great importance to the U.S. Military Establishment; this will be accomplished by phase-comparison, direction-sensing receivers which will use four antennas capable of determining the direction of intercepted signals with good accuracy on a pulse-to-pulse basis. With the combined frequency, directive resolution, and prf and pulse width analysis capability of these receivers, strategically important radar signals can be properly classified and the deployment of the radars may be determined.

1.5 Special Purpose, or Restricted Data, Advanced Reconnaissance

Based on a priori acquisition of certain intelligence data, e.g., from pioneer reconnaissance, special purpose receivers can be designed which will contribute a large capability to the data gathering process. These receivers will evolve from, and be modifications of, primary intelligence and direction finding advanced reconnaissance receivers with restricted range of signal intercept parameters. These will be simple ferret receivers with "yes or no" analyzers to seek out and identify specific radar types and to determine their location with great accuracy and high intercept probability. These missions may include flights for the purpose of detailed analysis of signals in a restricted frequency range to evaluate enemy industrial and military progress and weapons system capability. They may also include reconnaissance of c-w emissions from doppler radars and navigational systems.

1.6 Complete Frequency Coverage

During all phases of satellite reconnaissance, special purpose receivers with "fine tuning" in certain important frequency bands may be substituted. The crystal video receivers will "fill the gaps" and permit a complete frequency coverage capability on early flights. Direction or c-w reconnaissance equipments may be flown together with simple superheterodyne or crystal video "gap fillers" in order to continue a complete surveillance capability in advanced missions.

1.7 Microwave Surveillance

As a synthesis of the microwave network emerges from the various ferret reconnaissance missions, any changes in the network will yield the most important indications of enemy build-up and intent. Therefore, a complete surveillance capability will be required to monitor these changes. At this time considerable vehicle capability can be assumed, and it will be possible to include in the reconnaissance equipment the flexibility and ability to program required for this function. This phase of satellite ferret reconnaissance will require a recognition capacity in the analysis circuits for special c-w, f-m, or pulse coded signals, video data storage, and wide data transmission bandwidth. The frequency bands, analysis capability, and data handling will be programmed from the satellite control station.

1.8 Present Knowledge of Russian Radar Environment

The reports containing data on Russian radars at the disposal of this group are somewhat incomplete and perhaps out-dated. A brief tabulation of the important characteristics of several Russian radar equipments, obtained from recent reports (Refs. 1 and 2), are shown in Table 1-1.

Table 1-2 contains a list of radar functions and the frequencies of equipment operation obtained from these earlier sources. The most significant observation to be made in comparing this and the more recent data is the addition of a large number of X-band radars in the few intervening years.

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2. CRYSTAL-VIDEO PIONEER RECONNAISSANCE

2.1 General Description

A description and block diagram of a ferret system consisting of 26 crystal-video receivers is given in Appendix F of Ref. 3. This system will provide frequency quantization of radar intercepts from 50 to 18,000 mcs and provide a continuous indication of the number of pulses received in each frequency channel. From this, the prf of each radar intercept and, in most cases, the number of radars at the channel frequency can be determined. Fixed receiving antennas are employed. The approximate geographical location of each intercept is provided by navigational (clock) data.

This system is receptive 97 per cent of the time to any pulsed signal in its broad frequency band. Because of this wide-open feature, there exists a high probability of intercepting any signal. Increased atmospheric absorption, free-space transmission losses, and the unavailability of suitably broad-band r-f amplifiers limit the range of the system to 18,000 mc (see Subsystem J-Appendix; Refs. 3 and 4).

The final stage in each crystal video channel is a prf data reduction circuit which generates a voltage proportional to the number of pulses received in the channel. The data reduction circuit outputs are connected to 26 segments of a 30-segment commutator; 4 segments are used for synchronization, calibration, and timing. The commutator cycle is 1/30 second. During 32 milliseconds the prf data is recorded in each memory circuit; in the remaining millisecond, the data is read-out, and the prf detector re-set. The commutator rotor is connected to the recording circuits, and the data is stored on magnetic tape for future retransmission to a satellite control station.

The rapid commutation of data permits the resolution of events, such as multiple intercepts, for any interval greater than 1/30 second and reduces the probability of confusion when successive radars illuminate the vehicle.

The crystal-video receivers are designed to operate against the major lobes of target radars and, therefore, have their antennas oriented towards the satellite's horizon. Due to the noncoherence of target radar antenna scanning patterns, radars in the same frequency band will usually illuminate the satellite at different times, even though they are within the area aperture of the ferret antenna at the same time. During intervals where there are multiple intercepts, the combined prf's are recorded. In some instances, signals will be received for several successive cycles of the commutator, and radar beamwidths or scanning patterns may then be determined by proper data interpretation at the satellite control station.

The programmer, which receives commands and is re-set by the Command Receiver, turns off the ferret receiver-recorder when the satellite is over neutral or friendly territory and initiates the playback and data transmission when the satellite is in contact with a control station.

2.2 Operation

2.2.1 Antennas

Ferret antennas will be of three types. Between 2 and 18 kmc, they will be parabolic reflectors with helical feeds, selected for inherently large bandwidth and circular polarization. Each antenna will be designed to operate over at least one-half to one octave (the lesser bandwidth applying to the highest frequency range), with an effort to extend this performance to as much as two or more octaves. Circular polarization permits the reception of any linearly polarized signal with equal efficiency. It also permits reception of circularly polarized signals with one rotation; succeeding missions can have antennas polarized in the opposite rotation. These antennas are designed to have approximately 30 db gain.

Between 200 and 2000 mc, the antennas will be helices having approximately 10 db gain. Each antenna will have at least one octave bandwidth and will not exceed 3 feet in axial length. The size, which governs possible gain, is determined by practicable space limitations on the early vehicles.

In the 50 to 200 mc band, helical antennas have diameters which are approximately the diameter of the satellite and cannot be used for this reason. Crossed dipoles which are fed in time quadrature also cannot be used over this broad frequency range to obtain circular polarization. This leaves two possible solutions: (1) separate antennas for each polarization or (2) a single antenna oriented at 45 degrees to the vertical direction. The solution requiring two antennas also requires individual receiver front-ends. Based primarily on the available antenna space, it is proposed to use a single antenna at 45 degrees to the vertical direction, and to rotate the polarization 90 degrees from this direction on alternate missions. In this way signals whose polarization is normal to the 45-degree orientation of the antenna will be received during the alternate mission.

The 4 to 1 bandwidth will be accomplished using a biconical dipole.

2.2.2 R-F Preamplifiers (see Ref. 4)

The receivers must detect signals at the ferret antenna terminals which are of the order of 60 db below one milliwatt (see Table 2-1). With crystal video receivers, this requires at least 20 db r-f preamplification ahead of the crystal detector unit. In the higher frequency regions, this performance may be achieved using broadband traveling wave amplifiers which can operate over a band of frequencies approaching or exceeding one octave. The noise figures of currently available broadband forward wave tubes with 20 to 30 db gain is usually better than 20 db*; the over-all receiver noise will therefore be due entirely to the crystal video circuits. Thus, for a typical crystal video receiver with TWT r-f preamplifier having the following characteristics:

---

* Tubes have been built with noise figures of 10-14 db over the entire band of 2-4 kmc. Low current tubes (1-3 ma) which operate over the full octave bandwidths required by these receivers, can be expected to exhibit these low noise figures (See Sec. 3 of this Appendix)

Video bandwidth = 2 mc

R-F gain = 25 db

Noise figure of TWT = 20 db

we have:

Input Noise Power = 20 db - 204 dbw/cycle + 63 db cycles

= -121 dbw

Noise power at TWT output = -96 dbw

Attenuation of RF Coupling Networks & Filters = 5 db

TWT Noise power at Crystal detector = -91 dbw

= -61 dbm

Since the noise power due to the detector-first grid referred to the detector is usually -45 to -50 dbm, the TWT noise makes a negligible contribution to the total receiver noise. Hence the receiver sensitivity with r-f preamplification is increased in direct proportion to the r-f gain.

Table 2-1. Ferret Signal Level for Typical USSR Radars for Crystal-Video Receiver (5° ferret antenna)

Radar	Ferret Signal Level (-dbm)
SCR-584	
Whiff	41 to 58
SCR-682	43 to 60
L-band Types III, IV, V	40 to 65
Type VII	42 to 44
Token	35 to 40
Type X	22 to 28
Type VIII	47 to 49
	46 to 48

In the lower frequency regions, broadband r-f amplification is possible using distributed amplifiers. It seems advantageous, however, to consider using conventional amplifier circuits in each channel in preference to a wideband amplifier ahead of the r-f couplers. Amplifiers having low noise figures, such as cascode or triode circuits, are commonly used for this application.

2.2.3 Antenna Coupling Networks

To drive several channels from a common antenna, it is required to couple the channel filters to the antenna. As is well known, one of the problems is to match the combined filter impedance to the antenna. The following two paragraphs describe how this will be done in the frequency regions below and above 600 mc.

It is felt that the best approach for coupling at frequencies below 600 mc will be to isolate each filter by using a buffer amplifier in each channel. Since considerable r-f gain is required, it becomes advantageous to isolate each filter by means of grounded grid amplifiers common-coupled to the ferret antenna.

Filters between 600 mc and X-band may be achieved in several ways. Those whose input impedance is equal to their characteristic impedance in their passband and is low in their stop-band may be connected in series. Filters may be connected in parallel when their input impedance is high in their stop-band. The realization of these configurations can be achieved in waveguide, coaxial, or strip transmission lines in the frequency region involved, and the solution is neither new nor unique.

Above 11.5 kmc, it is presently expected to feed each channel from its own antenna, and therefore there is no coupling problem.

2.2.4 Bandpass Filters

A system of filters, covering the spectrum from 50 to 18,000 mc is required to analyze intercepted signals. Twenty-six adjacent-frequency filters having bandwidths of 25 per cent would obtain their inputs from 8 ferret antennas. The filter configuration is selected on the basis of realizability and suitability in each of the frequency regions involved in this system. The filter synthesis will be accomplished using established synthesis procedures which result in "maximally flat" selectivities, such as Butterworth filters. Approximately six resonant elements will be required for these filters to have the required bandwidth characteristics.

Capacitive coupled bandpass filters have been synthesized in frequency region below 600 mc for bandwidths of 10 per cent using a design procedure which is based on uniform recurrent ladder structures employing printed circuit techniques. It is expected that the same procedure will be used to synthesize the filters required by this system.

The frequency region from 600 mc to S band is borderline for both lumped-constant and distributed-constant techniques. Capacity-coupled cavity type filters may be realized using strip transmission lines. Since the filter may be several feet long at 600 mc, it will be necessary to fold it back on itself at least once at this frequency. An adequate solution may be accomplished using strip transmission lines.

The filters may be of the direct coupled cavity type for frequencies above S band, or quarter wave coupled resonant element type in either coaxial line waveguide or ridged waveguide, depending on frequencies. Also, cascade low pass and high pass filters may be used in the microwave region. Cursory investigation of actual filter designs indicates that the required characteristics can be realized in reasonably sized packages.

2.2.5 Crystal Video Detectors

The realization of matched detector mounts is relatively simple below 600 mc because the reactive components of the crystal impedance are negligible. Therefore, the detector mount devolves to a device which simply holds the crystal. In such case, impedance matching, if necessary at all, can be readily achieved with tuned circuits having low loaded Q's.

Above 600 mc suitable detectors may be designed in coaxial or waveguide structures. A coaxial mount (Fig. 2-1) has been designed using a 1N21B crystal which has a minimum sensitivity of -45 dbm over the frequency range from 500 to 4000 mc; it appears likely that a scaled version using a 1N286 crystal will be satisfactory up to 8 kmc. The Sylvania type 1N286 crystal which has an input impedance of 65 ohms up to a frequency of 22 kmc may be used in the detector to give suitable VSWR's and return losses. The shorted transmission line L, in shunt with the crystal, is used to improve the input impedance match and provide a return path for the detector signal (see Fig. 2-1).

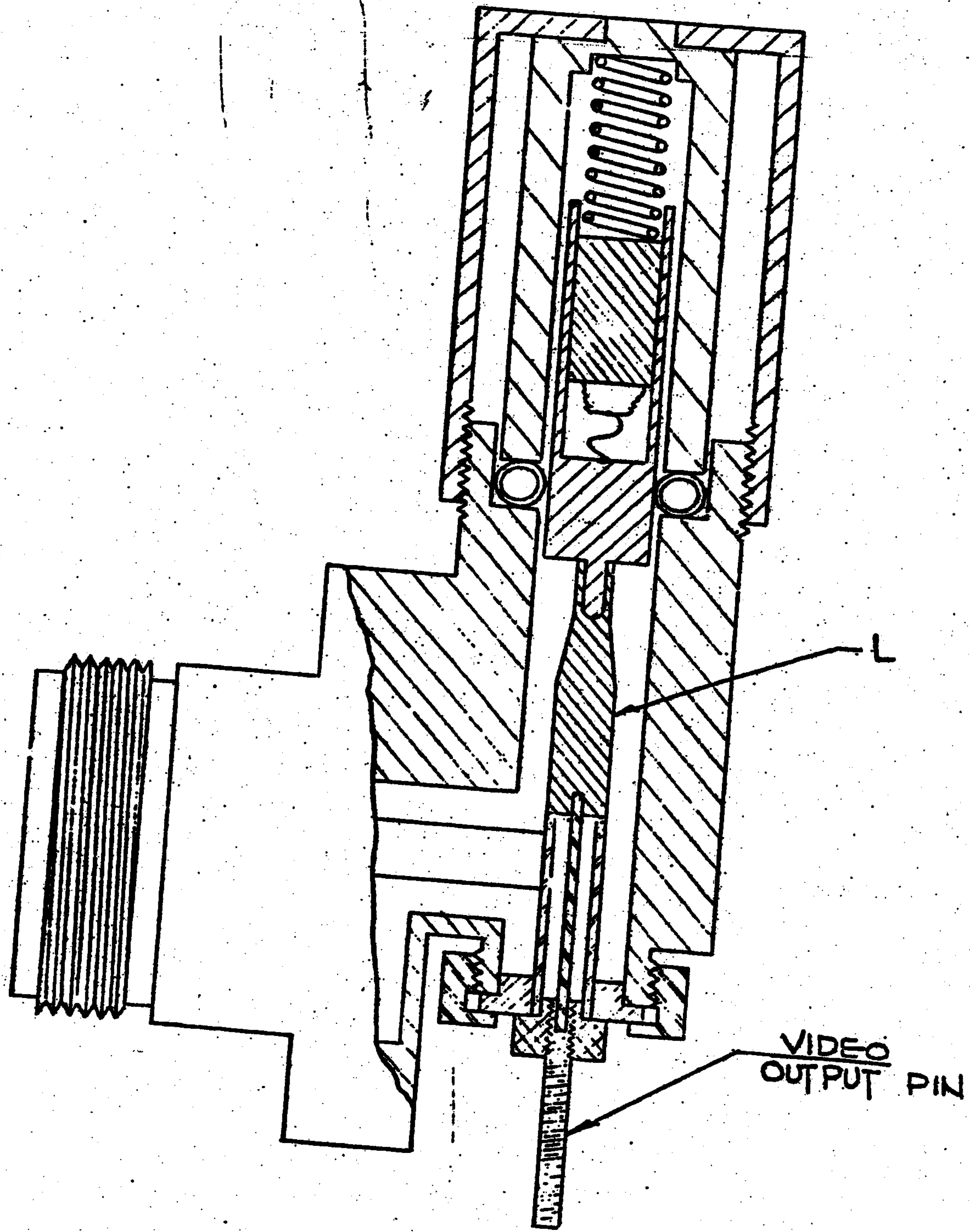

Fig. 2-1 Broadband Detector Assembly

In this frequency range, detectors can also be achieved in coaxial feed-through configurations. Above approximately 8000 mc, waveguide or ridged waveguide mounts are easily realizable with the required bandwidths. In these cases, it is customary to mount the crystal across the guide parallel to the electric field.

2.2.6 Video Amplifiers

In order to obtain the expected performance for the crystal video ferret receivers, the crystal detector-video amplifier circuits must be designed to exhibit the following characteristics:

Sensitivity. The required receiver sensitivity at the antenna terminals is -60 dbm. If we allow for a reasonable S/N ratio, with the insertion attenuation of the antenna coupling networks and band-pass filters, the sensitivity should be a minimum of -45 dbm measured at the input to the detector.

Rise Time. The rise time should be adequate to detect pulses as narrow as 0.2 microseconds.

Recovery. The amplifier should recover rapidly for any pulse. This can be accomplished in a uni-polar amplifier by using direct coupled pairs.

Bandwidth. To establish the bandwidth, it is necessary to consider the narrowest pulse to which the receiver must respond. If this is 0.2 microsecond, the rise time of the receiver must be 0.1 microsecond. Therefore,

$$\Delta f = \frac{.35}{\tau} = 3.5 \text{ mc}$$

Input Circuit. For the amplifier to have an over-all rise time of 0.1 microsecond, the input circuit must have a rise time of 0.04 microsecond. The input loading required is

$$R = \frac{\tau}{2.2c} = \frac{.04 \times 10^{-6}}{2.2 \times 15 \times 10^{-12}} = 1200\,\Omega$$

where C is the capacity of the first stage $\approx$ 15 micromicrofarads.

The use of electronic feedback (plate to grid) in the first stage to provide the proper loading improves the noise figure of the input circuit and may be obtained at a small loss in over-all gain.

Sensitivity. The sensitivity can be determined by considering the noise power at the output of the crystal. The crystal video resistance is approximately 20,000 ohms, while the input noise resistance of the first stage may be 1000 ohms or less for a triode and a few thousand for a pentode. Therefore, the noise voltage will be

$$V_{n} = \sqrt{4KTRB} \approx \sqrt{4 \times 1.37 \times 10^{-23} \times 300 \times 2.1 \times 10^{4} \times 3.5 \times 10^{6}} = 34\mu v$$

The minimum detectable power is given by

$$P_{min} = \left|\frac{S}{N}\right|_{volt.} \times \frac{\sqrt{4KTB}}{\text{CRYSTAL FIGURE OF MERIT}} = .5 \times 10^{-8}\,w$$

$$= -53 \text{ dbm}$$

Actually this value would be difficult to achieve due to decreased figure of merit and return loss from the detector. The latter may be minimized, however, by applying 1/100 to 1/10 ma bias to the crystal; sensitivities approaching this figure have actually been accomplished at S-band.

Gain. Since a minimum of 2 volts is required to trigger a blocking oscillator or establish a gate, the gain required will be, for small signals:

$$\text{Gain} = \frac{2}{35 \times 10^{-6}} = 95 \text{ db}$$

The required gain can be accomplished with 4 direct coupled triode pairs or five pentode stages.

2.2.7 PRF Trigger Circuit

The prf trigger circuit is the final stage in each crystal video channel. Video pulses appearing at the video amplifier output, which are at least 6 db above crest noise, are used to trigger a blocking oscillator. The blocking oscillator output pulses are used to feed the input of the data reduction equipment, described in Sec. 4.

3. ADVANCED RECONNAISSANCE SUPERHETERODYNE RECEIVERS

3.1 General Description

The system construction which follows is based on the use of scanning superheterodyne receivers. Nine receivers are required to cover the frequency range from 50 - 30,000 mc in bands which are approximately one octave wide; each has a basic capability of determining signal location, prf (+25 per cent at 50 pps), pulse width (+20 per cent), and frequency (+1 per cent). Lobe comparison techniques (and small antennas) for advanced reconnaissance are used in the low frequency region to ensure more accurate directional sensing than can be achieved with a single antenna. The receivers will have sufficient sensitivity to detect radar side lobes; the antennas may be pointed at the nadir to obtain the greatest directive resolution and accuracy.

3.2 Restricted Data Missions

The advanced reconnaissance receivers can have a variety of useful forms which are a modification of the basic construction; these will be decided on during the pioneer phase of satellite reconnaissance. At that time, the acquisition of certain intelligence data can be assumed; therefore, relatively simple ferret receivers can be used, e.g., those which sweep over a small band of frequencies and seek out and identify weapons systems. A direction finding system can then be used to locate the direction of the signal. "Yes or No" analyzers, such as frequency and pulse decoders, which accept or reject signals that do or do not fit a preset pattern of signal characteristics, can be used.

It has been pointed out that the initiation of this type of system naturally depends on some knowledge of the environment. For example, when the frequency bands of greatest importance are known, special receivers can be designated to seek out only signals in these bands. In other words, a restricted data mission need not analyze those signals which are not of interest and slow down the data gathering process.

It is felt that these "restricted data" missions will be evolved from the basic receivers which will scan over a frequency band of one octave and contribute a large capability to the data gathering process. More detailed data analysis or the application of "Yes or No" analysis techniques do not require a redefinition of the analysis problem, and neither do they alter the basic philosophy of the advanced reconnaissance mission. A description of the basic scanning receiver follows:

3.3 Design Criteria

The following discussion is based on looking at the radar side lobes while slowly scanning the receiver frequency.

The signal-to-noise ratio at the receiver is given by the one-way transmission equation. Reasonable values were assumed for L_1, L_2, and L_3 for each radar intercept, based on radar type, antenna gain beamwidth, elevation, and frequency of operation (see Table 2, Appendix F, Ref. 3). The basic receiver parameters are shown in Table 3-1. Advanced reconnaissance receivers using lobe comparison direction sensing at low frequencies will use multiple antenna configurations at these frequencies. These receivers are described in Section 3.4.3 below.

TABLE 3-1 RECEIVER PARAMETERS

F (mc)	Θ max (deg)	GR min (db)	t scan (sec)	prf (pps)	B (mc)	$\overline{NF}$ (db)	$\frac{S}{N}$ (db)	
18,000 - 30,000	11	24	7	300	6	14	6	(estim. for lg. rad.)
12,000 - 18,000	11	24	7	300	6	14	6	(estim. for lg. rad.)
8,000 - 12,000	11	24	7	200	6	14	12	
4,000 - 8,000	11	22	7	200	6	11	18	
2,000 - 4,000	11	22	7	100	6	11	24	
800 - 2,000	30	17	12	100	2	9	30	
400 - 800	60	9	30	50	2	9	36	
200 - 400	90	6	60	50	1/2	7	39	
50 - 200	120	0	120	50	1/2	5	42	

These relations are, of course, flexible and are given for intercept of radars now known to be in operation. The estimated values for $\frac{S}{N}$ are, however, given for the two highest frequency bands; this is because no data is available on Russian K-band radars. By extrapolation, however, it can be predicted that K-band radars (particularly those above 18 kmc) will be detected only under favorable circumstances.

We shall now investigate the data gathering capabilities of these receivers. First of all, it should be noted that the performance indicated in Table 3-1 is a weighted average for typical radars now known to be in operation. ~~These findings agree with~~ what one would expect. In the lower frequency regions, the expected $\frac{S}{N}$ ratio increases due to the decreased free space attenuation and also because of the decreased side lobe reduction usually found for 12 to 20 degrees radar antenna beamwidths found at these frequencies.

Second, it is implicit in this discussion that the minimum detectable prf is based on the incidence of a minimum detectable signal. For intercepts when the $\frac{S}{N}$ ratio exceeds 6 db, a greater number of pulses will be received through the "skirts" of the ferret antenna pattern. Generally, then many more than two pulses will be received in each frequency band for the prf's of known Russian radars operating in the band; this can be seen from Table 1-1, and is, of course, true because most Russian radars radiate more power and have higher prf's than was assumed in the construction of Table 3-1.

The i-f bandwidth and aperture time calculated for Table 3-1 are large enough to receive a sufficient number of pulses during the frequency scanning process. Note also that the ferret antenna beamwidth is based on simple (small) antenna configurations in the lower frequency regions. At low frequencies the aperture time (i-f bandwidth) in the receiver frequency scanning process can be reduced to the limit of the receiver's capability to respond to the pulse widths involved. Circumstances are in the designer's favor, because greater pulse widths are ordinarily used in these low frequency radars (Table 1-1).

Table 3-1 is based on pointing the ferret antennas at the nadir in order to obtain the greatest directive resolution and accuracy. The following capabilities are implicit for the receiver parameters given in Table 3-1.

Above 2000 mc the frequency and directive resolution are 6 mc and 60 miles diameter, respectively. With the expected radar densities, radar tuning bandwidths and channel spacings, reasonable resolution and identification of signal intercepts can be achieved for most radars. This is shown in Sec. 5. The process of resolving signal intercepts is also aided by the increased pulse analysis capabilities of the special purpose data processing (prf and pulse width).

In the lower frequency regions, with the decreasing directivities achievable with small antennas, (when no lobe comparison is used), the basic system capability devolves to determining with some accuracy only which frequencies are being used for radars in the USSR, China, and the satellite countries. Furthermore, multiple intercept resolution is not possible with the basic system.

Modifications to the receiver construction to overcome these limitations are discussed in succeeding sections. A description of the basic receiver follows.

3.4 Receiver Operation

3.4.1 General

A narrow band scanning receiver is shown in Fig. 3-1. This receiver used a backward wave superheterodyne converter which can

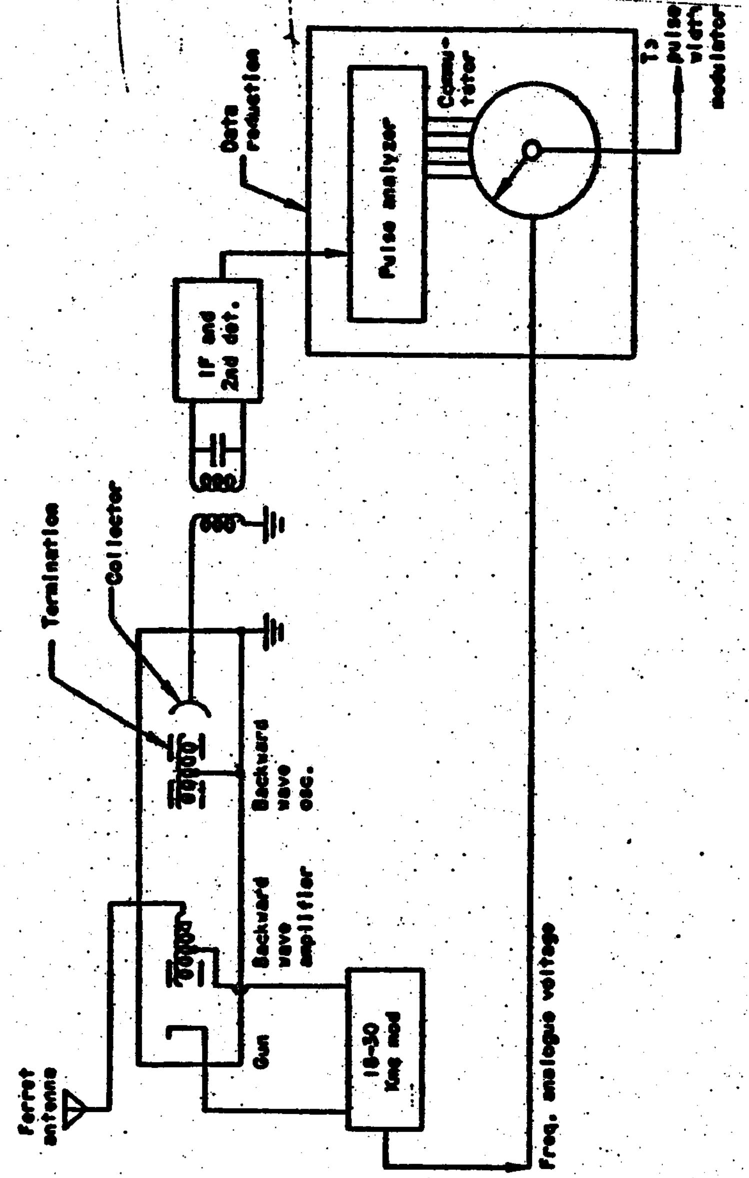

Fig. 3-1 Narrow Band Scanning Receiver

be voltage-tuned over approximately an octave in frequency. The first helix section of the tube fully modulates the electron beam. It has approximately unity gain and supplies the preselection required for image frequency rejection.

The second and longer helix sustains a backward wave oscillation, which also modulates the electron beam and results in r-f conversion over the broad frequency band of the tube. Both helices are physically similar and are easily tracked in frequency. The difference frequency is detected at the collector element, which is made part of the i-f circuit. Theoretically, a conversion gain can be realized by this tube.

Other circuits can be used which have backward wave local oscillators and, alternatively, backward wave or hardware mixers. Various traveling wave tube applications to this program are carefully analyzed in Ref. 4. In the low frequency region, the scanning receivers are conventional superheterodynes with oscillator tuning and preselection in this case being supplied by tuned cavities and the frequency quantization voltage by coupled potentiometers. In the high frequency receivers, the oscillator is voltage-tuned; a voltage proportional to the frequency of the receiver is fed to the data reduction equipment, as shown in Fig. 3-1. The output from the second detector also is fed to the data reduction circuits. The frequency quantization and pulse analysis (data reduction) are described in Sec. 4.

A block diagram of the Special Purpose System is shown in Fig. 3-2.

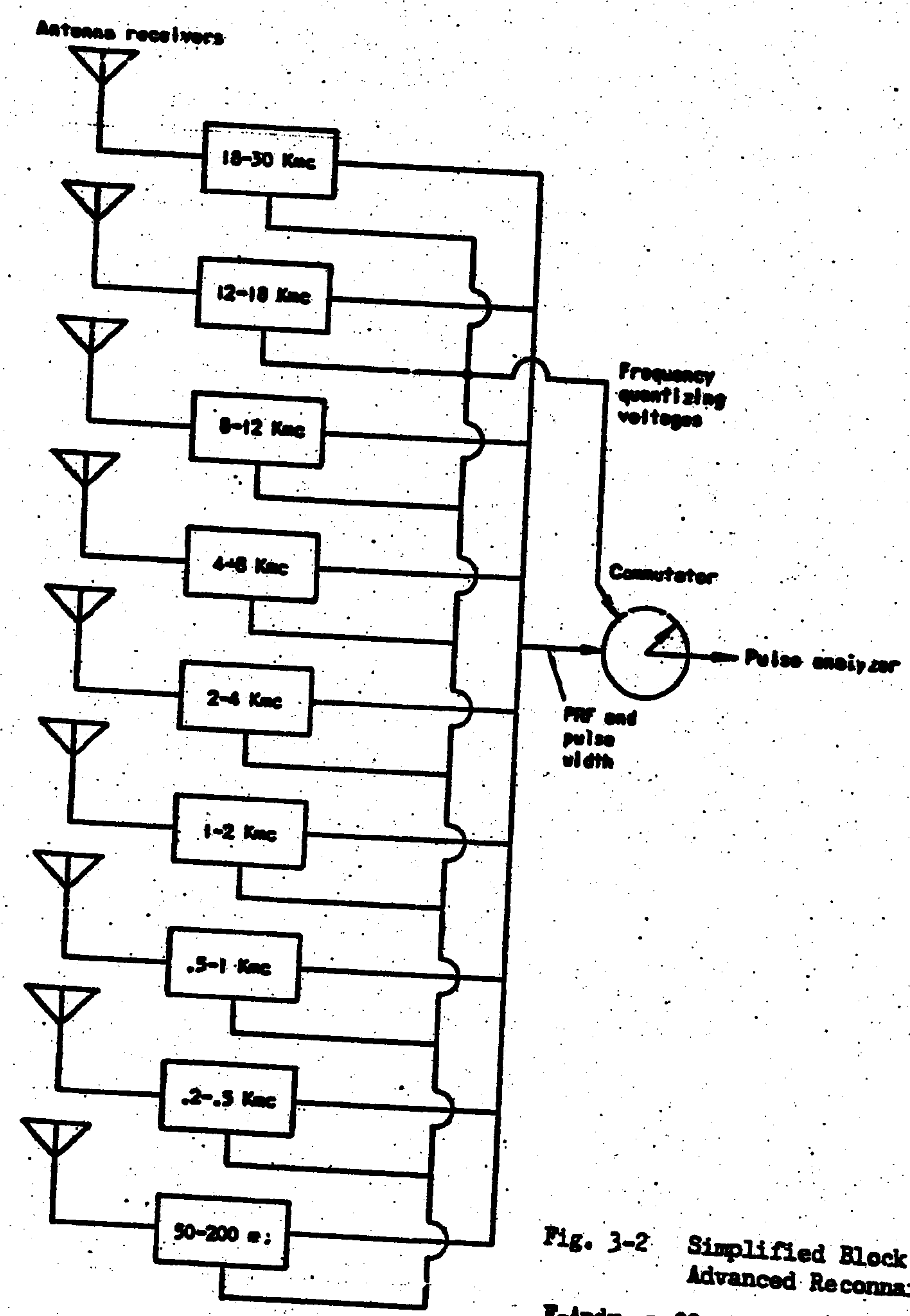

Fig. 3-2 Simplified Block Diagram of Advanced Reconnaissance System

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3.4.2 Multiple Intercept Resolution

In the higher frequency region, the area coverage (50 miles) obtainable with single antennas is small enough so that, with the frequency selectivity of these receivers, only one signal is generally received at a time. Radars clustered in a dense configuration, as for a defense weapons system, usually have channel spacings resolvable with the i-f frequency selectivity used. This means that each radar will be separately detected. When two radars are simultaneously within the radiation pattern of the ferret antenna and i-f bandpass, they generally will not overlap completely within the limitations of the pulse measurement. Therefore, they my be separated by analysis of the pulse data.

It will be shown in a succeeding section that for pulsed signals, direction can also be resolved at low frequencies using lobe comparison and nondirective antennas.

3.4.3 Direction Sensing Advanced Reconnaissance Receivers

At low frequencies it becomes impractical to produce a pencil type beam; therefore, lobe comparison techniques must be used to obtain good resolution in direction sensing. At higher frequencies, direction sensing is also required in order to resolve ferret antenna main lobe and side lobe intercept. Although lobe comparison direction finding usually allows a 180-degree directional ambiguity, this difficulty will need to be resolved in the final system design.

Direction sensing from ordinary aircraft frequently involves the determination of a single angle. Pinpointing the target is then achieved by plotting on a map each direction "cut" and finding circles of equal probability containing all the d-f cuts. Because of the magnitude of the parameters involved in direction finding from a satellite, it is questionable whether target location by this method is feasible. But if the declination and azimuth of the target are known at the moment of intercept, as well as the position of the satellite, then the target location may be determined.

The direction of a pulsed signal can be resolved using amplitude or phase comparison techniques which are well known. Direction is determined by simultaneous measurement of the azimuth and elevation angles. Usually this will require four antennas. Amplitude comparison direction sensing would be accomplished by amplifying the signals from four overlapping antennas in separate channels, and comparing the amplitudes at the output of each channel. While usable, this system places severe stability requirements on the amplifier gains, as well as the antenna gains and patterns over a large band of frequencies. For these reasons, a phase comparison is preferred; phase shift differences between the separate channels shift can be made sufficiently small, and in addition, reasonable antenna differences are not significant. A method is proposed here which may be used for direction finding with nondirective antennas. A block diagram is shown in Fig. 3-3.

In this system the four ferret antennas will be located on a quadrangle at the bottom of the vehicle and will radiate towards the nadir. The antenna patterns are not critical. Fig. 3-4(a) shows the

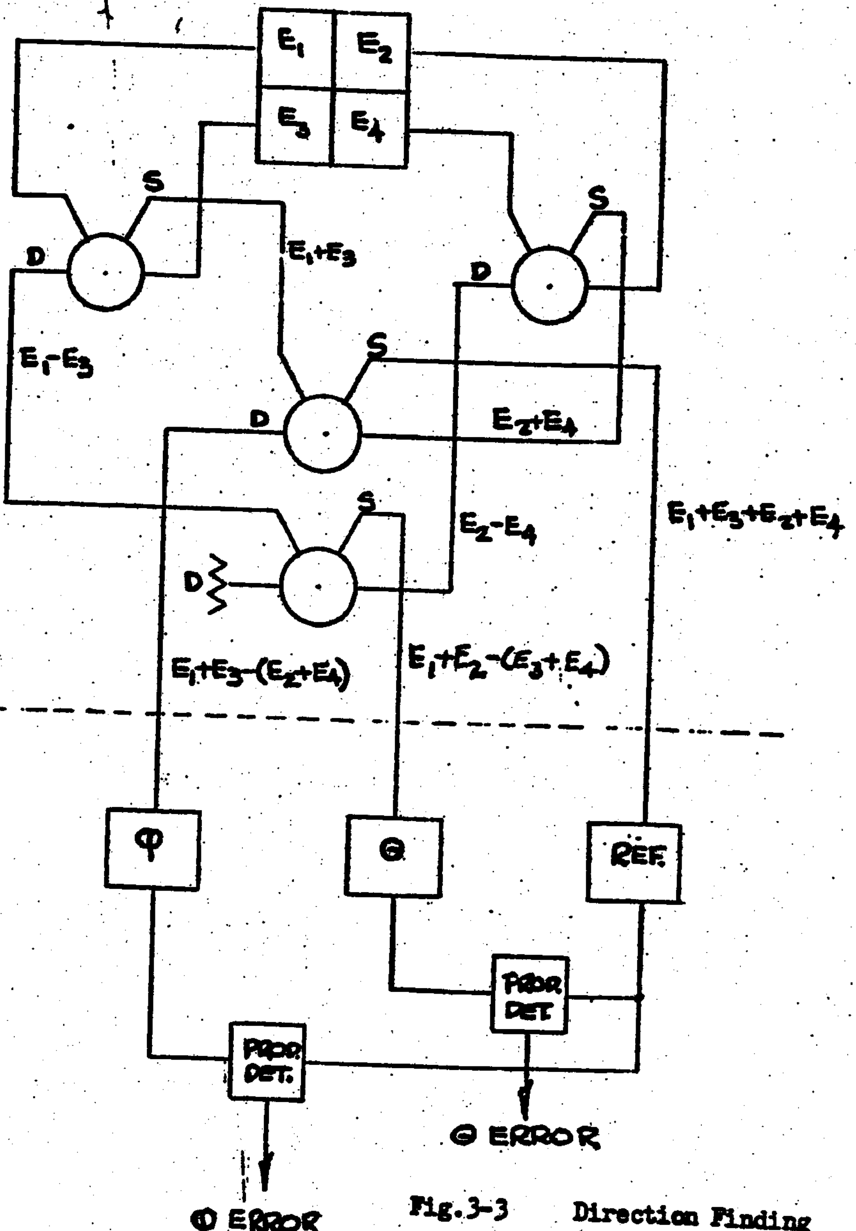

Fig.3-3 Direction Finding Advanced Reconnaissance Receivers

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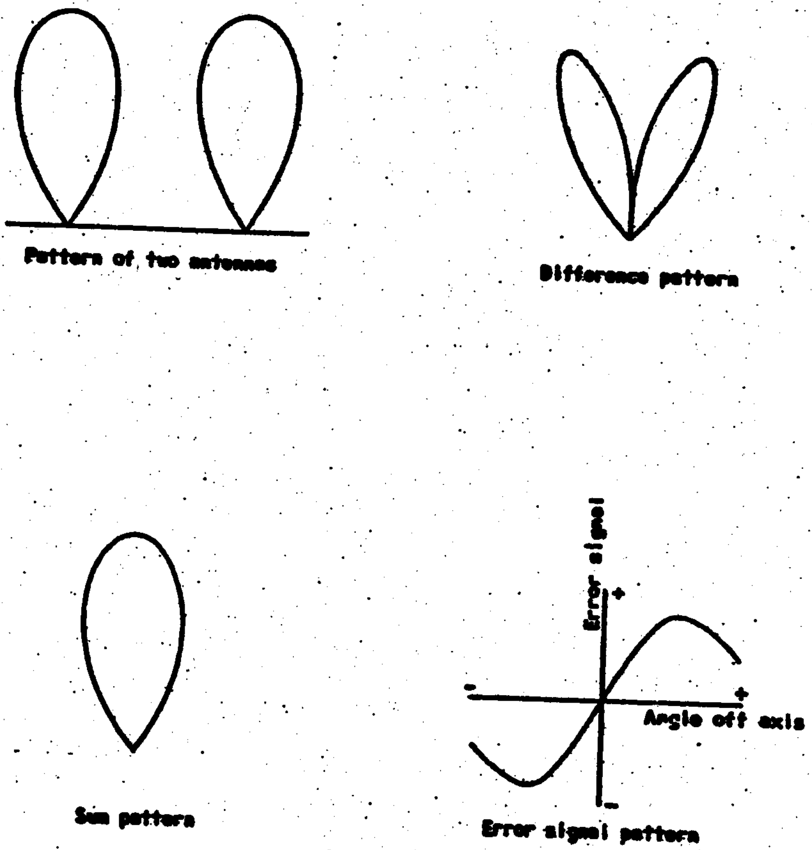

Pattern of two antennas

Difference pattern

Sum pattern

Error signal pattern

Fig. 3-4 Phase Comparison Direction Finding Patterns

patterns of the two antennas in one plane. The sum and difference and the error signal patterns for two antennas are shown in Fig. 3-4(b), (c), and (d).

When a signal is received that is not axial to the antenna configuration, the space-phase of the field incident on each antenna is different. The fields at the antennas are

$$E_1 = E_1 e^{j\psi_1}$$
$$E_2 = E_2 e^{j\psi_2}$$
$$E_3 = E_3 e^{j\psi_3}$$
$$E_4 = E_4 e^{j\psi_4}$$
$$E_1 = E_2 = E_2 = E_4 = E\,(e^{j\omega t})$$

The signals are combined in hybrid rings, which operate over a broad frequency band at the frequencies involved (Ref. 5). The resultant sum and difference signals are amplified in separate receivers; the relative phase remains unchanged by the heterodyning process. The difference signals are then compared to the reference (sum) signal in phase sensitive product detectors, as shown in Fig. 3-3. The error signals which result have the form of Fig. 3-4(d). They contain both amplitude and sense information. Therefore, on a single intercept two angle measurements giving the target to satellite direction are achieved. Since the measurement of wavelength is implied for direct sensing over a wide frequency band system, two alternatives are possible: (1) λ can be obtained from the receiver tuning and introduced into the direction analysis, or (2) the degradation due to changing can be accepted in the same way as altering beamwidth in a simple antenna. The problems of sensitivity and multiple intercepts will now be discussed.

3.4.4 Sensitivity

The detection of signals which are near the null of the error signal pattern implies enough sensitivity to detect the null in the receiver. The presence of the signal is indicated in the reference (sum) channel. This is possible because at these low frequencies the signal intercept level is sufficiently high.

3.4.5 Multiple Intercepts

In the system which is described, phase information is available on each received pulse. This is a large improvement over nutating or conically scanning direction finders and contains a solution to the multiple intercept problem.

Assume for example that two signals are received, one near and one far from the direction which the antennas are pointing. The output of the difference channels is discrete and is compared pulse-by-pulse to the sum channel output in the phase detectors. The phase detectors ignore any difference in signal amplitude. The data output then contains the direction of the signal for each pulse on a pulse-by-pulse basis. Only intercepts which fall near the null of the error signal pattern need be analyzed. The directive resolution will be ±3 to 5 degrees.

3.4.6 Note on Reconnaissance of CW Emissions

Even without demodulation of the information content, the reconnaissance of CW signals can yield valuable intelligence data. Military activities are generally accompanied by communications activities. Increased communication activity in strategically important areas may be the tip-off of military preparations or establishment of new units or depots.

In superheterodyne receivers, 10 kc modulation can be applied to the first detector (mixer). The output of the second detector then contains a 10 kc tone for any signal which may be received in addition to pulsed intercepts. The output is applied to a notch filter and to a 10 kc narrow band pass filter. The output of the notch filter contains the pulses which are handled conventionally. The 10 kc output contains the data that a continuous signal has been received at the receiver frequency.

CW reception can also be obtained in the crystal video receivers by modulating the transmission line ahead of the r-f preamplifier with a ferrite or crystal modulator. The modulation is applied ahead of the amplifier for two reasons: (1) it avoids modulation of receiver r-f noise and (2) it also permits residual 10 kc from being applied to the crystal detector when no signal is present. The video output is processed with notch and bandpass filters to separate the 10 kc and pulses in the same way as in the super heterodyne.

3.5 Typical Payload.

Estimated Weight and Power requirements for the Advance Reconnaissance System are tabulated below.

WEIGHT AND POWER REQUIREMENTS - ADVANCED FERRET

1. Sweeping Superhet Receiver = 200 lbs = 2000 watts
2. Data Reduction Equipment = 60 lbs = 360 watts
   2' x 1' x 1' = 2 cu ft
3. Data Recorder = electronics = 150 lbs = 200 watts
4. Data Transmitters (includes spare) = 8 lbs = 125 watts
   1' x 1' x 1' = 1 cu ft
5. Command Receivers (includes spare) = 8 lbs = 10 watts
   1' x 1' x 1' = 1 cu ft
6. Programmer = 10 lbs = 10 watts
   6" x 6" x 1' = .25 cu ft
7. Power Converter = 50 lbs = 100 watts
   1' x 1' x 1' = 1 cu ft
8. Beacon Transmitter = 20 lbs = 50 watts
   [illegible]" x [illegible]" x [illegible]" = 2 cu ft
9. Telemetering Transmitters = Pickups 20 lbs = 180 watts
   1' x 1.5' x 1' = 1.5 cu ft

4. FERRET DATA HANDLING METHOD

The frequency, pulse counts, etc. collected from ferret data receivers must be reduced to useful data, recorded, and transmitted to the ground. The techniques for this are discussed in Appendix G of Ref. 3.

The Advanced data processing system will consist of a refined version of the Pioneer and Advanced systems. Pulse width discriminator and PRF gates will be arranged to reject all signals except those with predetermined characteristics. Upon reception of a signal of special interest the video tape recorder will be actuated and the signal recorded so that more detailed analysis may be made of its characteristics on the ground.

CW signals which will be ignored on the early flights may become of importance as Doppler Radar systems are perfected. Fig. 4-1 is a block diagram of a system which will indicate the presence of CW signals and still allow the receiver to be used for pulse analysis. In this system, the 20-kc oscillator modulates the incoming signals which are later detected and applied to a product detector whose reference signal is also obtained from the 20-kc oscillator. The output of the product detector will be a d-c voltage of small value for pulse signals and of large value for CW signals. The narrow bandwidth of the commutator system will effectively remove any modulation from the CW signal.

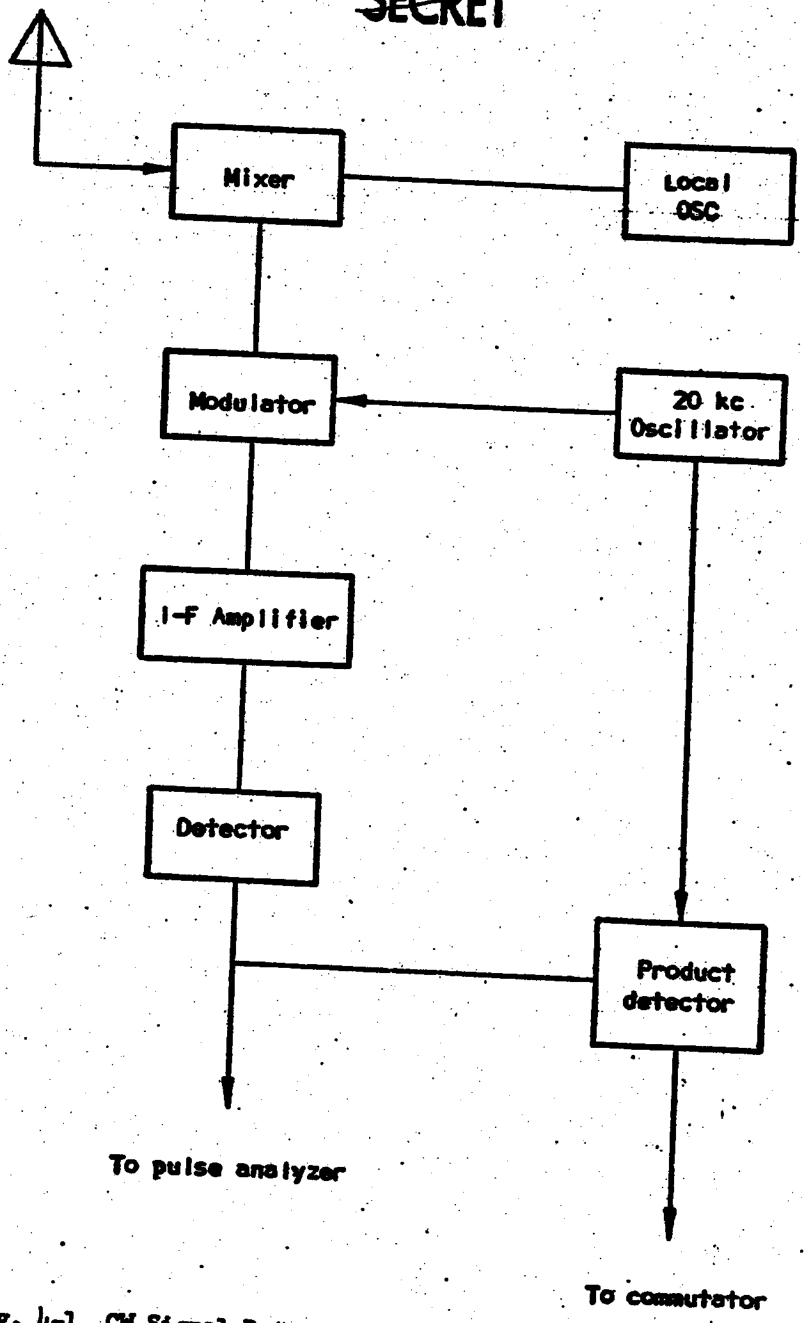

Fig. 4-1 CW Signal Detector

5. CONFIDENCE LIMITS

The probability of intercept problem can be resolved into two essentially different problems. One involves the interaction (or dependence) of the ground radar signal environment and the parameters of the reconnaissance intercept system, namely, the receivers and antennas. The other problem concerns the determination of the minimum input signal-to-noise ratio at the ferret antennas in order to achieve some prescribed maximum false-alarm rate when only noise (no signal) is present, and a prescribed minimum probability of detection when there is a signal present. Since it is tacitly assumed in the former problem that it will properly respond when the receiver is presented with a signal, the latter problem is logically treated first.

In general, the process of detection in a receiver implies a statistical decision as to whether or not a signal was present or not during a given time. For the purposes of analysis the following detection process is followed: the output of a square-law detector is sampled at m different instants of time far enough apart so that noise samples are uncorrelated. Assuming an average noise power, N, we decide a signal is present if the average of m samples exceeds N by an amount kN. Otherwise, no signal is present. In the actual system, this detection scheme is very closely approximated by continous integration, i.e., the usual type of detection.

During intercept, the various ferret receivers will be forming many averages. Thus, P_D is defined to be the ratio of the number of valid detections to the total number of averages that did contain the signal. P_N is the ratio of false alarms (deciding a signal is present when actually none is) to the total number of averages containing no signal. The relationships between P_D, and k, and P_N m, and $^S/_N$ ratio at the receiver input are shown graphically in Fig. 5-1. The analysis leading to these relationships will be included in Ref. 4. The data in Fig. 5-1 assumes that when the signal is present, it is present in every one of the samples. The curves in Fig. 5-2 indicate the magnitude of the effect on $^S/_N$ ratio for the signal being present during only half the samples.

The direct applicability of the relationships in Fig. 5-1 and 5-2 to the proposed ferret reconnaissance receivers depends on the equivalence of the sampling detection scheme described above and continous detection (integration). This latter type of detection method, which is by far the most common form, will be employed in the ferret receivers. The proof of this equivalence is based on setting up the joint probability distribution of the two processes, each having some probability distribution. The proof has been given by Barrett and Lampard (Ref. 6).

~~SECRET~~

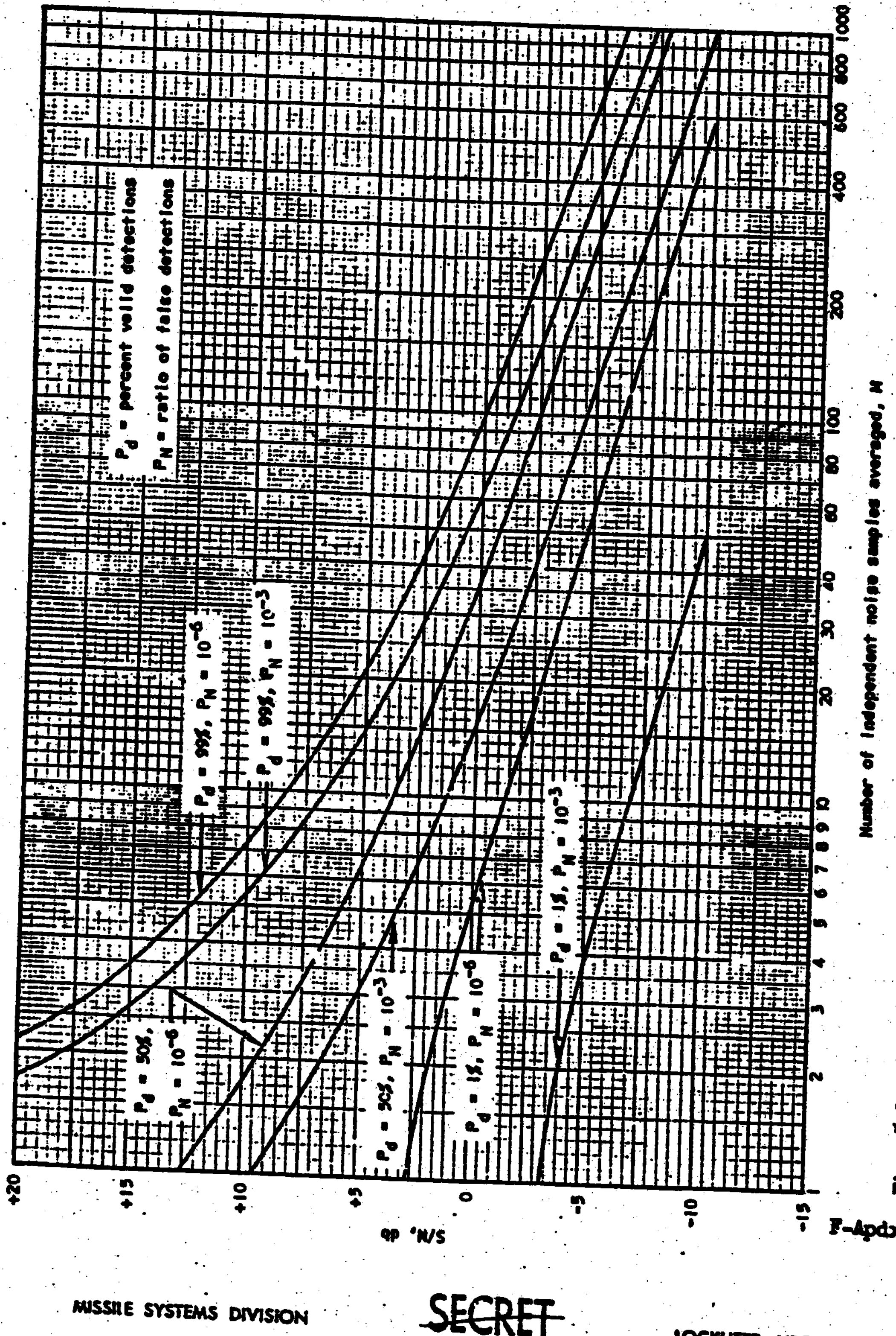

Fig. 5-1 Detection and False Alarm Probabilities vs. S/N and Number of Samples

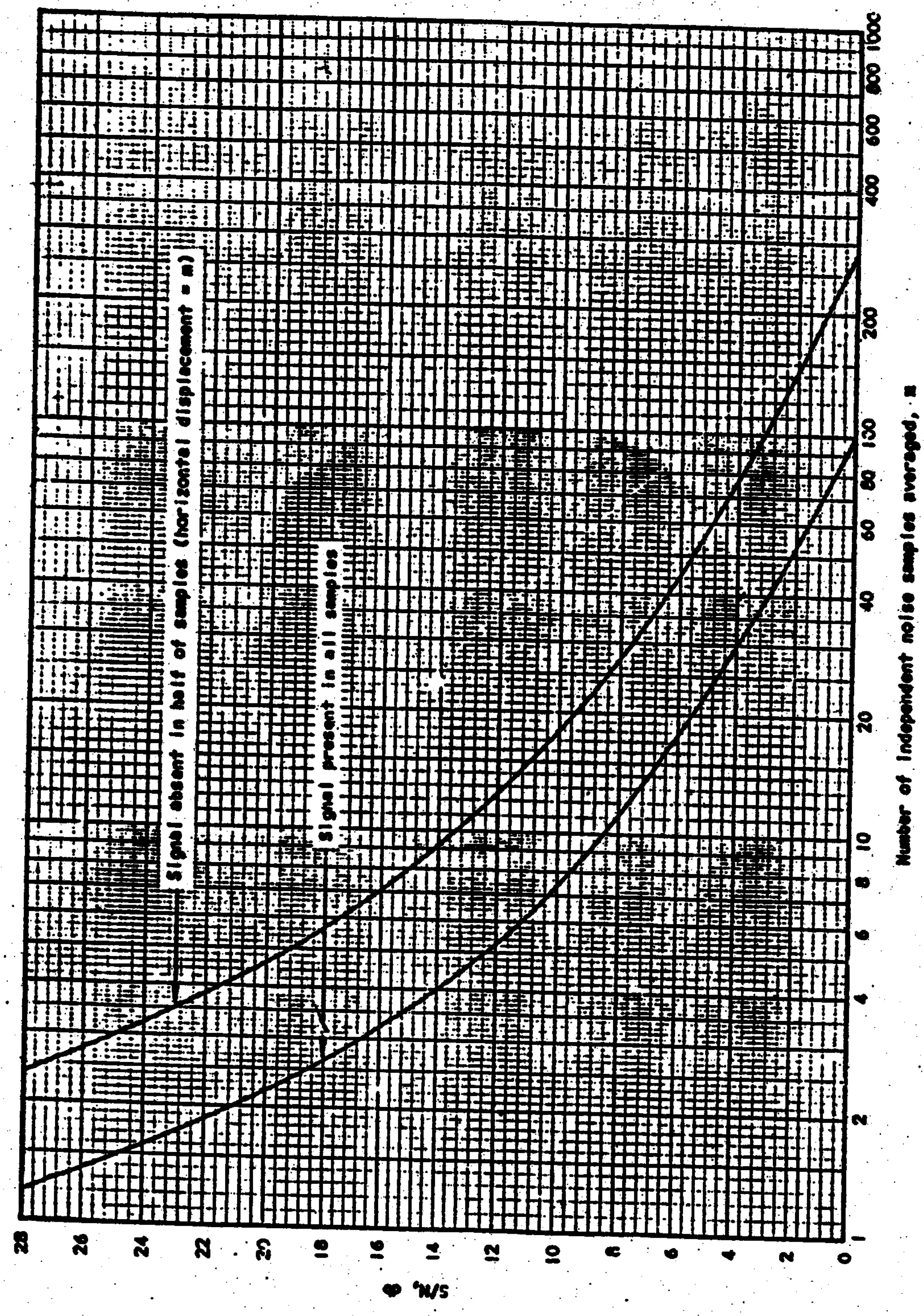

Fig. 5-2 Effect of Signal Not Always Present on S/N and Number of Pulses

6. RADAR ENVIRONMENT

6.1 Pioneer Crystal Video Receivers

Pioneer receivers will afford a first approximation of the Russian radar environment by indicating the relative importance of each frequency band, and correctly identifying perhaps 50 percent of the radar intercepts. The most active frequency bands will require the greater capabilities of succeeding high resolution superheterodyne receivers. According to the data given in Ref. 1 more than 75 percent of the radars intercepted can be properly classified with the measurement accuracies obtainable with the advanced reconnaissance superheterodyne receivers. For 100 percent measurement accuracy, 90 percent of the radars could be properly classified; the remaining 10 percent could not be classified due to the close similarities of certain radar types. It is clear then that by superimposing the data accumulated by the various missions, a reasonable picture of the enemy radar network will emerge.

A sampling time of $\frac{1}{30}$ of a second is obtained with the pioneer crystal video system. If a single radar illuminates the satellite during a complete $\frac{1}{30}$ - second sampling interval, it will clearly be identified, at least as to prf. When two or more radars illuminate the vehicle during a sampling interval, the combined prf will be indicated. Also, when a single radar illuminates the vehicle for only part of the interval, an erroneous prf will be indicated, since the prf measurement is an integration process which merely counts the number of pulses received in the interval. Thus, in order to obtain a high percentage of correct radar identifications, the following condition must obtain: each radar must singly illuminate the vehicle for a complete $\frac{1}{30}$ -second sampling interval. In general, this condition will be obtained for all radars, except certain precision GCA equipments which have cosecant-squared vertical patterns,but have narrow azimuth beamwidths and rapidly scanned antennas.

The intercept data will give a continuing record of radar intercept characteristics. Interpretation of the data obtained for a single intercept must necessarily be accomplished within the context of the complete record. For example, in a particular intercept, it may be confusing whether the vehicle was simultaneously illuminated by two radars or by one with a higher prf. This situation can often be resolved from a knowledge of prf's obtained from prior intercepts.

It has been assumed that when groups of radars illuminate the ferret system; no two of these radars are synchronized. This means that they do not simultaneously scan the ferret with a time phase displacement between the two radars of less than 30 milliseconds. The resolution of individual radars is enhanced by using ferret antennas as narrow as possible (this assumes that similar radars are not at the same location), more frequency channels, and more accurate measurement of prf. These narrow antenna beams and a more accurate prf are not completely possible for the pioneer system because of the specified limitations, but they will be the design objectives of the subsequent missions. In addition to the above signal characteristics, the measurement of pulse width will be included in the more advanced systems for additional data reliability as noted above.

6.1.1 Evaluation of Multiple Intercept Problem

The pioneer crystal video system uses wide open receivers with antennas oriented towards the horizon. For a 5-degree beamwidth ferret antenna oriented toward the horizon, the illuminated ground area is roughly 300 miles by 100 miles.

Based on a Project Lincoln environment, a perimeter defense matrix that could occupy an area 300 by 100 miles is given in Fig. 6-1. Note that only pulse radars are included in the sketch. Figure 6-2 is a sketch of a possible deployment of a Nike or Talos weapons system. Since the Talos missile is a beam-rider, the same equipment is used for tracking and command. Also, the Talos system has a much higher power so that the station spacing is somewhat larger, i.e., about 30 miles as compared to about 20 miles for Nike. In either case, the area coverage is much less than the area of ferret antenna illumination so that more than one such weapons system may be simultaneously encountered.

Furthermore, it was pointed out in Ref. 7 that current practice in the Soviet Union is to use 40 mc channel widths. The statement was also made that 5 mc is adequate for adjacent radars except when the antennas are pointed directly at each other. Consequently, this narrow channel width must be regarded as a future possibility. On the basis of a 40-mc spacing, of the radar density as shown in Figs. 6-1 and 6-2 of a uniform frequency distribution of the radars, and of the frequency channel

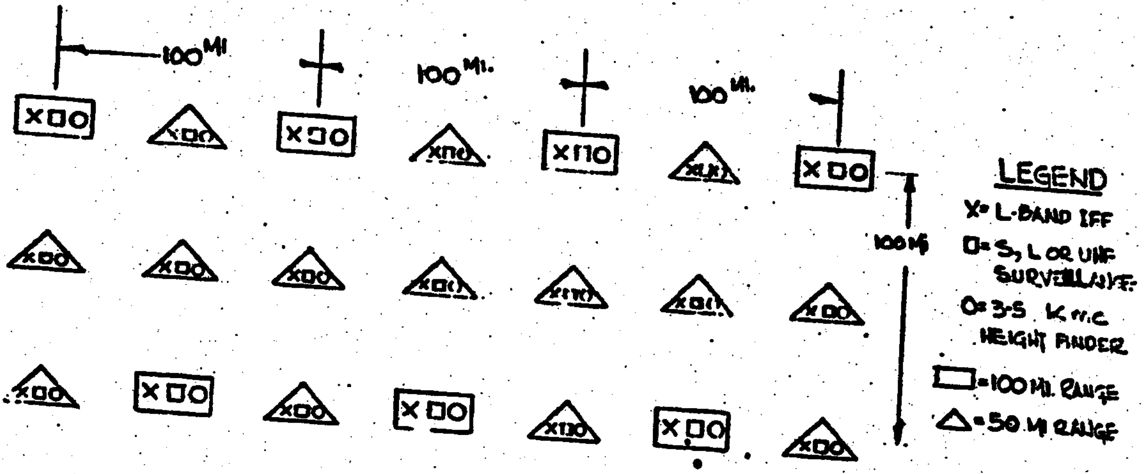

Fig. 6-1 Estimated Radar Environment - Perimeter

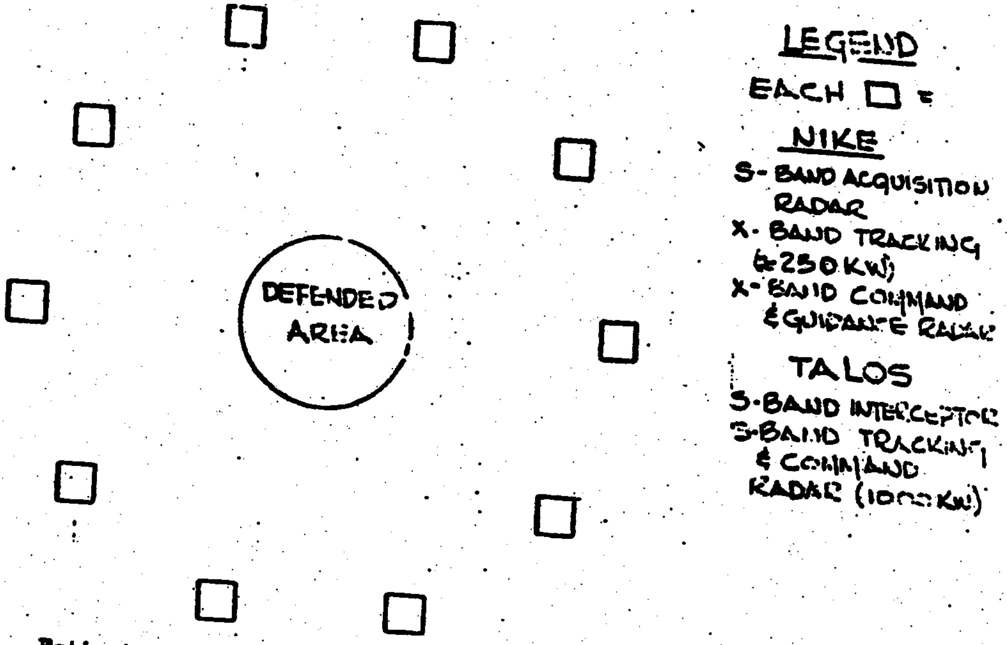

Fig. 6-2 Estimated Radar Environment - Weapons Systems

distribution of the pioneer system (Fig. F-17 of Ref. 3), roughly 5 radars will be on the same ferret channel. This quantity can be much larger, for example, if both IFF and surveillance radars of the perimeter defense matrix are in L-band.

The following relationships are useful in reducing the multiple signal intercept problem to a quantitative basis. Given some radar beamwidth, $\theta^o{}_R$, then the probability that the radar points at the satellite at some given time is

$$(PI)_\theta = \theta^o{}_R/360^o \tag{1}$$

By induction, it follows that the probability that n radars are pointed at the satellite at some given time is just $\left\{(PI)_\theta\right\}^n$. This formula is applicable to the situation in which the ferret illuminates a radar or a group of n similar radars as it moves across the earth.

Since the ferret antenna beamwidth is greater than the angular equivalent of the sampling period ($\frac{1}{30}$ second), the relative phasing between antenna scans becomes important. The probability that two identical radars having arbitrarily space-phased antennas will enter the ferret antenna beam within the angular equivalent of the sampling period of each other is given by

$$(PI)^2_{\theta_2} = \left(\frac{\theta_R + R_\theta}{360}\right)^2 \tag{2}$$

where R_θ = equivalent sampling period angle

$$= \frac{T_s}{60} \times \frac{1}{30} \times 360^\circ = \left(\frac{T_s}{5}\right)^\circ$$

T_s = radar scan rate (rpm)

where $\theta_R = \theta_{R1} = \theta_{R2}$, since the radars are assumed to be identical. Thus, at the extreme values of $R_\theta = 0^\circ$ and $360^\circ - \theta^\circ_R$, $(PI)^2$ reduces to the required boundary values $\left(\frac{\theta_R}{360^\circ}\right)^2$ and unity. For $\theta_R + R_\theta$ greater than (360), eq. (2) yields values greater than unity but it is invalid to test the formula for values greater than 360 degrees. Note that eq. (2) represents a generalization of eq. (1) by the inclusion of the tolerance factor, R_θ.

Now, the probability that two of a group of n radars will be space-phased by $\leq R_\theta$ is given by

$$\frac{n!}{2!\,(n-2)!}\,(PI)_\phi^2 \tag{3}$$

In general, the probability that m of n radars will be space-phased by R_θ is

$$\frac{n!}{m!\,(n-m)!}\,(PI)_\phi^m \tag{4}$$

where

$$(PI)_\phi^m = \left(\frac{\theta_R + R_\theta}{360}\right)^m$$

the average probability of a multiple intercept with the specified value of R_θ is given by the following weighted sum:

$$\sum_{m=1}^{n} \frac{n!}{m!\,(n-m)!}\,(PI)_\phi^m \tag{5}$$

Consequently, the probability of distinguishing between each of the n radars is given by

$$P_{d\phi} = 1 - \sum_{m=1}^{n} \frac{n!}{m!(n-m)!} (PI)_{\phi}^{m} \qquad (6)$$

To apply this last result to the case of five identical radars, assume that $\theta_R = 5$ degrees and $\dot{R}_\theta \approx 0$. Hence, the probability is very nearly given by using the first summation term of eq. (6),

$$P_{d\phi} = 1 - \frac{5!}{2!(3)!} \left(\frac{5}{360}\right) = 0.86$$

Also, for θ_R = 10 degrees

$$P_{d\phi} = 0.72$$

These values represent a significant degree of confidence which can be placed on the data during the specified conditions of intercept.

From the point of view of the ferret design, this quantity can be minimized by making n and therefore, θ_R as small as possible. This, of course, agrees with our intuition in the matter.

6.1.2 Look Time and Number of Pulses Received

Having discussed the basic ideas involved in the multiple intercept problem, relationships will be developed now which show how long each radar will illuminate the satellite and how many pulses will be received from each in a $\frac{1}{30}$ - second sampling interval. This is required to determine the probability of correctly identifying radar intercepts. The time that the satellite illuminates the radar is given by

$$T_F = \frac{\theta_F R}{V} \tag{7}$$

where

T_F = time ferret illuminates radar

R = range

V = satellite velocity

This assumes θ_F to be relatively small.

At this point, the results of the previous section on minimum detectable signal are employed. Assuming a minimum number of detectable pulses, $N = 4$, then minimum $S/N = 12$ db for a $P_d = 99$ percent and $P_N = 10^{-3}$. In general, the following inequality must hold

$$N_m \leq \frac{\theta_R}{360^\circ} \times t_R \times prf \tag{8}$$

where

θ_R = radar beamwidth, degrees

t_R = time per radar scan, seconds

prf = radar pulse frequency, pulses per second

N = minimum number of detectable pulses.

Applying eq. (8) to same typical radars, the results are tabulated below.

Radar	Freq.	prf	Scan Time (rpm)	θ_R°	T_s ms	N_s	T_p	N_p
Kniferest	65-83 mc	50	1	25	33	2	4 sec	208
bCR-527	209 mc	300-650	6	12	33	11-20	$\frac{1}{3}$ sec	100-216
Token	S-band	350	4-6	1	33	12	40-26 ms	14-9
AN-TPS/3	610-690 mc	200	0-10	12.5	33	7	200 ms	741
Type X	X-band	assume 1000	18	0.5	33	34	4.5 ms	4

T_s = Sampling time

T_p = radar look time

N_s = number of pulses per T_s

N_p = number of pulses per T_p

ȝ = milliseconds

Note that for the TPS-3, t_R = 6 seconds is a minimum value since the maximum scan rate was used in the calculation. Calculations for other Soviet radars for which sufficient data is available indicate that the inequality is satisfied in most cases.

6.1.3 Probability that Radar Illuminates Vehicle

Basic to the entire discussion up to now have been these two factors: (1) that the radar and the ferret "see" each other during the time the ferret illuminates the radar, and (2) that the ferret receivers are sensitive enough to detect the various signals within a prescribed probability of detection and false-alarm rate. The probability that the two systems see each other is given by

$$(PI)_{\psi} = \frac{(6T_S) \times T_G + \theta_R}{360} \qquad (9)$$

where

T_S = radar scan, rpm

$6T_S$ = degrees swept through by radar in 1 second

T_G = time ferret illuminates radar, seconds

θ_R = radar beamwidth, degrees

A 5 degree antenna oriented 5 degrees below the satellite horizon has an aperture in the direction of orbital scanning of 100 n. miles. Since the satellite ground speed is about 5 miles per second, T_G = 20 seconds. As an example of the application of this equation, for the Kniferest radar, T_S = 1 rpm and θ_R = 25 degrees. Under these conditions, $(PI) = \frac{120 + 25}{360} = 0.4$. However, the other Russian radars listed in the tables yield values greater than unity. A (PI) greater than unity merely indicates that the radar and ferret will "see" each other at least once during the pass of the ferret over the radar.

This leads to the question of the average number of searches to intercept a radar, such as Kniferest, with 0.99 probability (PI). The (PI) that the radar is undetected after S searches is

$$(1 - PI)^S = 1 - .99 = .01$$

Therefore, $S = \frac{-2}{\log(1-PI)}$. In the case of Kniferest,

$$S = \frac{-2}{\log .6} = 9$$

Thus it will take 9 searches to say with 0.99 probability that the radar is not present. The average number of searches required to detect the radar with 0.99 probability is

$$S_{av} = \sum_{1}^{9} n\,(1-PI)^{n}$$

Each term in the sequence is the number of searches, n, times the probability that the radar is undetected after n searches. For $n = 9$, $PI = 0.4$, we have $S_{av} \approx 3.5$. Since there must be an integral number of searches,

$$S_{av} = 4$$

Thus, for the assumed conditions, the radar will be detected with an average of 4 searches.

6.2 Advanced Reconnaissance Ferret System

Another aspect of the intercept problem is associated with the reconnaissance system employing scanning superheterodyne receivers. As the receiver scans in frequency, ~~it must dwell long enough at a particular frequency,~~ it must dwell long enough at a particular frequency to pick up the minimum number of detectable pulses. This relationship applies to the proposed system using scanning superheterodynes. The probability of intercept is then given by:

$$(PI)_{\lambda} = \frac{B_I}{B_T} \times \frac{prf}{N_m} \times T_c$$

where

B_I = receiver I-F bandwidth

B_T = receiver R-F bandwidth (total)

N_m = minimum number of detectable pulses

prf = radar pulse frequency, pulses per second

T_σ = time ferret illuminates radar = time to scan B_T in frequency

In this equation, $\frac{prf}{N_m}$ essentially determines the fastest receiver tuning rate. As an example, the S-band token radar has a prf = 350. For a ferret antenna of beamwidth = $\frac{1}{6}$ radian, T_σ = 10 seconds. Furthermore, assuming B_I = 5 mc, B_T = 2000 mc, and N_m = 4, (PI) = 2.2. As before, a PI greater than unity implies "overdesigned" ferret intercept parameters. Thus, when PI = 1 under some set of circumstances, B_I, B_T, and N_m may be approximately adjusted to achieve just the necessary unity.

7. SYSTEM SENSITIVITY REQUIREMENTS

7.1 Summary

In order to accomplish a radar intercept, it is assumed that the ferret receiver will be sufficiently sensitive to detect the radar. This leads to the question of a signal level at the ferret receiver when the ferret antenna is pointed in various directions within the satellite's line-of-sight cone. The radar and ferret will generally "see" each other only when the ferret antenna is pointed near the horizon. In all other cases, including pointing the ferret antenna at the nadir, the ferret receiver must be sensitive enough to detect the radar's side lobes. The signal level for intercepts made for each of these orientations is determined by: (1) derivation of the necessary geometric relations and (2) calculation of the field strength at the ferret antenna for typical Russian radars using each ferret antenna orientation.

The results of this derivation are that ferret receivers will require approximately -57 dbm sensitivity to detect typical Russian radars when the ferret antennas are pointed near the horizon, and -74 dbm for antennas pointed toward the nadir (see pp F-14 to F-33 Ref. 3). The lower sensitivity can be accomplished using wide open crystal video receivers and r-f preamplifiers; the greater sensitivity, with scanning superheterodyne receivers.

7.2 Direction Sensing with Advanced Reconnaissance Receivers

At low frequencies pencil beam radiation patterns cannot be obtained with reasonably sized antennas. Therefore a lobe comparison receiver using four antennas for direction sensing will be employed in order to achieve a higher degree of directional resolution than can be accomplished with a single broad beam antenna. Lobe comparison techniques are also required to resolve the directional ambiguity which results when signals are intercepted by the ferret antenna side lobes. Lobe comparison direction sensing is therefore required whenever accurate radar location is required in advanced reconnaissance missions.

7.3 Probability of Intercept Analysis

The capabilities of the proposed ferret reconnaissance systems will be demonstrated by applying the various probability-of-intercept relations to several typical radar situations. From the tables of known Russian radar equipments (Tables 1-1 and 1-2 and Ref. 3) several typical equipments were selected which operate over the most essential portion of the frequency spectrum. These equipments were placed in ground environments typified by those outlined in Figs. 6-1 and 6-2.

The results of these considerations are shown in the following tables, Table 7-1 outlines the assumed radar situations for each of the radars and arrives at an expected number of operating radars. Following this, Table 7-2 then presents the PI for each radar; this is a measure of the system capability. In addition, Table 7-2 lists the number of pulses per sampling period and the number of pulses per radar look time.

As can be seen from these tables, the multiple intercept problem may be rather serious in the pioneer system. The situation

Table 7-1 ESTIMATED RADAR SITUATION

Radar	Radar Function	Area Assumed to be Illuminated by Ferret	Assumed Radar Environment Within Illuminated Area	Total No.	Operating Radars = 2/3 Total
Type X	Precision GCA	100 × 300 mi.	10 airfields; 3 GCA equipments per airfield	30	20
Token	EW or GCI	150 × 300 mi.	3 weapons system; 20 token radars per weapons system	60	40
AN-TPS/3	EW	400 × 800 mi.	Gap filler; 50 mile spacing	60	40
Kniferest or Dumbo	EW	1000 × 1500	75 mile spacing along perimeter; 3 such radar lines in depth	90	60
SCR-527	Height Finder or GCI	400 × 800 mi.	One Height Finder radar at each site in a perimeter defense matrix	60	40
Type V	Acquisition	250 × 500 mi.	One Acquisition radar per site in a weapons system; 5 weapons systems in whole area	100	60
Type VII	Surface Search & Traffic Control	150 × 300 mi.	Two such radars per airfield 10 airfields in entire illuminated area	20	15

Table 7-8 ESTIMATED PROBABILITY OF INTERCEPT OF PIONEER SYSTEM

Radar	Radar Function	Freq.(kmc)	PRF	Antenna Scan Rate rpm	Antenna Azimuth Beam-width	Ferret Data Sampling Period	No. of Pulses Per Sampling Period	Radar Look Time, (Milli-sec.)	No. of Pulses Per Radar Look Time	Approx. Fe./et. Ant. BW at Radar Freq. for pioneer receivers	Estimated Total No. of Operating Radars Illuminated by Ferret	Estimated** No. of Radars Per Ferret Channel	Estimated probability that not more than indicated no. of radars simultaneously illuminated the ferret within 2R₀			
													≤1	≤2	≤5	≤10
Type X	Precision GCA	8-10	1000*	6 or 18	0.9°	$\frac{1}{30}$	34	25 or 8.33	25 or 8	3°	20	10	>.99	-	-	-
Token	EW or GCI	2.88 - 3.04	350	4-8	1.0°	$\frac{1}{30}$	12	42-48	14-9	6°	40	20	>.99	-	-	-
AN-TPS/3	EW	.61 - .69	200	0-10	12.5°	$\frac{1}{30}$	7	> 208	> 41	40°	40	40	.05	.58	>.99	-
Kniller [illegible]	EW	.065 - .083	50	1	25°	$\frac{1}{30}$	2	4170	208	90°	60	60	0	0	0	.32
SCR-527	Height Finder or G C I	.209	300-650	6	12°	$\frac{1}{30}$	11 - 22	333	100 - 217	40°	40	40	.07	.58	>.99	-
Type V	Acquisition	.85 - 1.0	150*	3*	4°	$\frac{1}{30}$	6	166	25	20°	60	60	.78	.35	>.99	-
Type VII	Surface Search and Traffic Control	2.7 - 2.9	2000*	4, 8, 12	3°	$\frac{1}{30}$	67	125, 62.5, 42	250, 125, 83	6°	15	15	>.99	-	-	-

* An assumed value based on the nature of the radar function

** Based on the ±125 frequency resolution.

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may be resolved, however, by means of the following factors:

(1) A priori knowledge of radars in the particular frequency band where dense signals are occurring.

(2) Prior intercept of the same radars in a low signal density area such that the individual radars and their prf's could be evaluated.

(3) By noting whether or not the indicated prf increments between successive sampling periods are submultiples of the indicated prf's during the successive sampling periods. In this case, the lowest submultiple would then be interpreted as the true radar prf.

The advanced reconnaissance system overcomes these difficulties by virtue of its increased frequency resolution (1 percent), more accurate prf measurement (maximum of 25 percent at 50 pps), and the incorporation of direction-sensing techniques. Inclusion of D-F methods greatly reduces the area effectively illuminated by the ferret. A comparison of the two systems is shown in the table immediately below in Table 7-3.

Table 7-3

RADAR	Probability that not more than 1 radar will illuminate ferret	
	Pioneer	Advanced
Kniferest or Dumbo	0	0.85
SCR-527 or AN-TPS/3	0.07	0.95

8. INTELLIGENCE PARAMETERS AND WARNING INDICATORS

The intelligence requirements for the period 1960-1965 have been established. In the order of their priority these have been given in Ref. 8:

(1) strategic warning
(2) enemy military forces in being
(3) enemy military stockpiles of thermonuclear and atomic weapons
(4) enemy logistics capabilities
(5) enemy industrial war capabilities

These are total requirements from all sources in which electronic reconnaissance is expected to play a very important part. The interweaving of electronic communications and weapons systems within the military fabric is, by now, well established. There are indicators associated with each of these intelligence requirements from which the intelligence may be inferred. The data obtained from the reconnaissance missions and its subsequent interpretation yield these various indicators. In the following table the various indicators are listed under their appropriate intelligence category. The performance capability of both the Pioneer and the Advanced Reconnaissance receivers with respect to each of these indicators is shown in the adjacent columns.

Table 8-1

Intelligence Requirement	Pioneer Reconnaissance	Advanced Reconnaissance
1. Strategic Warning		
a) Increased signal activity	Approx. radar count; approx. freq. and prf for recognition of radar type; app.georgraphical distribution	Accurate radar count; accurate freq., prf, location and coarse pulse width for recognition of radar types and particular radars such as weapons system, EW, GCI, etc.
b) Concentration of enemy forces in being	Same as (a); may indicate high signal density area associated with military establishments	Same as (a); high signal activity especially weapons system, GCA,GCI etc; in area where no large city is located indicates important military establishment, airfields, etc.
c) Changes of concentration	Same as (a) and (b)	Same as (a) and (b)
d) Buildup of air, ground, & naval forces	Same as (a) and (b); same as ARS but a lower degree of confidence	Same as (a) and (b); will indicate new areas of general and particular signal activity and increased activity in known areas
e) Buildup of military thermonuclear and atomic stockpiles	Same as (d):	Same as (d); these areas will be highly protected; this intelligence will be essentially corroborative
f) Identification of special military establishments, e.g., ICBM and other missile sites, MB and HB airfields, etc.	Same as (a)	Can identify locations of particular radar type such as missile guidance, GCA, GCI, surface detection, search and tracking radars, etc.
g) Enemy intent	See (a-f) same as ARS	See (a-f); intense signal activity will most likely precede an agressive military move.

Table 8-1 (Continued)

Intelligence Requirement	Pioneer Reconnaissance	Advanced Reconnaissance
2. Enemy Military Forces in Being	See 1 (b) to 1(f)	See 1(b) to 1(f)
3. Enemy Military Stockpiles of thermonuclear weapons	See 1(e)	See 1(e)
4. Enemy Logistics Capabilities	---	---
5. Enemy Industrial War Capabilities	Same as 1(a); no conclusive evidence	Same as 1(a); by detecting new frequencies, unusual signal characteristics, quantity of radars and radar types, electronic industrial capacity potential and buildup may be inferred.

At this point the reasonable assumption is made that radar strategy and planning is indicative of military strategy and planning. In addition, it is assumed that a basic correspondence exists between radar deployment and the deployment of the military establishment. Hence, by determining the radar network and the changes and additions to the network, the pertinent intelligence indicators referred to above can be measured. It must be emphasized again that electronic intelligence forms a part of the whole intelligence picture and must rely on other sources of information for its most efficient utilization.

9. FERRET DATA LINK

See Subsystem J - Appendix for material on ferret data link.

10. ATMOSPHERIC ATTENUATION AT MICROWAVE FREQUENCIES

See Subsystem J - Appendix and Appendix C of Ref. 3 for material on atmospheric attenuation.

11. FERRET ANTENNA DESIGN CRITERIA

11.1 Summary

The pioneer ferret mission uses simple antenna configurations which, used singly, define the direction of a signal within the limits of directive gain achievable with small antennas. The antennas for the "wide open" crystal video receivers are directed towards the horizon in order to receive the main lobe of the radar emission, while the antennas for the higher sensitivity, frequency-scanning superheterodyne receivers may be pointed in any direction, including the nadir, in order to receive side and back radiation, as well as the main lobe.

Direction finding in the pioneer vehicle uses the orbital scanning properties of the satellite and therefore differs from direction finding with aircraft, which requires scanning 360 degrees in azimuth to locate a target. Above S-band, approximately 30 db gain and directivity can be achieved with antenna configurations suitable for satellite application, while at lower frequencies, wider beams are employed to maintain a suitable maximum size.

The calculations are based on circularly polarized antennas operating over approximately one octave each throughout the very broad frequency range of 50 - 30,000 mc. Based on certain recent achievements which have been reported, however, it is hoped that greater bandwidth will be achieved in the performance of the proposed program. Section

11.3 below has a suggestion for the development of a super-broadband antenna for advanced reconnaissance.

For higher-resolution direction sensing in advanced ferret reconnaissance, combinations of small antennas will be employed. A phase comparison direction sensing receiver will be used. The individual antenna performance will be similar to that described in this section, except that 30 db gain is obviously not required of single antennas to obtain good directive resolution. Since high antenna directivity for individual antennas is not a prerequisite, the over-all weight and volume required for antennas in this system will not be unreasonable.

11.2 Design Criteria

11.2.1 General

Antennas in general may be divided into two generic types:

a. Aperture type

b. Endfire type

Aperture types obtain their directive properties from the field distribution over the aperture. Endfires, on the other hand, are essentially unit radiators arranged so as to achieve directivity by constructive superposition of the radiated fields in the desired direction and destructive in other directions.

Dipoles, slots, loops, and the like may be considered the building blocks of each of these types. Aperture antennas can be subdivided into the following:

1. Broadside arrays
2. Parabolic reflectors
3. Other reflector types
4. Horns
5. Lenses

Endfires can be subdivided into the following:

1. Endfire arrays
2. Surface wave
3. Dielectric Rods
4. Helices

These criteria are based on an evaluation of the various kinds of antennas for a ferret system in the frequency range from 50 mc to 18 kmc. The antenna characteristics are defined by the receiver properties. The system characteristics (antennas plus receivers) combine to give a high detection probability for unknown emissions.

The spectrum from 50 mc to 30 kmc was divided into a number of bands based on preliminary studies. These showed that the required gains of the antennas would not be the same in all bands. As a result of the gain requirements and physical characteristics of the antennas, the techniques of solution in these bands differ.

The bands were specified as:

2 to 30 kmc, 200 mc to 2 kmc, and 30 mc to 200 mc.

11.2.2 2-30 kmc Antennas

Let us consider each band seperately. The 2 to 30 kmc band requires that for circular polarization the antennas have an over-all gain of 30 db and directivity of approximately 33 db.

For 33 db directivity, the aperture type of antenna is the most efficient. The criterion for gain on this type of antenna is given by:

$$D_o = \frac{4 \pi k A}{\lambda^2} \qquad (1)$$

k = antenna efficiency

A = aperture area

λ = wave length

If we postulate an antenna efficiency of 66 per cent this equation becomes

$$D_o = \frac{8.0 A}{\lambda^2} \qquad (2)$$

and for a gain of 33 db, $D_o = 2000$.

so that

$$250 = \frac{A}{\lambda^2} \qquad (3)$$

If we now consider that the antenna should be circularly symmetrical,

$$A = \pi r^2 \qquad (4)$$

and

$$\frac{250}{\pi} = \left(\frac{r}{\lambda}\right)^2 \qquad (5)$$

$$9 = \frac{r}{\lambda} \text{ or } r = 9\lambda \qquad (6)$$

Based on the capabilities of the receivers the range of 2 to 30 kmc can be broken down further in sub-bands as follows:

2 to 4 kmc
4 to 8 kmc
8 to 12 kmc
12 to 18 kmc
18 to 30 kmc

Selecting the design frequencies in these bands 4. 8, 12, 18 and 30 kmc we have:

f(kmc)	λ (cm)	d(cm)	d(in)
4	7.50	90	36
8	3.75	64.5	25.4
12	2.5	43	16.9
18	1.65	28.5	11.2
30	1.00	17.0	6.6

where d is the diameter of the aperture to give these 33 db directivity and 30 db gain.

As pointed out previously, these apertures can be achieved in different ways. Broadside arrays which depend on the position and phase of discreet sources are dependent on these parameters being constant in order to achieve broadband characteristics. At the frequencies under discussion, where wavelengths are short, the manufacturing tolerances become very severe. This method was therefore discarded.

Horns, on the other hand, seemed to offer a good solution, structurally, and from a manufacturing view point. Investigations of horns by Rhodes (Ref. 9) showed that they have a tendency to have a pattern disintegration when the central flare angle becomes large, especially when the horn mouth is many wavelengths wide. Kraus (Ref. 10) gives optimum design characteristics of horns. From these curves we find that for our apertures a central angle of about 15 degrees is needed.

Using this to calculate the horn length, we have (see Fig. 11-1, p 74)

$$\tan 7\tfrac{1}{2}^\circ = \frac{9\lambda}{L}$$

$$L = \frac{9\lambda}{\tan 7\frac{1}{2}^\circ} = \frac{9\lambda}{0.13}$$

$$L = 69\lambda$$

A length of 69 λ is of course excessive; even at frequencies as high as 9 kmc, this would give a length of 178 inches.

As a result, two approaches remain open: (1) the reflector and (2) lens type antennas. The lens offers all the advantages of a reflector plus the fact that the problem of primary feed interference with the secondary radiation pattern is reduced. The only disadvantage is that lenses tend to be quite heavy in comparison with reflectors. Unless this latter difficulty could be overcome by use of thin lenses, using materials of high dielectric constant, such as polyfoam impregnated with Ti O_2, parabolas will be more desirable than lenses.

The reflectors, especially parabolic reflectors, offer the straightforward approach and are offered here as the best possible solution at this time.

The pattern of a parabola is as much a function of its primary feed as of its size. Unless the primary feed illuminates the parabola correctly and does not interfere with the secondary radiation pattern, the parabolic antenna will not radiate in the desired way.

For the purpose of obtaining the greatest flexibility of reception, it is proposed to feed the parabolas with primary helical radiators. These radiators will be right-hand circularly polarized; this will enable the detection of all lineally polarized and left-hand circular polarized radars.

The helices would be small in size, and since the direct reflection from the parabola would have the opposite circular sense, they would not be seen by the primary source. This would reduce the effect of mismatch caused by standing waves from the reflector effecting the efficiency of the antenna.

An investigation of the possibility of mounting two helices coaxially, one right-hand wound and one left-hand wound, is suggested, so that two bands could employ a single reflector. The possibility of making helices wider than one octave has been investigated. The use of conical or double conical helices could reduce the over-all number of antennas. This would require an extension to the higher frequencies of the work carried out in the 100 to 500 mc region (Refs. 11 and 12).

It is proposed in consideration of weight reduction to construct the antenna reflector of fiber glass. The fiber glass would be of a laminate construction with the reflecting surface either deposited on the surface or imbedded in the laminate.

The specific weight of this laminate is 0.07 pounds per cubic inch.

By employing the best known techniques, the weights of the parabolic dishes should be:

Diameter	Weight (lbs)
90-cm (36 in)	7
65 cm (25 in)	5
43 cm (16 in)	4
28 cm (11 in)	3

Using parabolas with an $\frac{f}{D}$ ratio of ^ 33, the total intercept angle of the dish from the focus is 150 degrees. This angle determines the dimensions, and hence the radiation pattern, of the primary helical feed.

The beam width of the helix can be expressed as

$$BW = \frac{52}{C_\lambda \sqrt{n S_\lambda}}$$

where the relationships are given in Fig. 11-2 and

n = number of turns

α = pitch angle

C_λ = circumference

S_λ = spacing

L = length of turn

For a typical feed, let

$N = 3$

$C_\lambda = 1.4$

$S_\lambda = .4$

The empirical values of the first null are

$115/C_\lambda \sqrt{n\, S_\lambda}$

For the high end,

$115/1.4 \sqrt{3 \times .4} = 76$ degrees;

For the low end,

$115/.7 \sqrt{3 \times .2} = 140$ degrees

Antennas of a similar type have been employed by earlier reconnaissance systems (Ref. 13) although not in this specific way. In an effort to hold the radiation pattern more constant over the band, variations from the cylindrical helix will be investigated.

A typical field distribution over the parabola, based on a center focus helical feed, is given in Fig. 11-3. With this

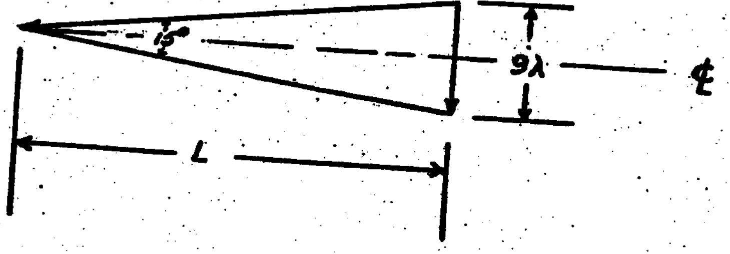
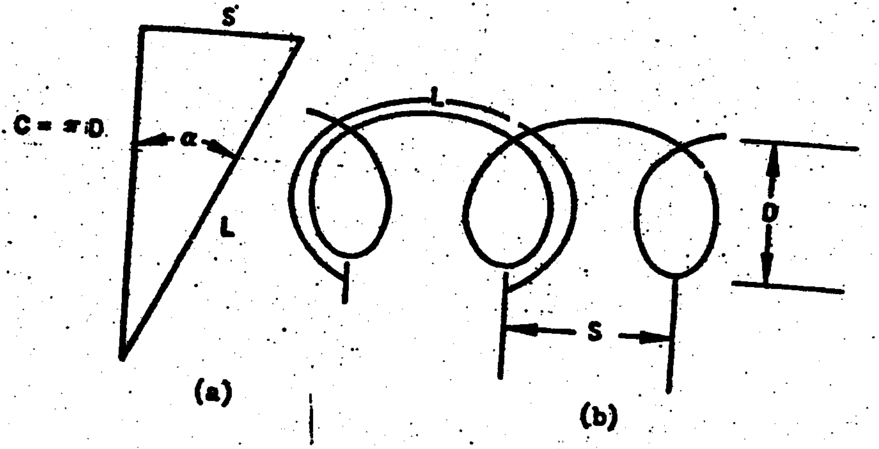


Fig. 11-1



(a)

(b)

Fig. 11-2

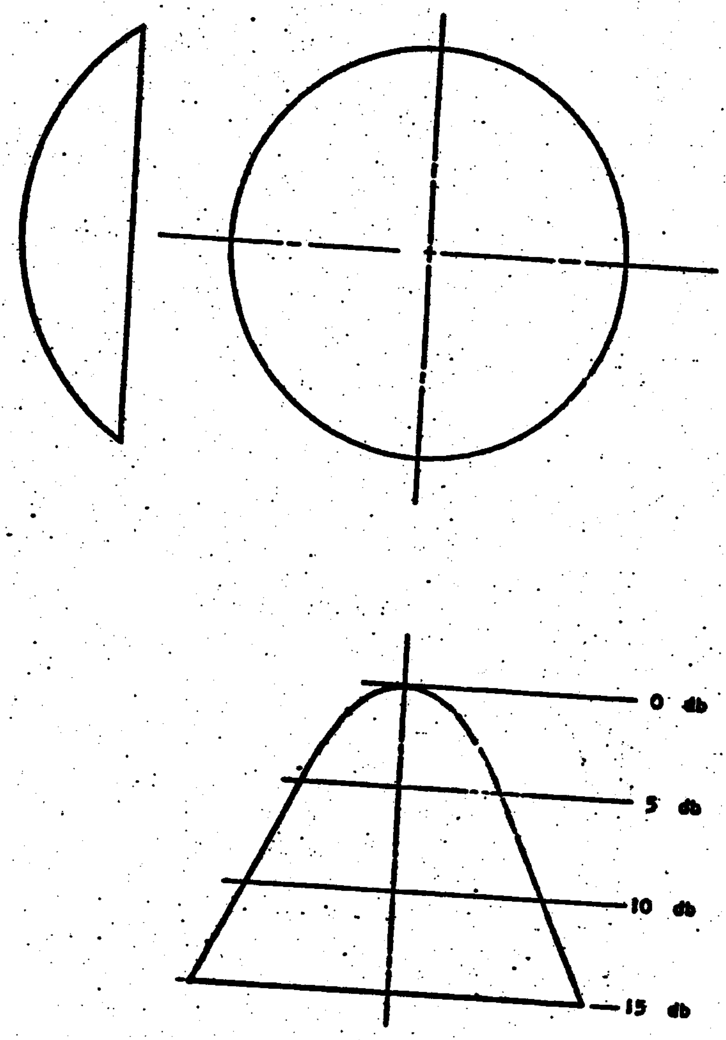


Fig. 11-3 Field Distribution Over Parabolic Aperature

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type of feed and the circular symmetry of the parabola, the distribution for both horizontal and vertical polarization will be the same.

It is well known that the transmission loss varies inversely as the wavelength squared for a given range. This fact, coupled with improved receiver noise figures at lower frequencies, permit the lowering of the antenna gain at this end of the spectrum, so far as system sensitivity is concerned.

11.2.3 50 - 2000 mc Antennas

In the frequency band below 2000 mc, the above considerations modify the antenna design criteria. As the need for gain decreases, it becomes advantageous to use simpler antenna structures.

The necessity of detecting both horizontal and vertical polarization requires that the antenna be circularly polarized. Circularly polarized antennas using horns with delay devices, quarter wave plates, and certain TE modes in circular guide are generally based on frequency sensitive devices. They were discarded as not being sufficiently broadband to meet the requirements of the over-all system.

Helices, on the other hand, are naturally broadband and circularly polarized. The helix operating in the beam mode presents an input impedance of approximately 140 ohms over at least an octave and is almost purely resistive.

Antennas for the 1000-2000 mc, 500-1000 mc, 200-500 mc, and 50-200 mc bands were designed using classical helical antenna theory (Refs. 14, 15, and 16).

Although these helices are of the cylindrical type, modifications of the basic structure into conical, biconical, and variable pitch helices seem to offer the bright possibility of extending their range as high as 5:1 in frequency (Refs. 11 and 12).

These antennas, like the parabolas, will have circular symmetry with the beam width equal in all planes.

11.2.4 Alternate Designs for Transitional Regions (50-200 and 1000-2000 mc)

It should be noted that the frequency bands in the 1000-2000 mc and the 50-200 mc regions are transitional. These bands cannot be readily placed in a precise antenna category for our purposes. Therefore, alternate designs were postulated for each band. In the case of the 1000-2000 mc band, both a helix and a parabola were considered.

In the 50-200 mc band several alternate antenna configurations may be considered in addition to helical antennas. These are: biconical dipoles* oriented at 45 degrees to the vertical direction, thick dipoles, and combinations of broadband slots to give 45 degrees or elliptical polarization. It is left to further consideration of satellite space allocation and system configuration to determine the ultimate design and also final evaluation of satellite versus other means of gathering data on the Russian radar complex in this frequency band.

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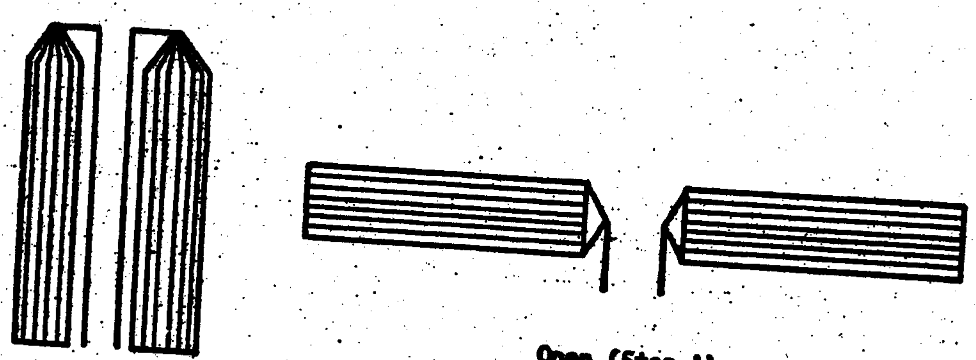
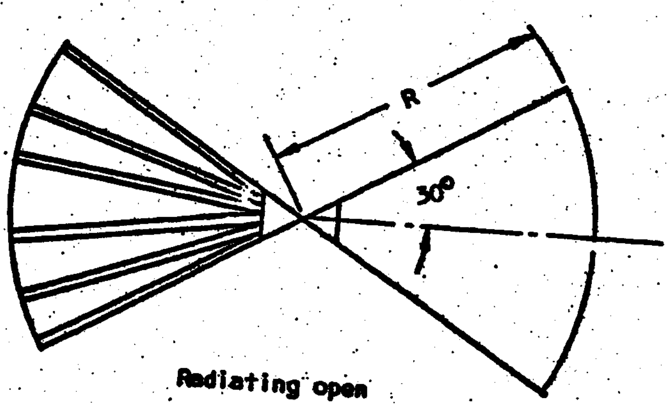
* Dipoles formed in the shape of cones have been shown to work over very wide frequency bands (Ref. 17). Conical dipoles fed from a balanced line have VSWR's below 3:1 over a band of 5:1. This type antenna also has little change in beam shape over the operating band. A sketch of a possible antenna configuration is shown in Fig. 11-4. The antenna can be made of hollow rods in an umbrella type construction that can be stored folded and opened when in use.



Stowed

Open (Step 1)



Radiating open

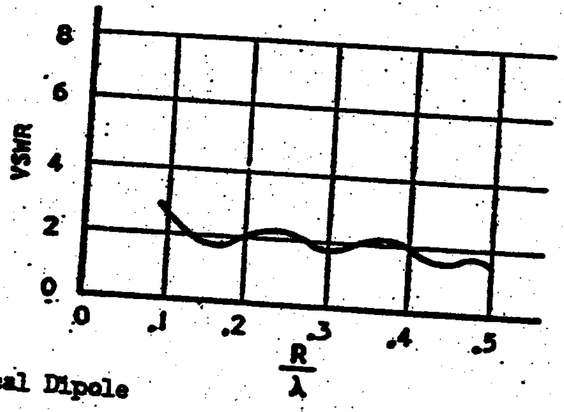


Fig. 11-4 Biconical Dipole

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Table 11-1 shows beamwidth gain, size, and weight of the proposed antennas.

TABLE 11-1

Frequency (mc)	Wavelength (cm)	θ Min (degrees)	θ Max (degrees)	G_0 Min (db)	Diameter (cm)
Parabolas					
30,000 - 18,000	1.0 - 1.65	4.0	6.5	28.0	17.0
18,000 - 12,000	1.65 - 2.5	4.0	6.0	28.0	28.5
12,000 - 8,000	2.5 - 3.75	4.0	6.0	28.0	43.0
8,000 - 4,000	3.75 - 7.50	4.0	8.0	25.4	64.5
4,000 - 2,000	7.5 -15.0	5.75	11.5	22.2	90.0
2,000 - 1,000	15.0 -30.0	11.5	23.0	16.3	90.0
Helices					
2,000 - 1,000	15.0 - 30.00	18.2	53.0	13.6	6.7 x 90
1,000 - 500	30.0 - 60.	22.2	62.5	10.2	13.4 x 90
500 - 200	60.0 -150.	37.4	100	5.4	26.8 x 150
200 - 50	150.0 -600.0	41.0	100	2.0	75.0 x 150
Dipoles					
200 - 50	150 - 600	>100	>100	1.5	120 cm long

11.3 Super Broadband Antennas

Broadband usually refers to an adequate impedance match over a wide frequency band of antennas. For the ferret system we would like to expand this concept to include also the idea of constant beamwidth.

The proposed Pioneer system antennas were designed with this in mind. The use of the parabolic reflector is basic in the extension of this concept.

It is generally known that lossless conductors reradiate electromagnetic energy regardless of the wavelength, provided it is less than the size of the reflector. The manner in which this energy is reradiated depends upon the method in which the reflector is illuminated.

If then we could illuminate a parabolic reflector in such a way that the amount of area illuminated was proportional to the wavelength squared, the resultant for field pattern would be essentially constant.

The Pioneer antennas were designed using "state-of-the-art" helices. This procedure left the possibility of extending the range of the antennas by extending the range of the helices. A parallel approach would be to design around the helices and, at the samettime, investigate some of the newer approaches to broadbanding, namely,

(1) Further development of conical helices along the lines of Chatterjee (Refs 11 and 12) whose work has extended these structures over a band of 5:1 at low frequencies.

(2) Use of the loaded dipolarized horns which were presented at the 1956 National Symposium on Microwaves* to have a bandwidth capability of 4:1.

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* Held at University of Pennsylvania, 2 - 3 February 1956.

(3) Extension of the unpublished work [illegible] W. E. Clark and Werner Koppl**, in which bandwidths as high as 20:1 have been estimated.

** Private communication with F. E. Shine, CBS Laboratories.

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