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Vol. II
Part J
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MSD 1536

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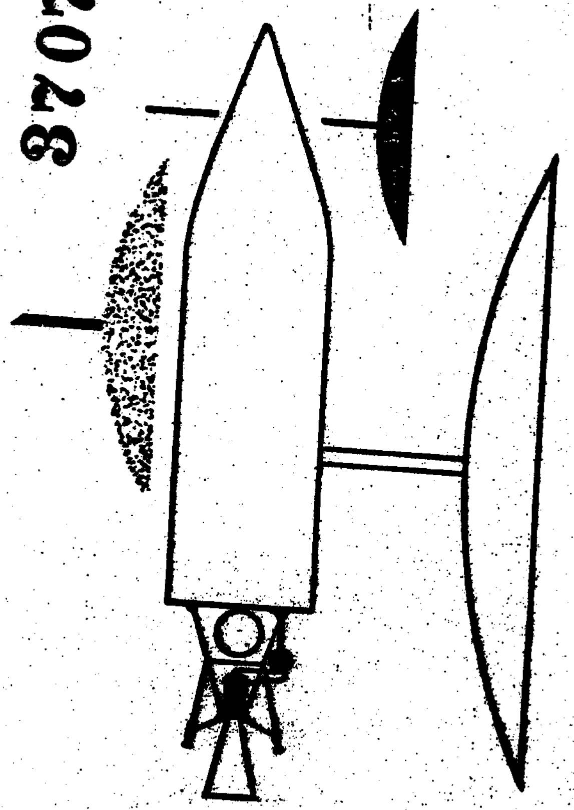

Pied Piper
DEVELOPMENT PLAN

VOL. II SUB-SYSTEM PLAN

J. Vehicle Intercept and Control, Ground Station

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LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION
VAN NUYS, CALIFORNIA

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MSD 1536
1 MARCH 1956

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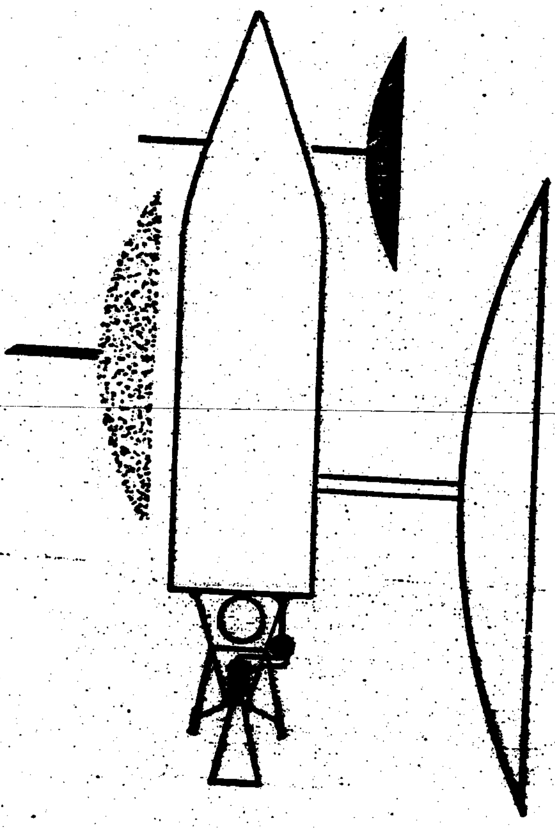

Pied Piper
DEVELOPMENT PLAN

VOL. II SUB-SYSTEM PLAN

J. Vehicle Intercept and Control, Ground Station

DOWNGRADED AT 12 YEAR INTERVALS;
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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 J Vehicle Intercept and Control Ground Station

SECRET
SECURITY CLASSIFICATION

MSD 1536

RDB PROJECT CARD

TYPE OF REPORT

REPORTS CONTROL SYMBOL DD-RDB(A)40

1. PROJECT TITLE
VEHICLE INTERCEPT AND GROUND CONTROL STATION SUBSYSTEM
(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.
AF 33(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. The reconnaissance data obtained by the Satellite Vehicle will be transmitted to suitable ground base stations in quantity and variety previously not available, over a high performance data link. In order to maintain contact with the vehicle, a ground acquisition and tracking radar with associated orbit computer, and command control link must be developed. In addition, data link receiving equipment, and inter-station communications networks are required to accomplish these objectives.

b. The reconnaissance information obtainable will be of great value to SAC, TAC, and Air Defense.

c. A satellite has not been used previously in a reconnaissance mission. It will provide a major increase in the coverage available, resulting in a greatly increased Air Defense capability.

21. RDB
SW
CN
IC & F
X.
S.
C.

DD FORM 613

MISSILE SYSTEMS DIVISION

SECRET
SECURITY CLASSIFICATION

LOCKHEED AIRCRAFT CORPORATION

R&D PROJECT CARD
CONTINUATION SHEET

SECRET

MSD 1536

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
VEHICLE INTERCEPT AND GROUND CONTRCL STATION SUBSYSTEM (Unclassified) (PIED PIPER)	Secret	1115
	4.	5. REPORT DATE 1 March 1956

21 a. Brief and Operational Characteristics

The vehicle intercept and control ground station equipment will permit vehicle interception, tracking, and the transmission of specific commands over line-of-sight distances to the vehicle. This command capability will permit the proper orientation of Data Link and Telemetry antennas, insuring efficient read-out of reconnaissance information by the data link receivers in addition to the specific command capability required. A digital orbit computer will receive inputs from the microwave tracking radar in order to determine the future trajectory of the vehicle. The ground station sites and intercommunication techniques will be selected for optimum over-all performance.

21 b. Approach

A system of ground stations will be strategically located to provide efficient control and intercept of the vehicle. When the vehicle is in line-of-sight range from a station, a microwave radar system will acquire and track it and feed data to the orbit computer. Orbit computations will provide the basis for discrete program commands fed into the FM command transmitter. The high gain telemetry and data link receiving antennas will be coupled to the tracking radar system. The video output from the data link receiver will be available for decoding and data storage devices. The vehicle-borne data link antenna will be scanned so that the ground receiver can detect errors in its direction. These will be corrected over the FM command link.

The station locations are to be determined to provide maximum coverage while still preserving security. Inter-station communication systems are to be used, relying on a combination of wire lines and VHF scatter techniques as required.

21 c. Tasks of the Subsystem

The Vehicle and Control Ground Station development is divided into the following tasks:

1.a. Acquisition and Tracking Radar

b. Contractor: Lockheed Aircraft Corporation, Missile Systems Division.

c. A Microwave radar capable of acquiring and tracking the ARS vehicle at ranges out to 1500 miles line-of-sight, with high tracking accuracy.

DD Form 613-1, 1 Feb 56. Previous editions of this form may be used.

SECURITY CLASSIFICATION

SECRET

R&D PROJECT CARD
CONTINUATION SHEET

SECRET
SECURITY CLASSIFICATION

MSD 1536

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VEHICLE INTERCEPT AND GROUND CONTROL STATION SUBSYSTEM
(Unclassified)
(PIED PIPER)

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Secret

3. PROJECT NUMBER
1115

4.

5. REPORT DATE
1 March 1956

2.a. Orbit Computer

b. Contractor: Lockheed Aircraft Corporation, Missile Systems Division.

c. A digital computer to permit the computation of orbit parameters with sufficient accuracy and speed to predict the future trajectory of the vehicle to prevent loss of the vehicle and to permit interpretation of the reconnaissance data.

3.a. Command Transmitter

b. Contractor: CBS Laboratories

c. A high-powered FM command transmitter operating independent of the radar as the primary command technique.

4.a. Command Controller

b. Contractor: Lockheed Aircraft Corporation, Missile Systems Division.

c. A command unit associated with the tracking radar to permit the transmission of discrete commands over the radar link as directed by the orbit computer, by field requirements and by system operation. This is a backup command unit but is a capability inherent to the tracking radar.

5.a. Telemetry Receiving System

b. Contractor: Lockheed Aircraft Corporation, Missile Systems Division.

c. This equipment is required for the test phases of the program to receive and record pertinent data including pressures, temperatures, etc. for the development of the vehicle.

6.a. Data Link Ground Station

b. Contractor: CBS Laboratories

c. For Visual Reconnaissance a special high-performance receiver with associated high gain antennas capable of following the vehicle while within line-of-sight will be used. It will be under the control of the closely associated tracking radar and command link.

R&D PROJECT CARD
CONTINUATION SHEET

SECURITY CLASSIFICATION SECRET

MSD 1536

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
VEHICLE INTERCEPT AND GROUND CONTROL STATION SUBSYSTEM (Unclassified) (PIED PIPER)	Secret	1115
	4.	5. REPORT DATE 1 March 1956

This equipment must have interference rejection characteristics exceeding the generally accepted standards employed in television links at present.

The data link receiver will include a means to demodulate vehicle antenna scanning signals and to generate antenna tracking error commands for transmission to the vehicle.

A visual data recorder photographs the kinescope output of the data receiver and, using synchronizing pulses in the data link transmission, reconstructs the photograph as it was originally seen at the data link transmitter.

Electronic Reconnaissance data are transmitted over a PWM/FM telemeter link to the intercept and control station receiver. The ground station will be equipped to reconstruct the received data into digital form and to record it on magnetic tape.

7.a. Inter-Station Communications

b. Contractor: Lockheed Aircraft Corporation, Missile Systems Division.

c. A means whereby trajectory data and general communications can be exchanged between ground stations, either by land line or VHF scatter techniques, is required. It will be developed, or adapted from existing military or civilian installations as needed.

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MSD 1536

LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION

TABS

~~SECRET~~

Subsystem J - VEHICLE INTERCEPT AND CONTROL GROUND STATION

Tab 1 - General Design Specifications

I. GENERAL

A. Statement of the Problem

[illegible]

~~The Vehicle Intercept and Control Ground Station provides means for keeping track of the ARS vehicle; for receiving and collecting reconnaissance data; for controlling specific functions in the payload elements by discrete commands; and the intercommunication required between other ground stations, command headquarters, and intelligence evaluation locations.~~

B. Approach

A group of Vehicle Intercept and Control Ground Stations will be established. They will be located in a manner providing satisfactory coverage for the ARS vehicle both in the early test phases and in the later operational phases of this program.

Each station will employ a microwave radar for vehicle acquisition and tracking. Orbit parameters will be determined with the aid of a Digital Orbit Computer at each station location. The accuracy required is within the present state-of-the-art. The computed trajectory will permit prediction of the future trajectory of the ARS vehicle in order to assist in tracking acquisition and to provide geographical location tie-in of data as a function of the time of collection.

A Command Radio Link will be employed using high-power FM techniques to transmit up to 100 different commands to the vehicle. In this unit broad beam antennas on the ground will be used to "flood the sky" and permit very reliable command contact with the vehicle even in the event radar tracking is interrupted.

A Command Control unit designed into the tracking radar, and modifying the repetition rate or pulse spacing, will be used as a secondary command unit to transmit up to 10 discrete commands to the vehicle.

The Data Link receiving station for visual reconnaissance information includes steerable directional antennas as part of the ground station equipment. These antennas will be controlled in position by the associated tracking radar equipment. The receiver will derive vehicle antenna position error signals as the vehicle antenna is conically scanned. These error signals are then fed into the radio command link, and to the vehicle on-board data link transmitting antenna servos, which positions the vehicle data link antenna in a manner which aligns it with the ground data link receiving antenna. Data modulation is then transmitted over this link.

The ferret reconnaissance information is transmitted over a narrower bandwidth link making use of familiar PWM/FM telemetry techniques, and in fact, employing commercially available receiving equipment for this purpose. The receiving antenna will be directive and have in the order of 20-30 db gain as required. The received data will be reconstructed into digital form and recorded on magnetic tape.

In early phases of the ARS test program, Telemetry receiving equipment will be included in the complement of ground station equipment. The directive antenna arrays used with this equipment will be slaved to the tracking radar equipment.

Each ground station will operate as a complete unit but an interstation Communications Network will be used. Wire facilities are contemplated where station location permits. In other cases, HF communications and VHF scatter Techniques will be employed. This equipment is planned at present to be GFE until a more exacting indication of the requirements can be evolved.

A simplified block diagram of the ground station is shown in Fig. 1. It will be noted that the various sections of the ground station can be geographically separated but from the standpoint of logistical support of the operation, these equipments should be close together, and indeed, adjacent to ARS vehicle launching sites if possible.

Site selection is complicated by a number of factors including the desirability of achieving maximum tracking coverage on a variety of orbits; operational and domestic security; logistical support considerations including operator efficiency as affected by climate and working conditions; and finally, technical problems of transmission bandwidth, propagation factors, communication range between stations, etc. The map in Fig. 2 shows the recommended station arrangement. This three station arrangement with stations located in the vicinity of Portland, Maine, Honolulu, T.H., and San Francisco, California, gives adequate coverage while still providing good security and logistics support.

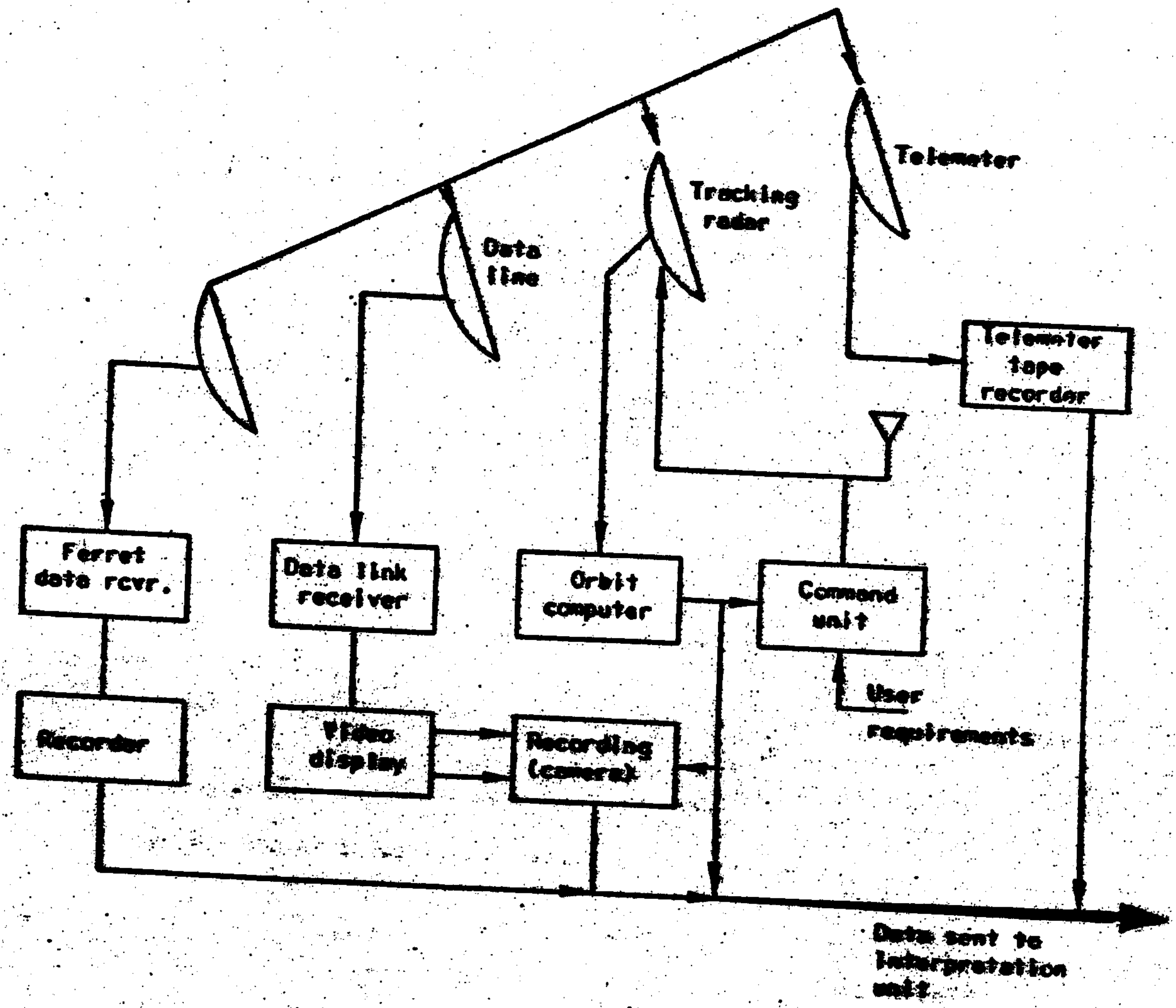
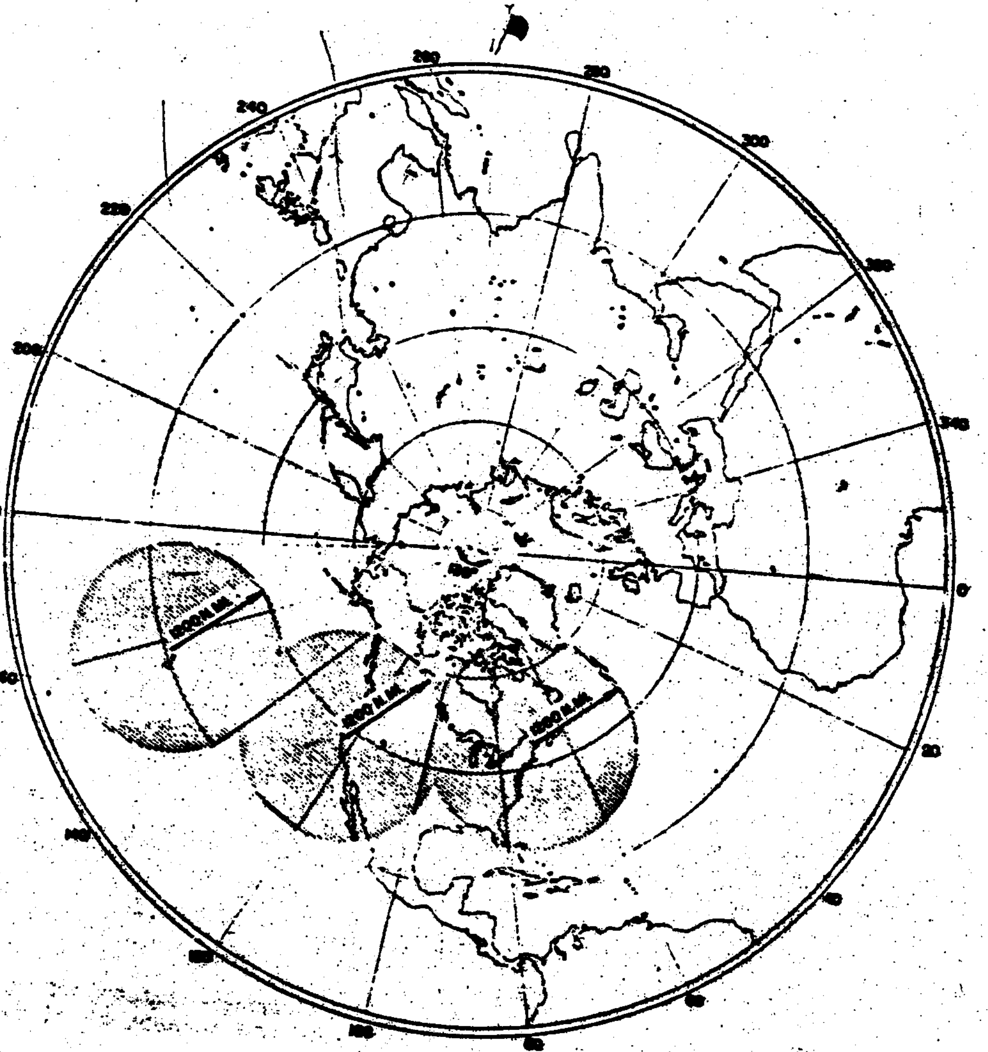


Fig. 1 Ground Station Simplified Block Diagram



Notes:

1. Stations at Portland, Me., San Francisco, Calif., and Oahu, T.H.
2. Contiguous coverage for 140° of longitude.
3. Intercepts 75% of all passes.
4. Misses 2 consecutive passes over east Siberia and Western Europe. Data stored till read out.

Fig. 1-1 Coverage by Three Ground Control Stations

Each ground station will acquire, track, receive and record data, perform orbit computations, etc. on an autonomous basis. The results of the orbit calculations will be made available to other stations and to a central information processing station via the Inter-station Communications circuit.

C. Solution and Recommendations

1. Operational Ranges or Limitations

The ground station equipment is to be designed to track the ARS vehicle out to 1500 n. miles range in all directions with an accuracy approaching ± 1 mil in azimuth and elevation and ± 0.5 miles in range. The two data links, the radio command unit, and the telemetry link will be capable of reliable operation during 80 per cent of the period the vehicle is under control of the associated tracking radar. The ground communications link will permit rapid and reliable data exchange from station to station.

2. Equipment Requirements

Specific requirements for the equipment forming a part of the Vehicle Intercept and Control Ground Station is discussed in detail in J-Appendix. Summarizing the equipment specified:

a. Radar

Initially, the currently available SCR-584 type, AFMTC-Mod. II equipment now going into operation at Patrick will be employed. The range extension problem is severe and it is realized that the range extension kits now being delivered to AFMTC giving 400 mile tracking will have to be improved. In view of the time scale involved and other factors discussed in J-Appendix this equipment is selected.

As the program progresses, the precision instrumentation radar, AN/FPS-16 (XN-2) being developed by RCA at Moorestown, New Jersey, will be brought into the system as rapidly as it becomes available. Other radar developments are also under constant surveillance for this task.

b. Orbit Computer

The orbit computer initially can be relatively straightforward, increasing in complexity as the multiple vehicle phases of the program appear. The basic objective of this equipment is the computation of orbit parameters with sufficient accuracy and speed to predict the future trajectory of the vehicle. A limited capacity digital computer is recommended, initially, followed by more elaborate equipment (Lincoln AICBM type) at later stages in the program.

c. Command Control

Two command links are supplied -- one an independent radio command, and the other a radar tracking link forming part of the tracking radar system. Certain critical commands may be transmitted over both links.

The radio command system is based on present state-of-the-art high powered (50 KW) FM transmitter techniques. A broad-beam antenna pattern is recommended to "flood" the sky with 100-250 mc radio command signals in order to insure maximum vehicle contact time. Up to 100 commands can be transmitted over this circuit and by judicious choice of audio tone combinations, a high degree of security can be obtained while reducing false commands to a minimum.

d. Data Link - Visual Reconnaissance

Two data link receiving equipments are employed. The first -- used for visual reconnaissance intelligence -- employes a 7500 mc circuit using a high gain steerable antenna slaved to the tracking antenna. This link will also receive error signals indicating the vehicle data transmitting antenna orientation. These latter signals when properly demodulated will be transmitted back to the vehicle over the radio command link to close the loop to correct the vehicle antenna in the optimum direction for air to ground data transmission.

A visual data recorder forms part of this task. This recorder photographs the kinescope output of the data receiver and, with the aid of synchronizing pulses in the received data, reconstructs the photograph as it was originally transmitted from the vehicle.

e. Data Link - Ferret Reconnaissance

In the ferret case, a much different technique is possible. A narrower bandwidth system employing presently developed PWM/FM telemetry techniques and operating on a carrier frequency in the 220 mc band will be used. In addition to the receiving equipment, moderately high gain steerable helix or other type antennas will be employed. The received data will be reconstructed into digital form and recorded on magnetic tape.

f. Telemetry

A Lockheed FM/FM 220 mc system currently in use on the RTV and other missile programs, is specified. This system with the addition of a higher powered radio frequency amplifier and high gain receiving helix antennas, will handle the earlier program phases. In the more advanced phases, a PWM/FM system may be employed.

g. Interstation Communications

Wire plus HF and VHF scatter techniques will be employed for the multitudinous task of communications in its many phases both in the test and operational stages of this program.

3. State-of-Art Feasibility

The ground station equipment all is within the state-of-the-art although considerable development and engineering design time is required before test hardware becomes available. Some of the critical areas include:

(1) Data Link receivers and antennas (CBS).

(2) Acquisition and tracking radar, range and zenith tracking problems.

(3) Propagation and solar energy effects on radar performance.

(4) Integration of orbit computer, radar, and command station.

4. Environmental Factors

If the ground equipment is operated in northerly latitudes, low temperature considerations become important. Special radomes which result in reduced system accuracy for the tracking radar may be required (See J-Appendix).

5. Special Development Tests

The usual laboratory and field tests will be required to develop the items specified. The special tests which are required will be derived from and be a part of the ARS vehicle development program which is described in ARS Systems Development.

6. Related Equipment Affected by Development Tests

The airborne beacon, airborne telemetering transmitter, airborne data link transmitter, command receiver and airborne command decoder are all related to the tests of the ground station equipment.

7. Station Reliability

Aside from natural and geophysical phenomena, no unusual reliability problems are anticipated in the case of this ground station equipment. Duplicate and independent equipment is recommended in most cases possibly including a second complete radar at each station. To further improve reliability, maintenance crews composed of trained contractors' civilian field engineers will tune up station equipment above the normal GI maintained performance level. Reliability will be improved by locating the stations in southerly locations to avoid the problem of polar and arctic operation.

8. Special Installation Considerations

The radar installations are influenced by the earlier discussion, and in addition should be located on relatively accessible peaks, giving unobstructed line-of-sight to horizon views in all directions. Due to the expense of the stations, where possible, existing housing and other military facilities should be used.

9. GFE

The basic ground station equipment with the exception of the data link will be largely GFE, with considerable MSD and CBS modification. The AFMTC Mod II and later the RCA AN/FPS-16 radar equipment will be government furnished. Other GFE will be the telemetry ground equipment, the orbit computer and the interstation communication link, along with all primary power equipment.

10. Subsystem Compatibility

The ground station discussed herein is compatible time-scale wise with the over-all ARS development plan schedule. The S-Band SCR-584 tracking radar specified has marginal performance but early availability, a monopulse C band set of the FPS-16 type is required for best performance but will not be available during the SRV program. This radar will be phased into the GTV and operational programs as soon as possible.

11. Curves, Charts

12. Schedule

13. Test

Shown by Tab 3 (ARDC Form 105).

14. Aircraft

Shown in Tab 4.

Subsystem J - VEHICLE INTERCEPT AND CONTROL GROUND STATION SUBSYSTEM

Tab 2 Summary - Subsystem Milestones

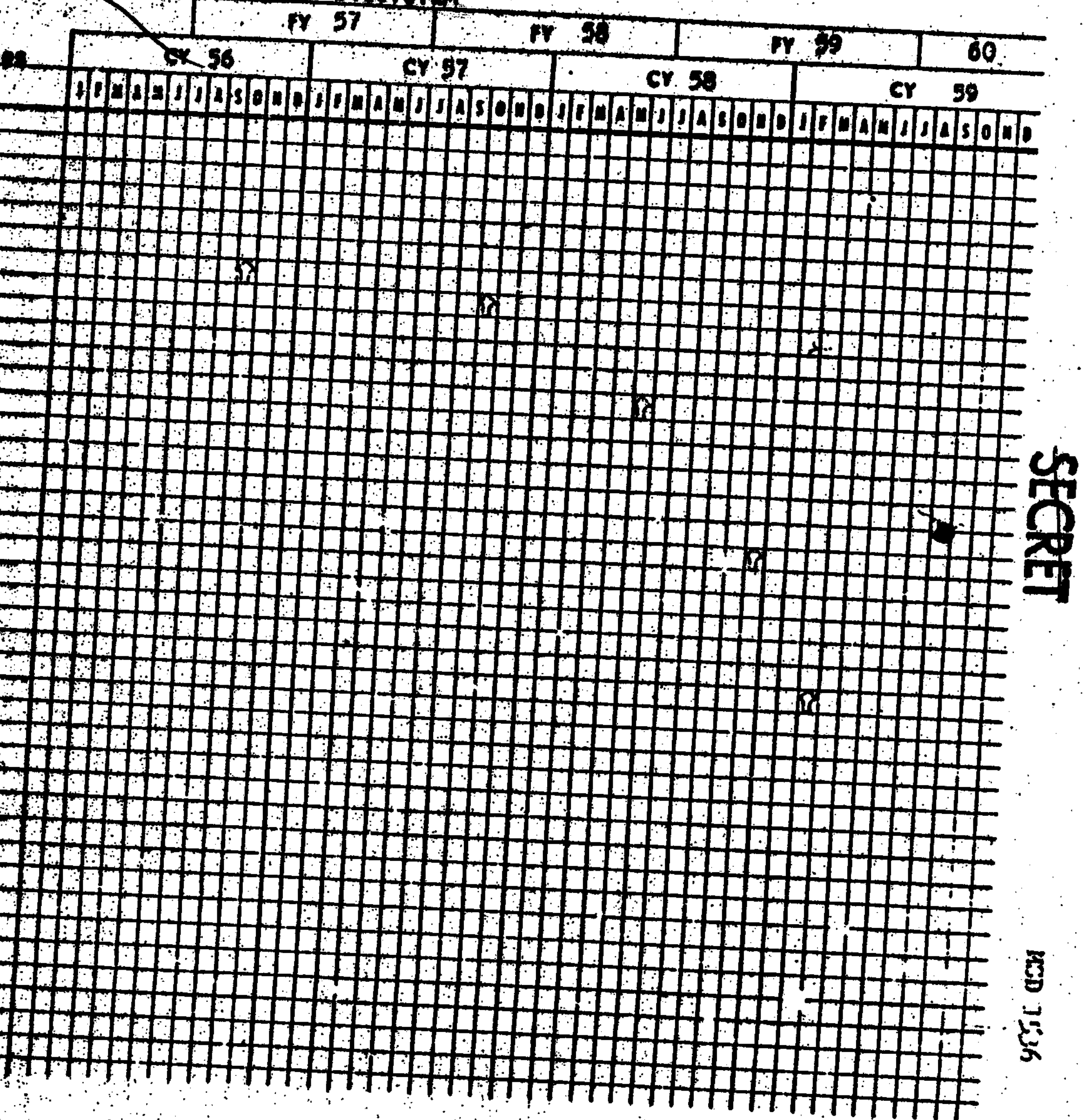
Control Ground Stations

AF-TD Station --
Initial Operation
Full Operation

West Coast Station -

Pacific Ocean Area Station

East Coast Station



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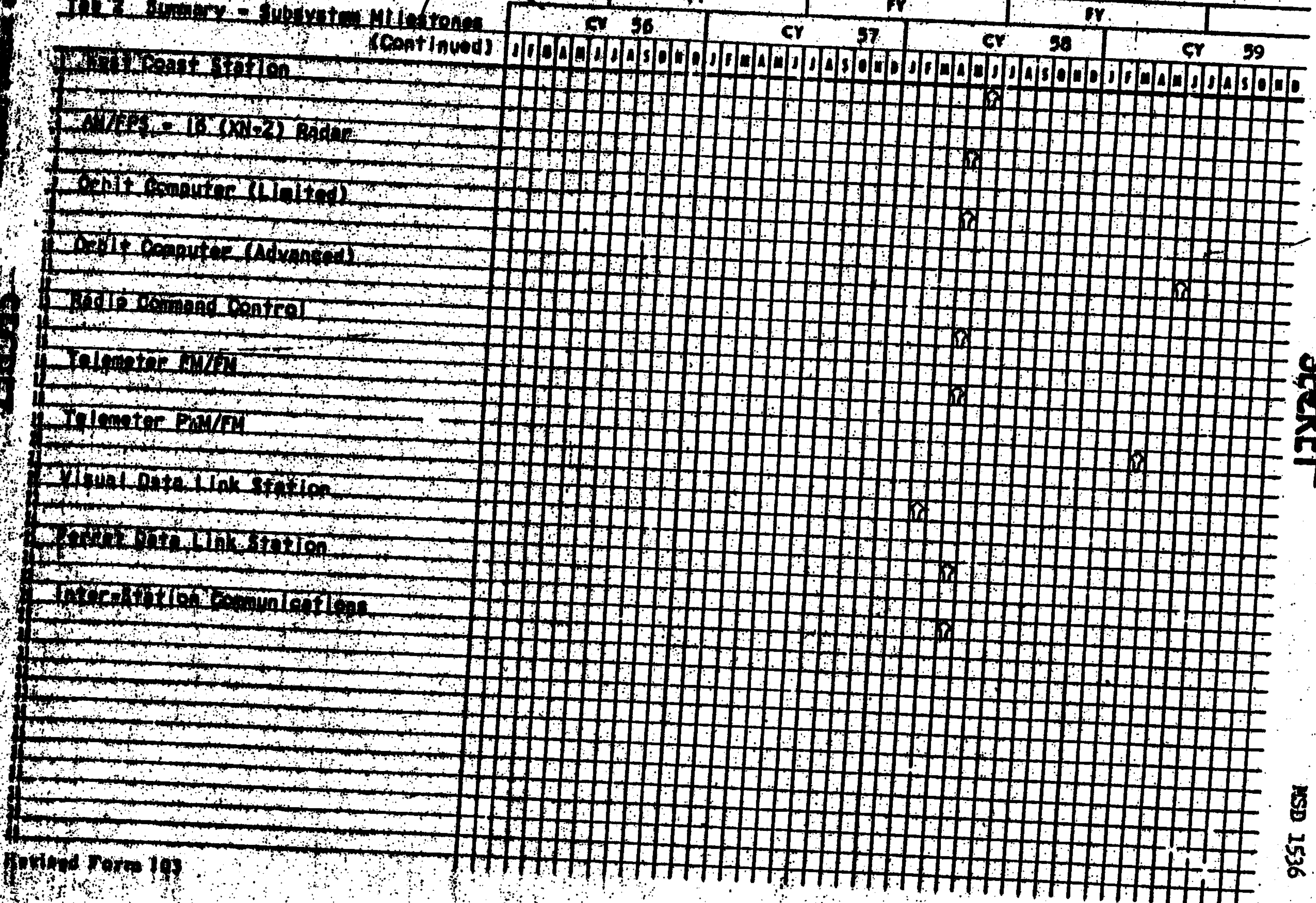
Subsystem J - VEHICLE INTERCEPT AND CONTROL GROUND STATION SUBSYSTEM

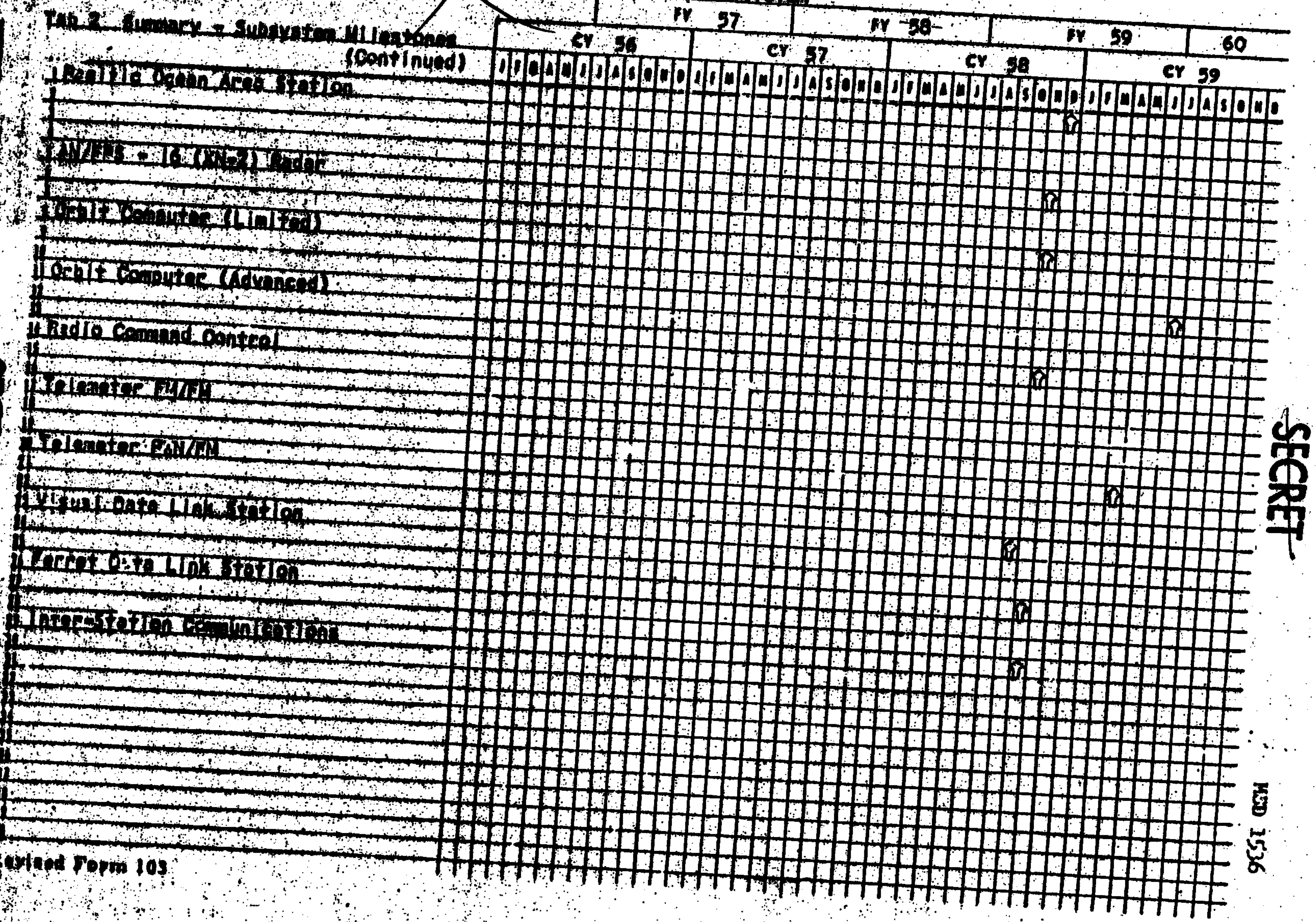
Tab 2 Summary - Subsystem Milestones (Continued)



Revised Form 103

Subsystem J - VEHICLE INTERCEPT AND CONTROL GROUND STATION SUBSYSTEM

Tab 2 Summary - Subsystem Milestones (Continued)



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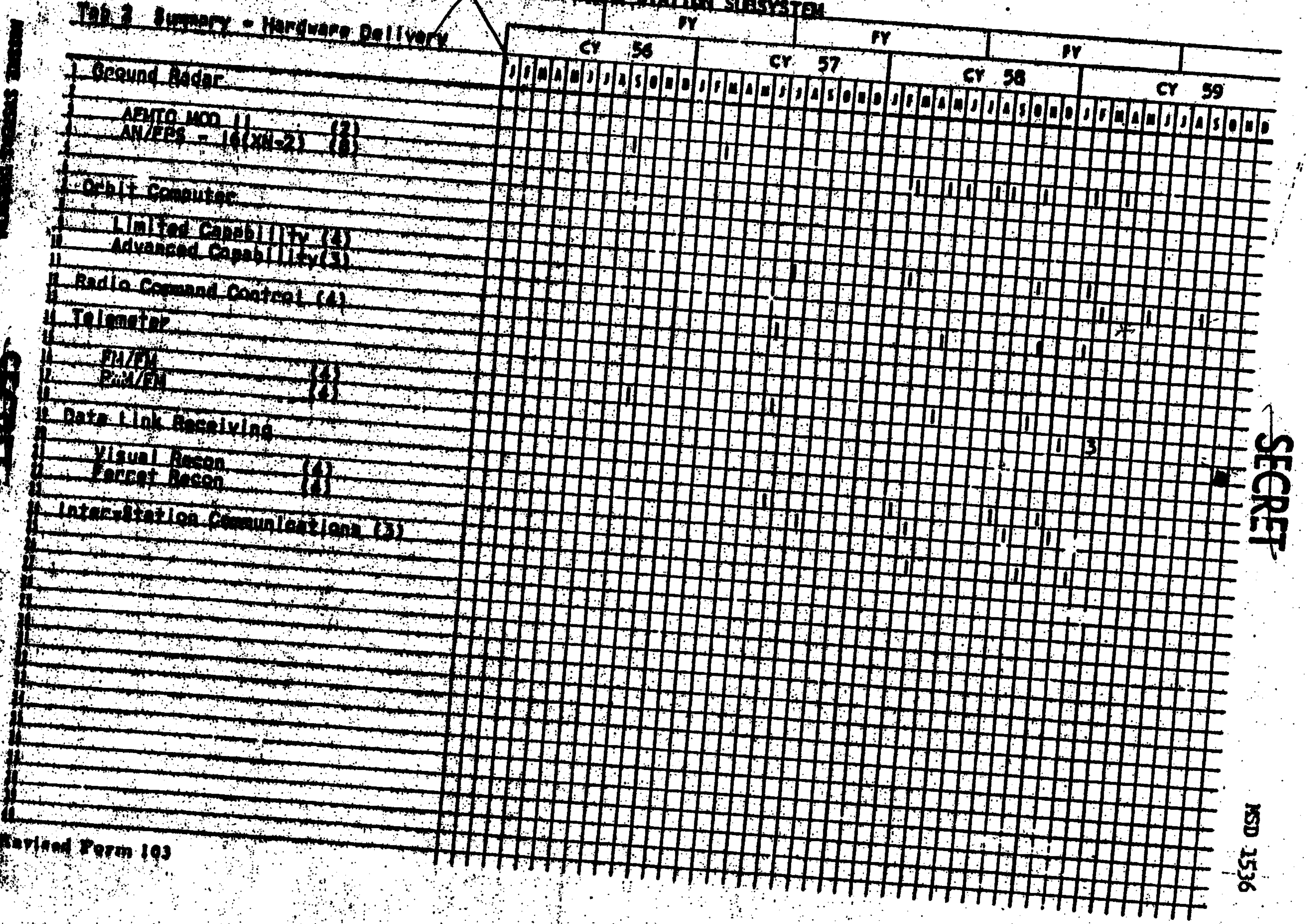
Subsystem J - VEHICLE INTERCEPT AND CONTROL GROUND STATION SUBSYSTEM

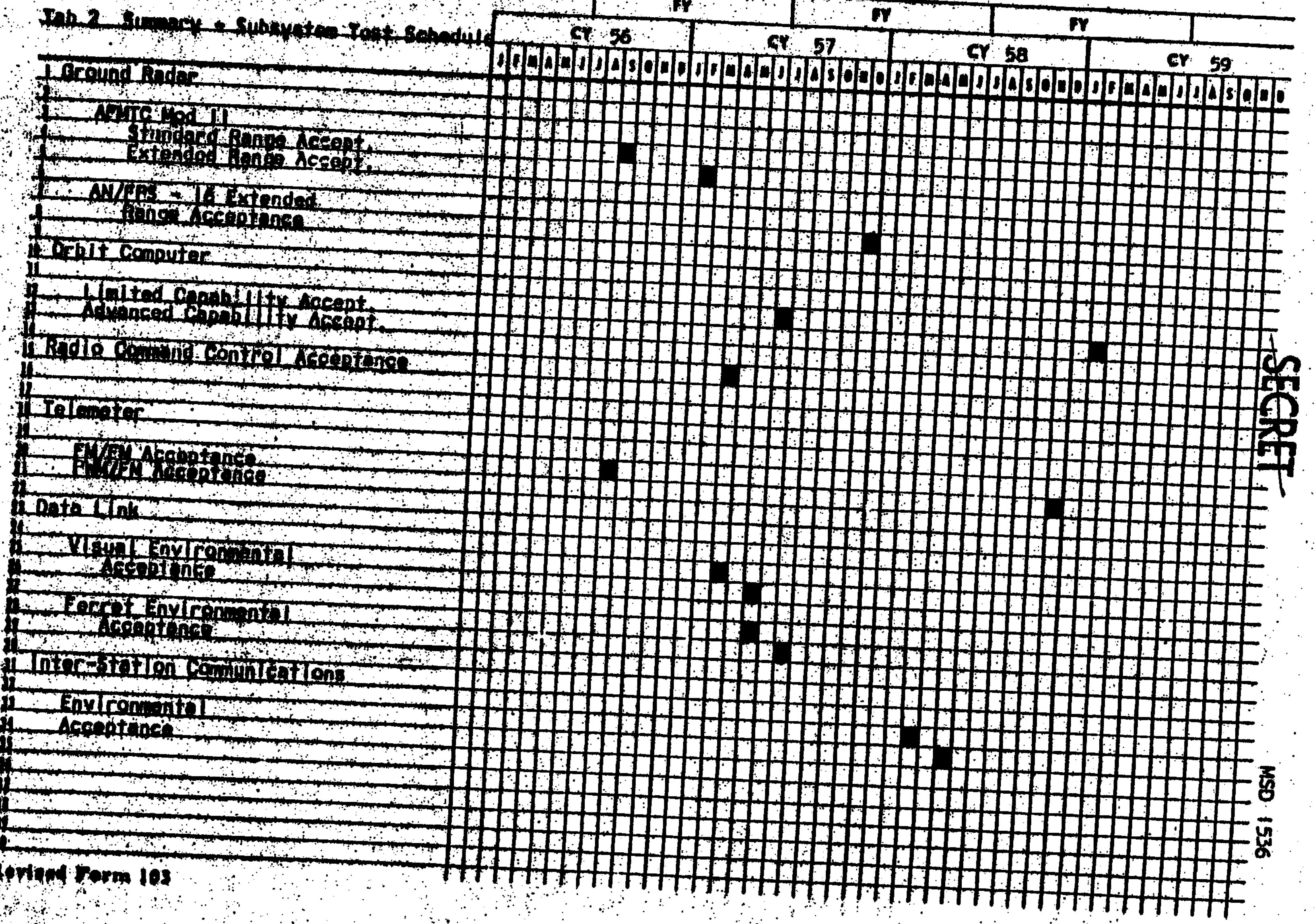
Tab 2 Summary - Hardware Delivery



Revised Form 103

Subsystem J - VEHICLE INTERCEPT AND CONTROL GROUND STATION SUBSYSTEM

Tab 2 Summary - Subsystem Test Schedule



Revised Form 103

SECRET

MSD 1536

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

1. REPORTS CONTROL SYMBOL

PAGE 1 OF 3 PAGES

2. DATE 1 March 1956

3. TITLE Subsystem J - VEHICLE INTERCEPT AND CONTROL

4. INITIAL ☒ CHANGE

5. NUMBER

6. RDT CENTER

7. PROJECT/SPONSOR

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. ROD TEST COMPL DATE
1	AFMTC Mod. II with Range Extension Kit	Target acquisition, tracking and range performance tests	AFMTC	Jan 1957	Feb 1957
2	AN/FPS-16(XN-2) with Range Extension Kit	Target acquisition, tracking and range performance tests	AFMTC	Nov 1957	Dec 1957
3	Digital Computer (Limited capacity--Exact nature to be specified)	Functional tests with specified inputs	MSD Inplant Facility	May 1957	Jul 1957
4	Digital Computer (Advanced capacity to be specified)	Functional tests with specified inputs	MSD Inplant Facility	Nov 1958	Jan 1959

ADDITIONAL UNITS REQUIRED AT EACH STATION AS PROGRAM PROGRESSES

TEST CENTER APPROVAL

20. NAME ORGANIZATION

21. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

DATE

ARDC FORM JUL 56 105 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

3. REPORTS CONTROL SYMBOL

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5. DATE 1 March 1956

4. TITLE Subsystem J - VEHICLE INTERCEPT AND CONTROL

6. NUMBER

7. INITIAL ☒ CHANGE

8. RESP CENTER

6. 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
5	FM Command Control Transmitter	Functional tests with specified commands (Development Tests)	CBS Labs.	Nov 1956	Feb 1957
6	FM Command Control Transmitter	Functional tests under field conditions (Acceptance Tests)	AFMTC	Feb 1957	Apr 1957
7	AFMTC Standard (FM/FM) Telemetry Ground Stations	Functional operation and inter-station coordination	AFMTC	Aug 1956	Sep 1956
8	ASCOP (PWM/FM) Telemetry Ground Stations	Acceptance Tests	AFMTC	Oct 1958	Dec 1958

TEST CENTER APPROVAL

20. NAME

ORGANIZATION

21. NAME

ORGANIZATION

DATE

RESPONSIBLE CENTER APPROVAL

22. NAME

ORGANIZATION

DATE

DATE

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J - Tab 3, p 2

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MSD 1536

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

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5. DATE 1 March 1956

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4. TITLE Subsystem J - VEHICLE INTERCEPT AND CONTROL

7. R&D CENTER

8. PROJECT OFFICER

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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. R&D TEST COMPL. DATE
9	Data Link Receiving Equipment - Visual	Functional Tests (Development tests)	CBS Labs.	Jan 1957	Mar 1957
10	Data Link Receiving Equipment - Visual	Functional Tests under field conditions (Acceptance Tests)	AFMTC	Mar 1957	Jun 1957
11	Data Link Receiving Equipment - FERRET	Functional Tests (Development Tests)	CBS Labs.	Apr 1957	Jun 1957
12	Data Link Receiving Equipment - FERRET	Functional Tests under field conditions (Acceptance Tests)	AFMTC	Jun 1957	Aug 1957
13	Interstation Communications Equipment	Functional operation over field ranges	AFMTC	Mar 1958	Jun 1958

TEST CENTER APPROVAL

20. NAME ORGANIZATION

21. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

DATE

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1\. R & D TEST AND TEST SUPPORT AIRCRAFT ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

MSD 1536

2\. REPORTS CONTROL SYMBOL

PAGE 1 OF 1 PAGES

3\. DATE 1 March 1956

4\. TITLE Subsystem J - VEHICLE INTERCEPTION AND CONTROL GROUND STATION

5\. INITIAL ☒ CHANGE ☐

6\. NUMBER

7. ITEM NUMBER	8. AIRCRAFT REQUIRED QTY.	TYPE, MODEL AND SERIES	SERIAL NUMBER	9. ASG CODE	10. MOD CODE	11. DATE REQD AND LOCATION	12. ESTIMATED RELEASE DATE	13. RECOMMENDED DISPOSITION	14. MOD COST	15. EST COST
		AIRCRAFT -								
		FLIGHT TESTS REQUIRED CALLED OUT IN VEHICLE ELECTRONICS SUBSYSTEM - H								

ARDC FORM 1 JUL 55 306 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

SECRET

MSD 1536

R & D MATERIEL ANNEX

☒ SYSTEM ☐ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 1 PAGES

4. TITLE
Subsystem J - VEHICLE INTERCEPTION AND CONTROL GROUND STATION SUBSYSTEM-ARS

5. INITIAL ☐ CHANGE

5. DATE 1 March 1956

6. NUMBER

7. MATERIEL REQUIREMENTS [illegible] (Use Columns as cited in Examples)

GOVERNMENT FURNISHED EQUIPMENT:

	DATES REQUIRED
1. 4 complete Ground Stations, includes:	
2 - SCR 584 Type, AFMTC Mod. II Radars	
8 - AN/FPS - 16(XN-2) Radars	Aug., 1956
6 - Digital Computers (Types to be specified)	Oct., 1957; Dec., 1957, Feb., 1958 Apr., 1958 (2 each)
4 - FM/FM Telemeter Receiving Stations	(Mar-Apr., 1957 (3 limited) (Oct-Nov., 1958 (3 advanced)
4 - PWM/FM Telemeter Receiving Stations	Aug., 1956; Mar., 1957; July, 1957 Nov., 1957
4 - Interstation Communication Systems	Sept., 1958
(Details to be determined)	Feb. - Aug., 1957

ARDC FORM JUL 56 107 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

SECRET

SUBSYSTEM J - VEHICLE INTERCEPT AND CONTROL

DATE 1 March 1956

ITEM: {INPLANT TEST FACILITY *
{AFMTC *

USING AGENCY: LOCKHEED MSD

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	L	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:

Revised Form 108

Tab 7

R & D Contract Funds

Subsystem J - Vehicle Intercept
and
Control Ground Station

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[illegible] J. [illegible]

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

	FY 57				FY 58				FY 59				FY 60	
[illegible]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
(1) Research and Development	40	71	89	121	132	184	224	250	270	285	294	329	314	134
[illegible]	113	201	256	344	453	497	533	549	549	517	457	437	217	439
Sub Total	154	272	344	465	586	681	757	799	820	802	751	766	531	574
Fee	15	27	34	46	58	68	75	79	82	80	75	74	53	57
TOTALS	170	300	379	512	645	750	833	880	902	882	827	843	585	631
Total Fiscal Year				1361				3108				3455		
Differences in totals due to rounding														

RSD 1536

[redacted] SECRET [redacted]

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Schedule 2. [illegible] (Cont'd)

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

	FY 60		FY 61				FY 62				FY 63			
	15	16	17	18	19	20	21	22	23	24	25	26	27	TOTALS
(1) [illegible] and Development	304	424	449	429	442	389	334	329	342	332	362	338	208	7,602
[illegible]	346	272	257	232	232	232	2	202	212	224	229	227	137	8,256
Sub Total	629	697	707	662	652	622	537	532	554	557	572	559	346	15,938
Fee	62	69	70	66	65	62	53	53	55	55	57	55	34	1,593
TOTALS	691	766	778	729	717	684	591	585	610	613	629	616	381	17,532
Total Fiscal Year		2616				2908				2399			1626	17,531

1/Differences in totals due to rounding.

[redacted]

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[redacted]

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Tab G

Estimate of Manpower Requirements

Subsystem J - Vehicle Intercept
and
Control Ground Station

[illegible] SECRET [illegible]

SECRET

Subsystem F. [illegible]

Tab A. Estimate of Manpower Requirements

WORK TYPE	TYPE OF MANPOWER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
[illegible] Research and Engineering	[illegible]	8	14	17	21	29	35	44	48	53	56	59	66	63	67
[illegible] Scientific and Engineering	1	8	13	15	19	22	25	26	27	26	25	23	23	11	14
[illegible] Engineering Support	2	8	15	21	30	36	43	48	51	49	47	43	41	26	27
[illegible] Manufacturing	4	5	10	13	18	22	24	25	24	22	19	14	12	0	0
Sub Total		21	38	49	67	80	92	99	102	97	91	80	76	37	41
TOTAL		29	52	66	80	109	127	141	151	150	147	139	142	102	[illegible]
Minimum:															
Tot Type 1 - Scientific & Technical															
Tot Type 2 - Engineering Support															
Tot Type 3 - Management & Administration															

SECRET

SECRET

[illegible] 7. [illegible]

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

WORK TYPE	TYPE OF MANPOWER	15	16	17	18	19	20	21	22	23	24	25	26	27		TOTAL MAN QUARTERS
610 Research and Engineering	1,2,3	77	85	90	86	84	78	67	66	68	66	68	66	41		1525
620 Scientific and Engineering	1	10	17	15	11	13	13	11	11	11	12	12	11	7		
630 Engineering Support	2	28	29	29	27	27	27	24	24	26	27	28	29	17		
640 Manufacturing	3	0	0	0	0	0	0	0	0	0	0	0	0	0		
Sub Total		38	46	44	40	40	40	35	35	37	39	40	40	24		1472
TOTAL		119	131	134	126	124	128	102	101	105	105	108	106	65		2997
Manpower																
101 Type 1. Scientific & Technical																
102 Type 2. Engineering Support																
103 Type 3. Management & Administration																

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Pied Piper

MSD 1536

LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION

APPENDIX

~~SECRET~~

Subsystem J

VEHICLE INTERCEPT AND CONTROL GROUND STATION

APPENDIX

1. GENERAL

The reconnaissance satellite system must include the means for removing reconnaissance data from the vehicle as it is collected; in addition some means to facilitate the correlation of data collected with its geographic source is required. Consideration has been given to vehicle recovery but the problems of re-entry, location, and recovery appear to be considerably more difficult than remote control and communication through a data read-out link. Furthermore, the time delay from data collection to receipt is minimized with a data read-out system.

The path of the vehicle can be predicted with rather high precision from observation of its motion. Since aerodynamic drag is not completely negligible, the motions of the ARS vehicle are somewhat less predictable than the motions of celestial bodies. Tracking of the vehicle with radar or optical means is then required in order to measure the effects of this drag and to maintain current estimates of the significant orbit parameters required to obtain a position-time correlation.

Optical tracking of the vehicle is apparently limited in application to favorable sun azimuths and to a 1/2 hour period in the evening (Ref. 1). Due to this limitation, and because optical tracking does not provide range data, radar tracking is considered essential.

[redacted]

[redacted]

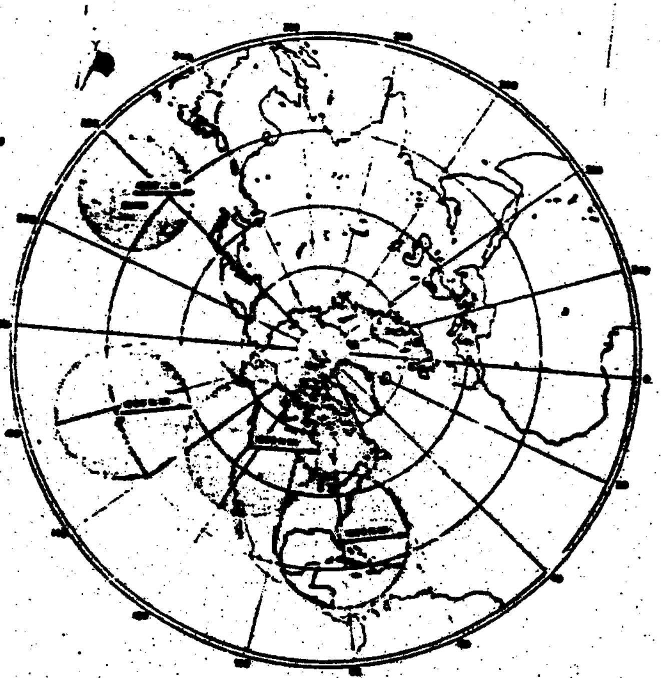
The automatic tracking radar system will be used for pointing directional reconnaissance data link and telemeter antennas at the vehicle as it passes within communication range of the ground station. The radio transmissions, modulated to contain command control information, will be transmitted to the vehicle.

While the ARS tracking and communication stations need not be directly associated with the launching sites, it is nevertheless desirable from a standpoint of logistical support. The tracking and the data link receiving stations must be located together, since the high gain of the data link receiving and telemetering antennas requires that they be slaved to the radar tracking antenna.

In selecting sites for these stations consideration has been given to problems of logistical support and operational and domestic security, as well as the technical problems of transmission band width, communication range, etc. A system of three stations located at sites in the neighborhood of Portland, Maine; Seattle, Washington; and Honolulu, T.H. appears to provide a satisfactory operating system, Fig. 1-1.

While consideration has been given to location of data read-out stations in the vicinity of the North Pole, at Thule, Greenland, and along the DEW line in Northern Canada, it is felt that these stations should be maintained in the Continental U.S. and its territories. This arrangement provides satisfactory logistics and communications, but, more important, it provides the U. S. with political control of the stations and the information derived from them. In addition, this location places the communication

Notes:
1. Stations at AFMTC, Seattle, Wash., and Oahu, T.H.
2. Contiguous coverage for 120° of longitude.
3. Intercepts 67% of all passes.
4. Misses 3 passes over east China and western Europe. Data stored till next read out.
5. Station at Guam would improve coverage.



Notes:
1. Stations at Portland, Me., San Francisco, Calif., and Oahu, T.H.
2. Contiguous coverage for 140° of longitude.
3. Intercepts 73% of all passes.
4. Misses 2 consecutive passes over east Siberia and western Europe. Data stored till next read out

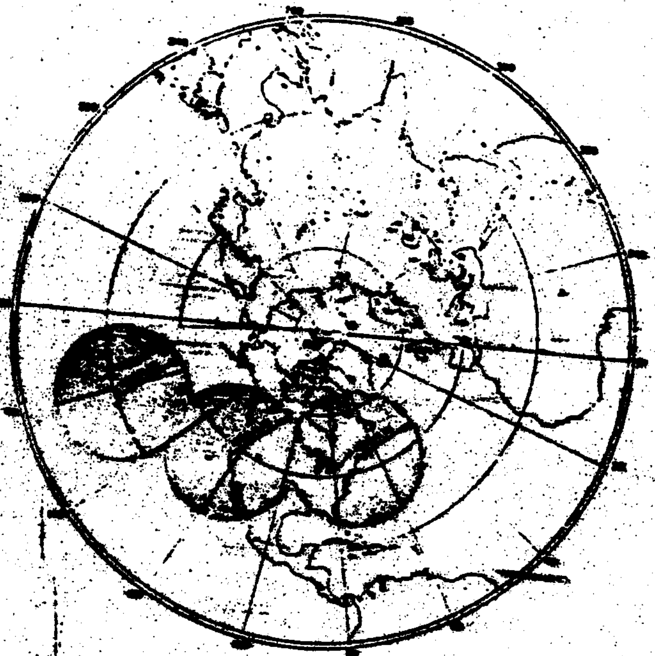


Fig. 1-2 Sites of Communication Stations

or readout cycle of the vehicle over territory friendly to the U. S. and reduces the chance of unfriendly interception and control of the ARS vehicles.

An analysis of the operational advantages of several systems of stations appears in Ref. 2. The referenced analysis shows the band width required for effective read-out of visual reconnaissance data to be 20 megacycles or less for the chosen system of stations.

Because test launchings will occur at AFMTC and also since West Coast launchings in California may be considered, the effect of moving the two U. S. stations north and south along the east and west coasts has been examined. Fig. 1-1 shows how the coverage is affected by the locations of the East Coast Station and the Pacific Ocean Station. Coverage is not materially changed by changing the location of the West Coast Station; accordingly, the vicinity of San Francisco is shown on the diagram as typical.

Each control and intercept station will be capable of autonomous operation. It will track, receive data, and perform orbit computations without need for data input from other stations. The results of orbit calculations will be made available from other stations as available.

A typical ground control and intercept station is shown in the block diagram in the General Design Specification, Tab 1.

The several Vehicle Intercept and Ground Control Stations must be interconnected with data and command communication links, but otherwise each station must be capable of autonomous operation. In addition to the

Data Link and Telemetering Receivers and the Command Control Unit, each individual station will employ means for acquisition and tracking of the vehicle. Orbit parameters will be determined with the aid of an orbit computer at each station and will be refined with each successive pass.

As a result of the study it is clear that the ground control installations will require the application of specialized skills in construction, radar systems engineering, and range instrumentation. Accordingly, Lockheed has given consideration to subcontracting this work.

Several potential subcontractors have been considered and assurance has been obtained that satisfactory arrangements for this work can be made with the Ralph M. Parsons Company of Pasadena whereby Parsons would assume the task of constructing the ground stations, installing, adjusting and calibrating all of the ground station equipment, and setting up necessary inter-station communication networks.

The Parsons Electronics Division has considerable systems experience in range instrumentation work, including various types of missile tracking systems, navigation projects, range tracking and timing systems, miss-distance indicator equipments, telemetering, aerometric instrumentation, micrometeorological investigations, data handling systems, and specialized airborne and ground test equipment for airplanes and missiles.

[redacted] [redacted]

2. GROUND DATA LINK

2.1 Visual Data Link

The receiving equipment of the Visual Reconnaissance Data Link forms a task within the Vehicle Intercept and Control Ground Station Subsystem. This equipment, to be developed by CIS, is discussed in more detail in another appendix.

This Visual Reconnaissance Data Link is similar to the ferret station except that in order to realize the required signal-to-noise ratio at the range and video band width, the ground antenna must have a high gain and operate in a tracking mode. The operating frequency in the case of the visual link will be 7.5 kmc. The following calculations determine the ground station parameters:

The minimum usable signal, S_{min} is given by

$$S_{min} = \frac{S}{N} \overline{KT}\ \overline{NF}\ \beta$$

$$S_{min} = 95 \text{ dbm}$$

where

S/N = 40 db = minimum signal to noise ratio (power)

KT = -204 db w/cycle

NF = 9 db

β = 10 mc

The necessary transmitted power to complete this link has been calculated using the following characteristics:

Receiver Usable Signal = -85 dbw

Range = 1400 mi

Receiver Antenna Gain = 50 db

Transmitter Antenna Gain = 35 db

Transmission Loss Coeff. = 3 db

The ground antenna for this visual link will be a circularly polarized parabolic antenna with a directivity of 53 db. The antenna will have a gain of 50 db for a linearly polarized signal.

Expressing parabola directivity as:

$$D = 8\pi\left(\frac{r}{\lambda}\right)^2$$

$$\text{Diameter} = 2r = 20 \text{ feet}$$

This antenna will be steerable, and servoed from the beacon tracking link to keep the antenna continuously pointed at the vehicle. A modified gun mount will probably be used to mount the antenna.

The receiver will employ standard microwave techniques except that a rapid frequency scan technique will be employed. In this unit the receiver local oscillator will be initially swept over ± 1% in frequency to accommodate vehicle transmitter drift, and then locked on when acquired.

Balanced mixers and possibly TW tube techniques may be employed. The receiver characteristics will include a noise figure of 9 db, and a 10 mc band width.

2.1.1 Vehicle Data Link Antenna Tracking

Fig. 2-1 is a simplified block diagram of the vehicle to ground signal links. The "time chart" for vehicle acquisition and data transmission is given below.

[illegible]

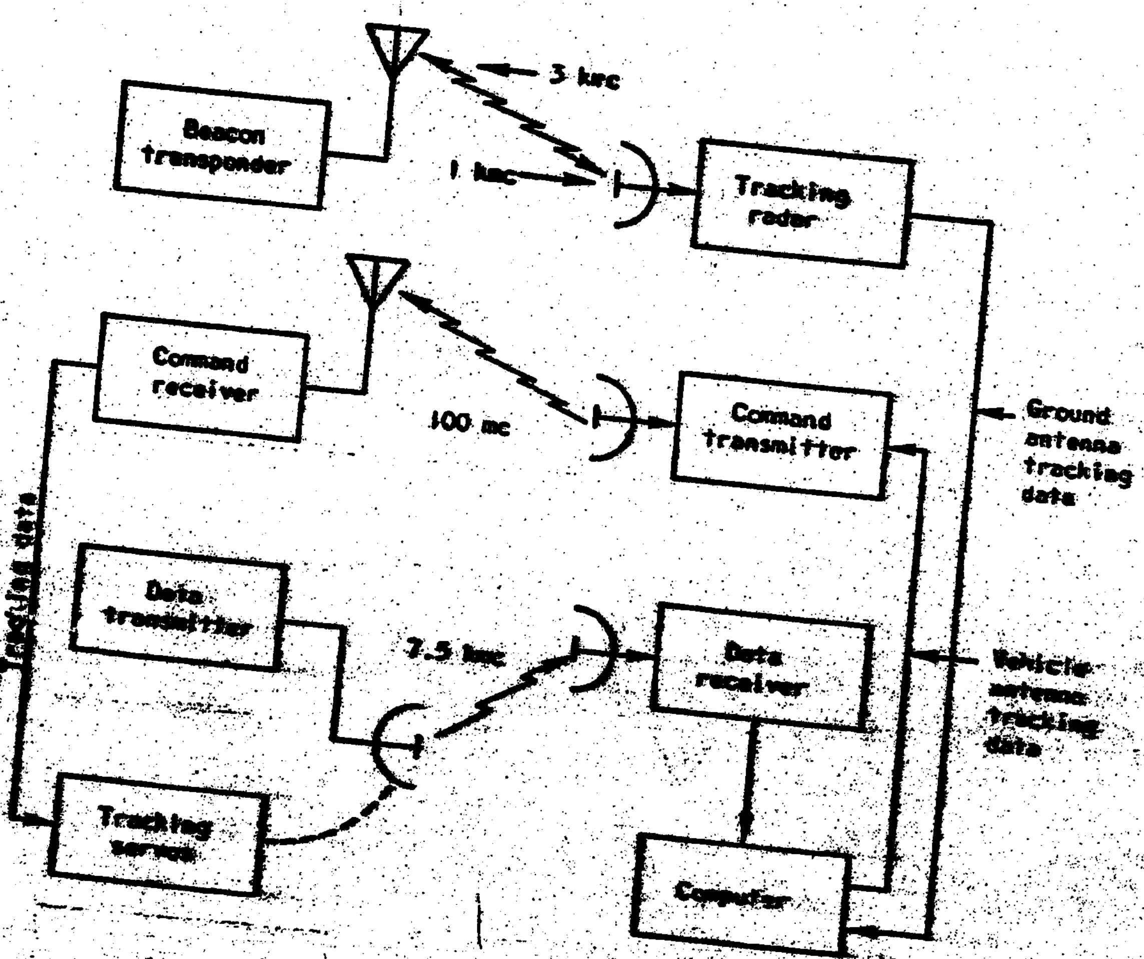


Fig. 2-1 Vehicle-to-ground Signal Loops

1. Programmer turns on command receiver.
2. Command transmitter sends signal to command receiver to turn on beacon transponder and data transmitter, but without data modulation. Data transmitting antenna is conically scanning (local search).
3. Radar interrogates and tracks on beacon, sending vehicle position data to computer, which also receives vehicle antenna position data from data receiver.
4. Computer sends vehicle antenna tracking data through command link to vehicle tracking servos (eliminating the need for airborne tracking receiver and computer).
5. When both ground and vehicle antenna tracking errors indicate lock-on, computer, through command link, turns on data modulation.
6. As vehicle leaves tracking range, computer, through command link, slews vehicle data antenna to azimuth for next interrogation (succeeding orbital pass over friendly territory).

To describe the operation of the Visual Reconnaissance Receiving Station it is necessary to go into some detail on the overall air-ground operation of this data link.

<u>Vehicle Circuits</u>. Fig. 2-2 is a block diagram of the vehicle station data circuits and tracking loop. When the command is received from the ground station, the command receiver turns on the data link transmitter without modulation. Simultaneously the antenna starts to scan conically at 30 cps which generates a reference signal to indicate the antenna position phase in the conical scan with respect to a fixed position. This reference signal modulates the data transmitter amplitude.

The ground station sends error data through the common channel to drive the vehicle antenna to the line of sight position. When these error signals reach a predetermined minimum value, the data link is completed.

The ground computer keeps the vehicle and ground antenna continuously pointing at each other until the data has been completely transmitted or until contact is broken. At this time it computes the presetting of the vehicle antenna for the next orbit or next read-out station, and turns off the system, thereby completing the cycle.

<u>Ground Circuits (Fig. 2-3)</u>. When the ground station expects the vehicle to reach the horizon, the command antenna, the radar tracking antenna, and the data receiving antenna are all positioned at the calculated direction of intercept. The command link then orders the vehicle beacon to "on". The radar tracking link proceeds to the search-acquisition mode.

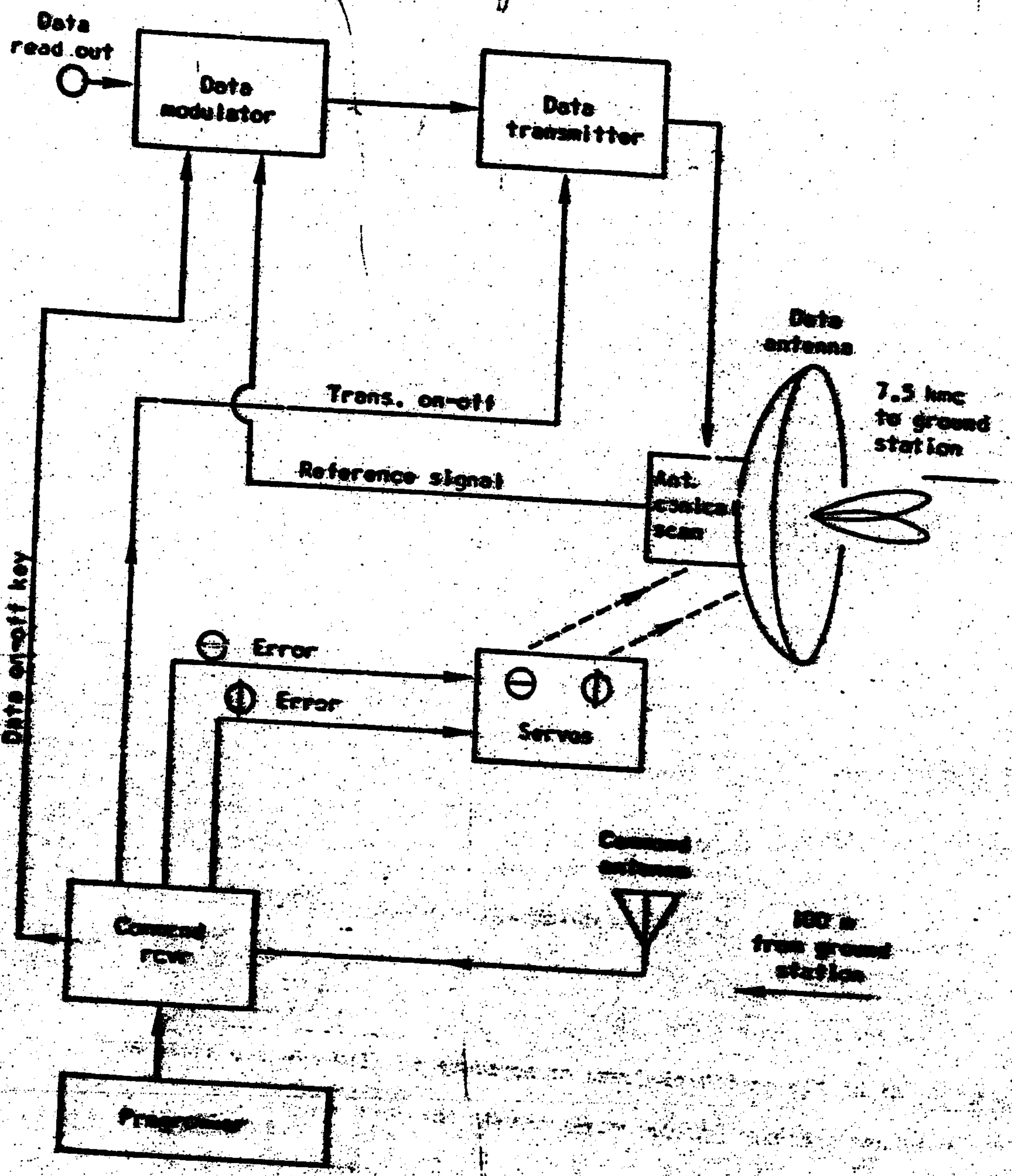


Fig. 2-2 Vehicle Station Data and Tracking Loop

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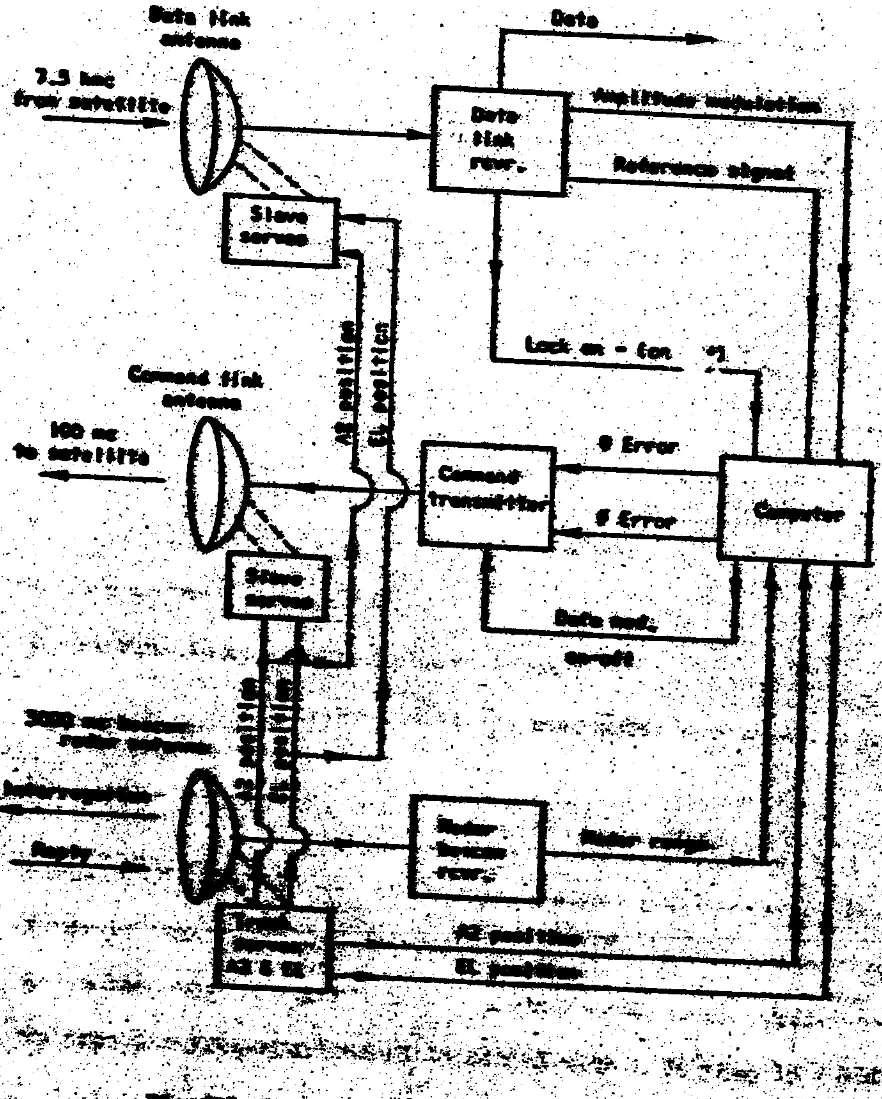

Fig. [illegible] Ground Station Tracking Loop

When the tracker has been locked on and the other two antennas are slaved to it, the command link turns on the vehicle data link transmitter and conical scanner. When the error signals show that the ground and vehicle data link antennas are on the line of sight, the reconnaissance data are frequency modulated onto the data link. The received signal therefore contains the wide band (± 5 mc deviation) video and narrow band reference signal, in addition to the amplitude modulation at the 30 cps conical scan rate.

The amplitude modulation is removed and compared with the reference for tracking information. The amplitude limited signal is then processed in the FM data read-out analysis circuits.

This process continues until all data is read out or until contact is broken. At this time the next station information is sent to the vehicle and the cycle completed.

2.2 Ferret Data Link

The receiving portion of the Ferret Data Link makes use of telemetry techniques currently in use in other programs. It has been decided to use telemetering equipment which is currently available in the 215 to 235 mc band. A survey has shown that telemetering transmitters are available which can withstand 500 g shock, and which have a power output of 50 watts. One such equipment weighs three pounds and requires an input power of 125 watts. Using this equipment, 40 and 70 kc subcarriers will be pulse-width modulated for data transmission. The following calculation shows that adequate signal to noise ratio can be obtained at the telemetering receiver using this transmitter and suitable vehicle and ground antennas.

The equipment parameters are:

P_T = transmitted power = 50 watts

β = Band width = 350 kc.

$\overline{NF}$ = Receiver noise figure = 5 db.

The vehicle to ground ferret data link will require a combined antenna gain of approximately 25 db for satisfactory telemetering communication at 1400 miles slant range. A single helical antenna having a 25 db gain would require 50 turns and 65 feet axial length. An area array for the ground receiving antenna would be more desirable. Either the vehicle or ground antenna may be circularly polarized.

The vehicle antenna will be a small vertical helix which has a gain of approximately 4 db at the horizon relative to a vertical dipole. The polarization of the transmitted signal will be elliptical, with the eccentricity running the full range of values as the angle of radiation is varied. Therefore, the ground station will employ diversity receivers, one for horizontal, and one for vertical polarization. The antenna will be a 12' x 12' x 3' deep mattress array of 6 vertical and 6 horizontal dipoles with directors. Each bay will have a gain of 25 db and the receiver outputs will be combined to preclude fading due to the disappearance of one or the other polarization at the receiving antenna.

Introducing the values G_R = 21 db, G_T = 4 db into the transmission equation, and assuming all transmission losses, including holes in the antenna patterns due to interference to total 24 db, a value of

$$\frac{S}{N} = 16 \text{ db}$$

is calculated. This value is adequate for telemetering communication.

2.2.1 Diversity Receivers

The signals from the satellite data link are at their lowest level at the output terminals of the receiving antenna, and they are therefore most vulnerable to interference and noise at that point. To reduce the losses inherent in the antenna ground station transmission line, a low noise preamplifier will be located at the antenna to amplify the incoming signal before applying it to the transmission line.

The type APA-a preamplifier is a low noise, high gain wide band, two stage RF amplifier, manufactured by Applied Science Corp. of Princeton. It is housed in a waterproof box so that it can be located on the antenna exposed to the weather. The power supply which contains monitoring facilities is located remotely at the ground station.

The receiver [illegible] used will be a standard Clarke type 16/E telemetering receiver which amplifies and demodulates the incoming data signal. Its output is composed of all the subcarrier signals that originally modulated the transmitter aboard the vehicle. The standard receiver covers 175-260 mc [illegible] with a noise figure of less than 9 db and a band width of ± 250 [illegible] discriminator is sufficiently linear to pass the frequency [illegible] with less than 1% total harmonic distortion. The receiver band width can be reduced with minor modifications to improve the signal to noise ratio at the output. The receiver has a discriminator tuning indicator and a signal strength meter to aid in tuning.

A significant signal-to-noise ratio improvement results when the preamplifier is used ahead of the receiver. This is shown by the equation for the overall noise figure which is:

$$F_{ab} = F_a + \frac{F_b - 1}{G_a}$$

F_a = preamplifier noise figure = 1.7

G_a = preamplifier gain = 40

F_b = noise figure of receiver = 5 (selected tubes)

F_{ab} is therefore = 1.8 = 2.5 db

The internal noise power developed in the receiving system is therefore only 1.8 times theoretical noise power $KT \Delta F$.

2.2.2 Ground Data Recording and Reproduction for Ferret Reconnaissance System

The output of the data receiver will normally be connected directly to the input of the Data Reconstruction Equipment which will have a high enough operating speed to allow it to keep up with the incoming signal without any need for storage. The possibility of failure in the data reproducer, however, makes it mandatory to have some means of storing the incoming signals and delivering them to another location for processing. For this reason, a standard Ampex Model 300 recorder operating at 60 inches per second will be used to store the 40 and 70 kc subcarrier outputs from the receiver.

The data reconstruction system is described in detail in Ref. 3.

3. GROUND RADAR EQUIPMENT

The early date for initial operations of the Pied Piper vehicles precludes the development of new, special radar and beacon equipment for acquisition and tracking of the vehicle, until after the vehicle development program is complete. Investigation shows that the 3,000 mc SCR-584 type, AFMTC - Mod II tracking radar in conjunction with an MSD developed beacon will permit acquisition and tracking at ranges up to 1,500 n. miles, but without directional antennas on the vehicle the performance is marginal. The method for utilization of these equipments entails visual detection and tracking of the blip on type "A" oscilloscopes by experienced engineers who will keep the various equipments in peak operating condition. It is recognized that this situation cannot exist and function properly for more than the first several flights, but it is proposed as an interim solution for readily available systems until more adequate equipment is developed. The later phase radars and beacons require additional gain in the beacon-transpond path over that achieved with the AFMTC - Mod II. This additional gain may be achieved by operation at a lower frequency in which case an entire tracking radar system must be developed, or more simply by increasing the capability of the basic SCR-584 and the vehicle beacon.

The newly developed AN/FPS-16 (XN-2) radar, which operates at three megawatts peak power at C Band, and uses monopulse techniques, appears [illegible] attractive as a later operational equipment because of ease of acquisition and from a tracking range standpoint.

The SCR-584 AFMTC Mod II radar can employ a limited command function, performed by a 3-pulse code group transmitted to the beacon in the interim system, and, if necessary, in the later-phase system. Information on the RCA FPS-16 radar indicates that it possesses greater command-code generation capability.

In any tracking problem of this kind, consideration should be given to systems such as Azusa and the ICBM Radio Inertial Guidance Radar. For reasons of availability, and since analysis of the orbit computing problem shows it is not essential, these radars have not been scheduled into this development plan. If future study should indicate that such equipment is needed for precision, or ease of acquisition, or if they are available, then such equipment should be employed in the ARS program.

The characteristics of a radar system and a vehicle beacon capable of detection and tracking at a maximum range of 1,500 miles can be established, and are realizable with present-day techniques. However, in view of the early date for launching first models of the vehicle, it is advisable that presently available radars be used for initial launchings. Modifications to the radars will be permitted, but they should be kept to a minimum to meet schedules. A review of tracking radars indicates that, while tracking systems have been made at nearly all frequencies utilized for radar, they are available in quantity only in the 3,000 mc, 6,000 mc and 10,000 mc bands. Propagation investigations[1] have shown that the errors in angle indication are not excessive at 3,000 mc and above. On the other hand, the attenuation suffered through the troposphere is not excessive at frequencies of 3,000 mc and below. The 3,000 mc band seems to be a fortunate choice from a propagation standpoint, and in addition, tracking systems at that frequency are available.

3.1 AFMTC - Mod II, Beacon Considerations

A number of SCR-584, AFMTC Mod II radars are available at Patrick AFB where the initial launchings will take place. In addition to immediate availability, this system meets the requirements for accuracy. Table I contains the pertinent parameters, as supplied by AFMTC personnel. Using these parameters, the performance of the tracking system will be examined.

3.2 Range Considerations

If the vehicle receiving antenna has a gain of unity (effectively omnidirectional), the available beacon-receiver power is given by the radar equation. If values for the SCR-584 Mod II are substituted with R = 1,500 n. miles, we obtain

$$P_r = 1.08 \times 10^{-8} \text{ watts}$$

$$= -50 \text{ dbm}$$

3.3 Beacon Characteristics

Production beacons have a sensitivity figure associated with them which varies from about -45 dbm for a beacon employing a crystal

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[1] Losses and range and angle errors which are functions of frequency are reported separately in Sec. 4 of this appendix.

video receiver to about -70 dbm for one with a superheterodyne receiver. This figure of sensitivity is based not only upon the noise figure of the receiver itself, but on an arbitrary signal-to-noise ratio which is necessary to insure "reliable triggering". This latter term is used somewhat loosely, but implies that, with an interrogating signal strength corresponding to the sensitivity figure, the beacon will be triggered 100% of the time, having only a small number of triggers (½% of the interrogation rate) allowed which are caused by noise interrogation. In practice, the signal-to-noise power ratio must be about 10 to achieve the "reliable triggering" condition.

A comparison of these numbers shows that a beacon with a crystal-video receiver will not be interrogated reliably by the SCR-584 Mod II at a range of 1,500 n. miles. On the other hand, one with a superheterodyne receiver will have a S/N ratio nearly 20 db over that required for adequate triggering. A 3 db loss is experienced with the conical-scan crossover, and the maximum estimated one-way tropospheric attenuation (at 3° elevation) is about 4 db; thus about a 13 db excess S/N remains over that required. It seems reasonable that the beacon will be reliably triggered at a range of 1,500 n. miles.

In the other direction, however, the picture is not so bright. Presently available S-band beacons of practical size have peak powers of the order of 250 watts. The same equation is applicable, with the peak transmitter power replaced by 250 watts. The available power at the radar antenna terminals is:

$P_r = 9 \times 10^{-13}$ watts

$= -90.4$ dbm

Thermal noise level for the 3 mc band width of the SCR-584 Mod II receiver is -109 dbm. From Table I (p 33), the receiver sensitivity is given as -97 dbm for reliable tracking and this includes the 3-db loss associated with the scan crossover. This would imply that the receiver noise figure would be at most 9 db. It is possible to produce an S-band receiver with a 9-db noise figure, but quite difficult to maintain it at that level in field operation. Assuming no field degradation of the radar for the moment, this would provide an excess of 7 db over the "reliable tracking" figure. The worst atmospheric attenuation at 3° elevation is about 4 db (of which oxygen contributes about 1.5 db). This worst condition is calculated for the ray traveling through a heavy thunderstorm 200 miles in extent. Under this condition, a 3 db excess signal would result. Both the oxygen and rain attenuation decrease rapidly as the elevation angle is increased. At 5°, for example, the attenuation drops to 2.6 db, while at 30°, the total attenuation in the thunderstorm condition described above is 0.5 db.

At an elevation angle of zero degrees and under severe atmospheric conditions, the signal strength received from the beacon will not be large enough. Moreover, even with the radar in optimum condition this safety margin remains very small at larger angles where the tropospheric attenuation is negligible.

In addition to the low signal-strength safety factor, an additional problem of jamming and false beacon interrogation must be faced with operation in the S-band which is filled by airport surveillance system, etc. It is proposed that for this system, radar and beacon transmitting tubes be selected to operate outside the normally used band. It is believed that the radar RF components will be sufficiently broad band to permit this type of operation. This frequency separation and the use of a coded beacon interrogation should largely overcome the interference problem.

3.4 Improvement Techniques

The signal strength can be directly improved by the increase of any or all of the following:

1. Radar receiver sensitivity
2. Radar antenna gain
3. Beacon transmitter power
4. Beacon antenna gain

At S-band, the receiver sensitivity cannot be reliably increased; in fact, it would be better to allow a few decibels for deterioration. The SCR-584 antenna gain is 36 db, and any increase in this will require rather extensive antenna design and fabrication; it does not qualify as a short-time modification. It has been implied in this analysis that a 250 watt beacon transmitter and a unity-gain vehicle antenna will be employed. Powers of the order of 250 watts can be obtained with a number of present-day beacons. Increased beacon power can be obtained, but the weight of available systems is much greater than that of the 250 watt beacons. Moreover, high-power (2 kw) beacons such as the AN/DPW-1 are packaged for use in aircraft while the lower-powered beacons have been designed for rugged environment. Without a great deal of redesign and packaging effort, therefore, it is not likely that more than 250 watts can be obtained. A 250 watt S band beacon designed to operate in ramjet missiles is under subcontract development by Stewart-Warner for use in a MSD missile. It is proposed to utilize this beacon in the interim Pied Piper system. The last possibility for signal-to-noise improvement is to increase the gain of the beacon-transmitter antenna. It is desired that this antenna have an essentially omnidirectional characteristic, since it is possible for the vehicle to tumble. In this eventuality, valuable orbit information can still be obtained if it is possible to track the vehicle. If the beacon antenna were directive rather than omnidirectional, it would be less likely that a track could be obtained on a tumbling vehicle. It appears that with reasonably good attitude control, an antenna having 10 db gain can be employed.

In other words, if the dates are to be met, there is nothing much that can be done to increase the safety margin of received power in the beacon-transpond path. It is thought that the available margin can be successfully used, however, by some rather careful operational techniques.

In view of the small number of flights to be accomplished early in the initial phase, it is reasonable to expend professional experienced talent as detection and tracking operators and for maintenance purposes. The radar and beacon equipment can be put into peak operating condition by experts prior to flight, and a few decibels can be realized by selection of critical components. Between in-range appearances of the vehicle, there is a minimum of 80 minutes during which time the radar can again be completely checked and, if necessary, placed in the optimum operating condition. The same, or equally qualified, engineers involved in this maintenance would function as radar operators for initial acquisition and during the tracking phase. In addition to the use of first-class talent as operators, special techniques will also be required. These special techniques are related to a general philosophy to be used in the detection, tracking, and read-out phases of the vehicle transit over the data-gathering ground base.

3.5 Propagation Factors

The propagation investigation in Sec. 4 discloses that refraction errors are negligible at elevation angles above 10 degrees for 3,000 mc radar. It has been arbitrarily decided that a smooth track will have been achieved at 10 degrees and that read-out (for visual vehicles) will be initiated by elevation angles of 15 degrees. To achieve good tracking data at 10 degrees, the vehicle must be detected and track initiated at an elevation angle of about five degrees.

In comparison to the marginal S/N ratio which is available with this system, the propagation losses at zero-degree elevation are excessive. Because of these losses, it is not planned to detect the vehicle before it has risen to about a 3° elevation. Since the lower angles are not particularly useful, the radar will be operated with the antenna elevated to place the lower 3 db point of the pattern on the horizon.

3.6 Acquisition

For initial acquisition, the radar must also search over some azimuth angle because of the vehicle orbit path uncertainty. This problem is especially severe on the first transit before precise knowledge of the orbit equation is obtained. A reasonably good estimate can be made of the appearance position if accurate track data are obtained for the first 1,000 miles of flight after launching. These data, comprising range and two angles from the launch site, and possibly similar information from other radars along the island string, can be provided by the same radars to be used in acquiring the vehicle on the first transit. It has been estimated that such data will permit prediction to within ± 5° of the radar azimuth angle at which the vehicle will appear. It is through this angle that the radar must be searched.

The SCR-584 has a conically scanned 3° beam with 3 db overlap; between outer 3 db points, the beam scans a 6° cone at a 30 cycle rate. If the antenna were sector-searched over a total of 6° while scanning, a total azimuth angular coverage of 12° would be obtained. For a 1,500-mile unambiguous range presentation, the repetition frequency is of the order of 50 cycles. If one postulates a minimum of 10 pulses on the target during an azimuth scan, the 3° beam must remain on target for

0.2 sec. This permits an azimuth search rate of some 15°/sec, or an equivalent rotational speed of 2.5 rpm during the 6° sector. A sine-wave azimuth-drive function can be used to avoid difficulty in reversing the antenna motion with only a slight loss in time at the sector limits. In traversing this pattern, the antenna beam will sweep out a solid angle 12° wide and 6° high. It is proposed that a minimum of three SCR-584 Mod II radars be used in the first initial acquisition. Proof of techniques and radar-beacon performance will be established at this time, and it may be possible to eliminate at least one of the radars for later flights. These three radars will be staggered in elevation: the number one scan axis elevated to 3°; number two, to 6°; and number three, to 9°. Each radar will be operated in the scan mode, and will be separately searched over the 6° azimuth angle. A drawing of the proposed azimuth-elevation search coverage is shown in Fig. 3-1.

Before knowledge of the orbit is obtained, there will be an uncertainty in the vehicle altitude above the earth. It is expected that the initial vehicle orbit will be at an altitude between 250 and 300 n. miles.

The geometrical relationship of the orbit about the earth established the following equation relating the slant range from radar R to radar elevation angle ϕ in terms of the vehicle height and the radius of the earth r_e:

$$R = \sqrt{r_e^2 \sin^2 \phi + 2hr_e + h^2} - r_e \sin \phi$$

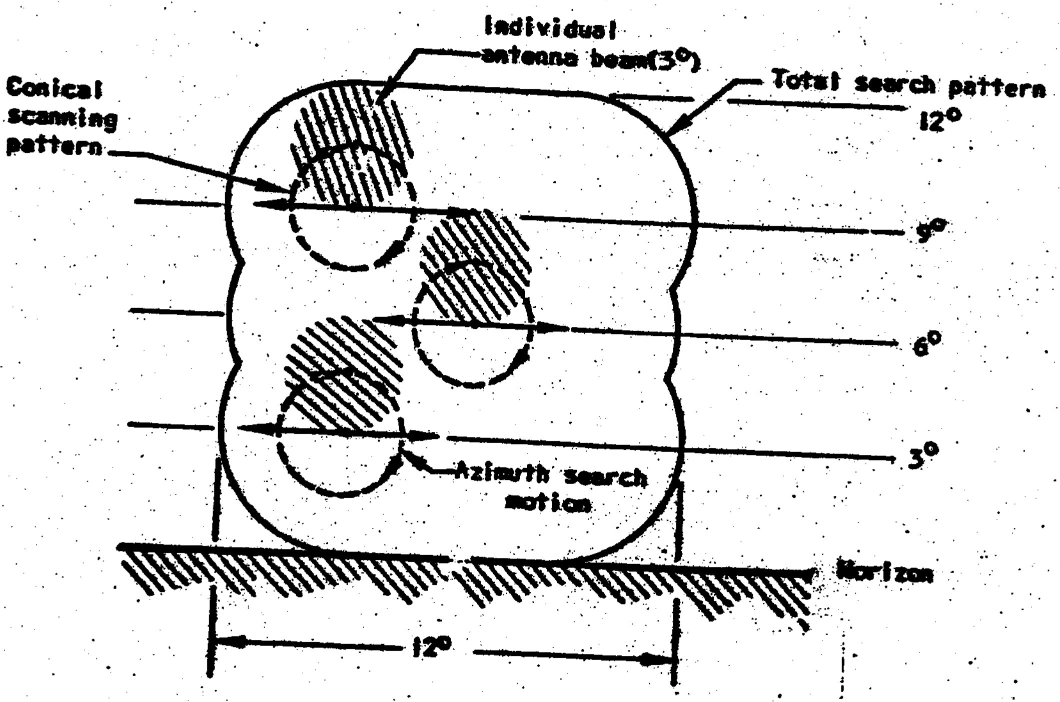

Fig. 3-1 Initial Acquisition - Azimuth - Elevation Search (Three Radars)

This equation is plotted in Fig. 3-2 for the altitude limits. The unknown altitude yields a range increment which must be searched in the detection phase in addition to the azimuth search. Figure 3-3 shows the range-elevation profile for the three radars. Each radar must examine the range increment shown as the heavy lines in the drawing. At any angle under 9°, this range increment is about 130 n. miles, but each radar must search over more than this increment because the separate radar beams overlap. The total range to be searched by each radar is about 300 miles. The vehicle rises from zero degrees to 12° in about 80 sec. In the 30 sec. available for each radar, it is not feasible to scan a range gate over the 300 mile range interval a sufficient number of times to permit automatic search in range.

It is here that the experienced operators come into play. It is proposed that a type A oscilloscope be used for initial detection for both azimuth and range lock-on. Inspite of the small excess signal, and the collapsing loss which occurs as a result of antenna scanning, a good operator will be able to detect a signal a number of decibels below that required to initiate automatic track. After positive detection, all operators can initiate an aided track in range, elevation, and azimuth. Until sufficient signal strength exists for automatic tracking, the operator will be required to use an aided visual track using the oscilloscopes.

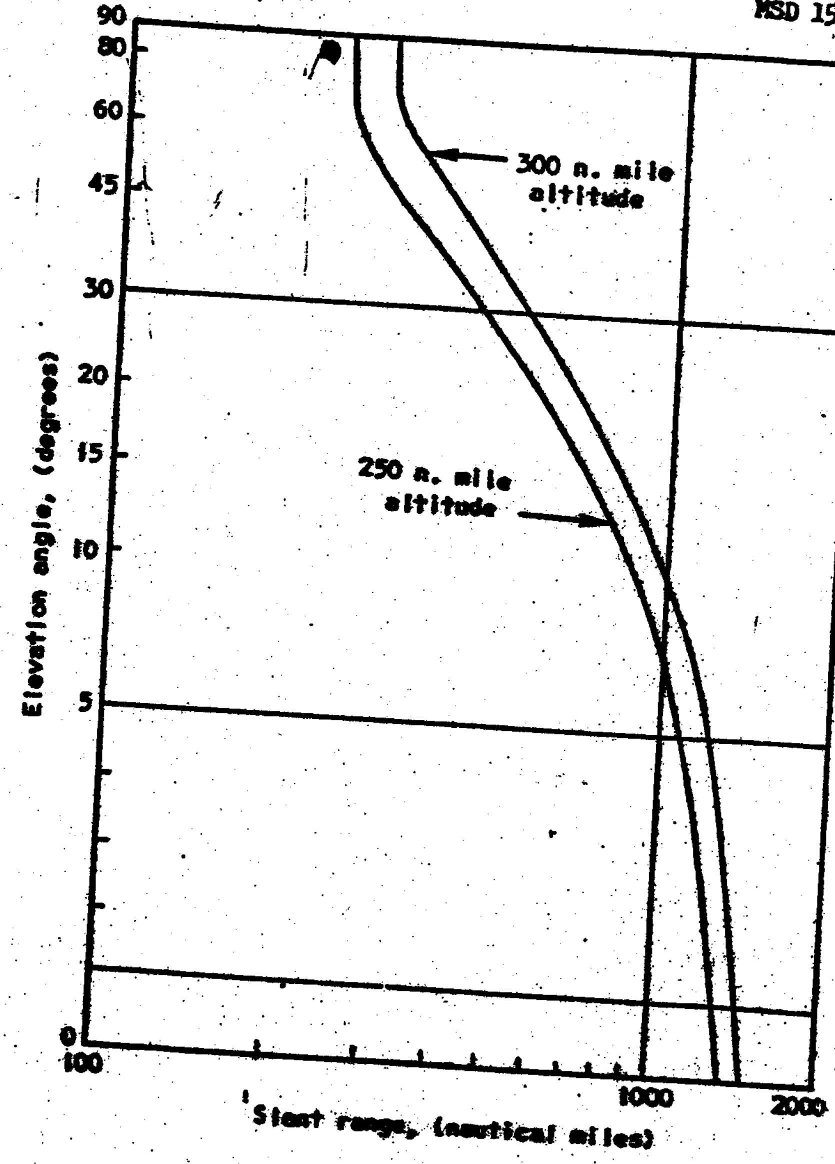

Fig. 3-2 Slant Range as a Function of Elevation Angle for Verhicle Altitude Limits

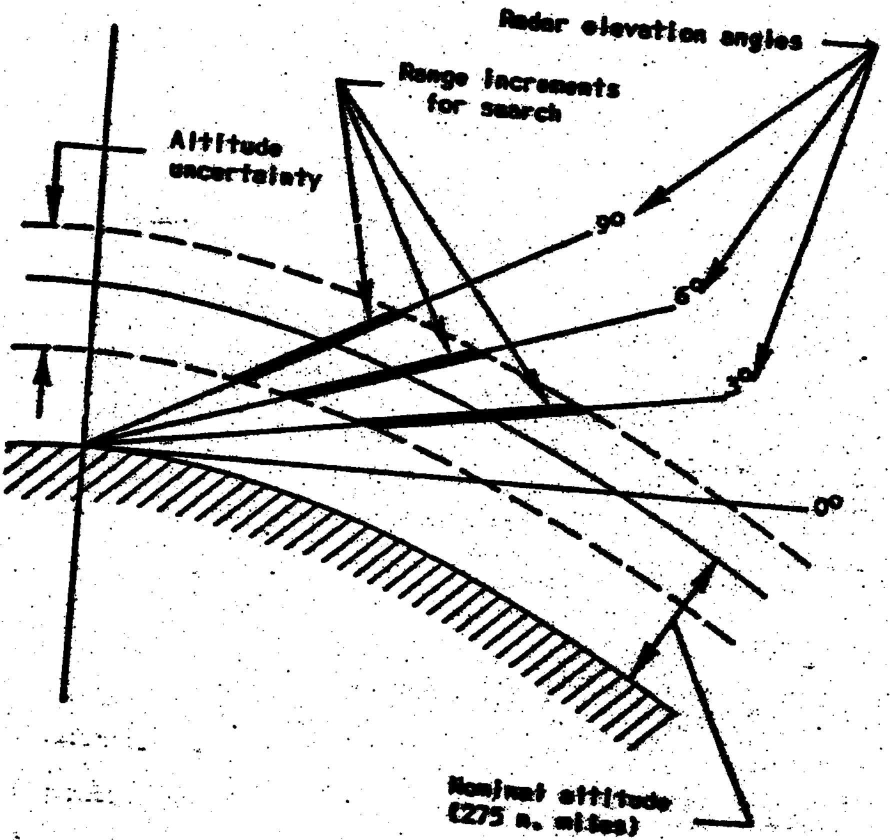

Fig. 3-3 Initial Acquisition - Range - Elevation Search (Three Radars)

It is believed that this procedure, while undesirable because of the necessity of using expert engineers, is feasible. By this method, existing radar equipment and beacons can be used, and the stringent time limits met. Moreover, engineer operators who are involved in the Pied Piper program will have the incentive to make the program succeed. As this procedure can only be followed for a limited number of flights, an adequate radar-beacon system must be developed to follow the interim tracking system described.

3.7 Recommended Improvements

The following are possible approaches:

1. Increase the directivity of the beacon antenna. The degree of vehicle altitude stability should be demonstrated by the time that a final tracking system is needed. A beacon transmitting horn of 10-db gain could be attached to the slaved video-data-link antenna in the altitude-controlled vehicle.
2. Use of a larger radar transmitting antenna. This would decrease the beam-width and perhaps furnish better angular data. Ten-foot dishes are currently being installed on some SCR-584 modifications, and this would afford about a 2 db increase in S/N.
3. Repackaging of a beacon similar to the AN/[illegible]-1 which would provide a 2 kw output, providing an additional 9 db S/N. Since, in the later-phase vehicles, the command

system will turn on the beacon, the power requirements for the additional transmitter power will not be severe.

These three modifications can be performed without excessive effort, and will afford an approximate 21 db increase in received S/N for a total of 28 db over that required for reliable track. This should prove adequate.

Sect 3 Table I

SCR-584 MOD II RADAR

Transmitter Power:	300 kw
Frequency:	Tunable 2,700-2,900 mc
Normal Operating Frequency	2,900 mc
Transmitter Stability	± ½ mc
Receiver Sensitivity:	-97 dbm (for reliable tracking)
Antenna Gain:	36 db (3980)
Beacon AFC Pull-on Range:	± 10 mc
Polarization:	either H or V
Scan:	30 cycles/sec; nutating feed
PRF:	Steps; 341 to 1,707 cycles/sec
Pulse Length:	0.8 ± 0.3 microsecond
IF:	30 mc
Band Width:	3 mc

Notes:
1. D. C. Plotting Board in addition to shaft rotation
2. Accuracy of ± 25 yd in range and 1 mil in azimuth and elevation.
3. With AN/DPN-17 beacon in an aircraft (-45 db receiver) the SCR-584 Mod II has achieved a consistent 180 n-miles tracking range.

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4. PROPAGATION

Work on propagation effects has been devoted to the determination of the position errors introduced into the tracking system by atmospheric refraction, and the attenuation to be expected under various atmospheric conditions at the frequencies contemplated for use in the tracking-radar beacon link. The initial work on this portion of the project was reported in Ref. 3. Further progress is summarized in the following paragraphs. These results will provide the basis for the design of a system which will provide adequate tracking and minimum errors resulting from refraction effects. A more complete report will appear in the Pied Piper Progress Report for March, 1956.

4.1 Refraction

An approximate formula for an upper limit for range deviation has been derived. This formula shows that the range deviation due to normal refraction will not exceed 10 yd at an elevation angle of 15° for frequencies of 3000 mc/sec or higher. Due to the effect of the ionosphere, this range deviation may exceed 20 yd for a frequency of 1200 mc/sec.

An approximate method of determining an upper limit for the angular deviation due to refraction has been used to calculate an upper limit of maximum deviation δ_i of elevation angle due to ionospheric refraction and upper limit of deviation $\Delta\delta$ from some "median" elevation angle deviation due to tropospheric refraction as a function of apperent ground elevation angle β_1 (Fig. 4-1). The probable error of true elevation angle β_o, resulting if ionospheric refraction is neglected would be of the order of ($\delta_{1/4}$) 0.1 mils at 1200 mc/sec and 0.1 mils at 3000 mc/sec. Similarly, the probable error of β_o resulting from the use of a "standard" elevation angle correction (as a function of β_o) would probably be less than $\Delta\delta/_2$. The probable error resulting from tropospheric refraction could be further reduced by making frequent measurements of the index of refraction and perhaps in addition its change with height.

The actual value of ground elevation angle deviation δ for normal refraction has been determined by an approximate method of integrating the ray integrals. The results are plotted in Fig. 4-2 as a function of β_1.

4.2 Attenuation

Attenuation through the troposphere has been calculated as a function of true elevation angle β_o for two tropospheric models at frequencies of 1200, 3000, and 5000 mc/sec. The results are shown in Fig. 4-3 for a clear day and in Fig. 4-4 during a heavy thunderstorm (25 mm per hr). In Fig. 4-4 the upper branch of each curve (broken line) assumes the horizontal extent in the direction of sight to be more than 200 n. miles, whereas the lower branch (solid line) assumes a horizontal extent of 10 n. miles in the direction of sight.

Calculations have been made which show that the attenuation in the ionosphere is negligible for frequencies above 1000 mc/sec. However,

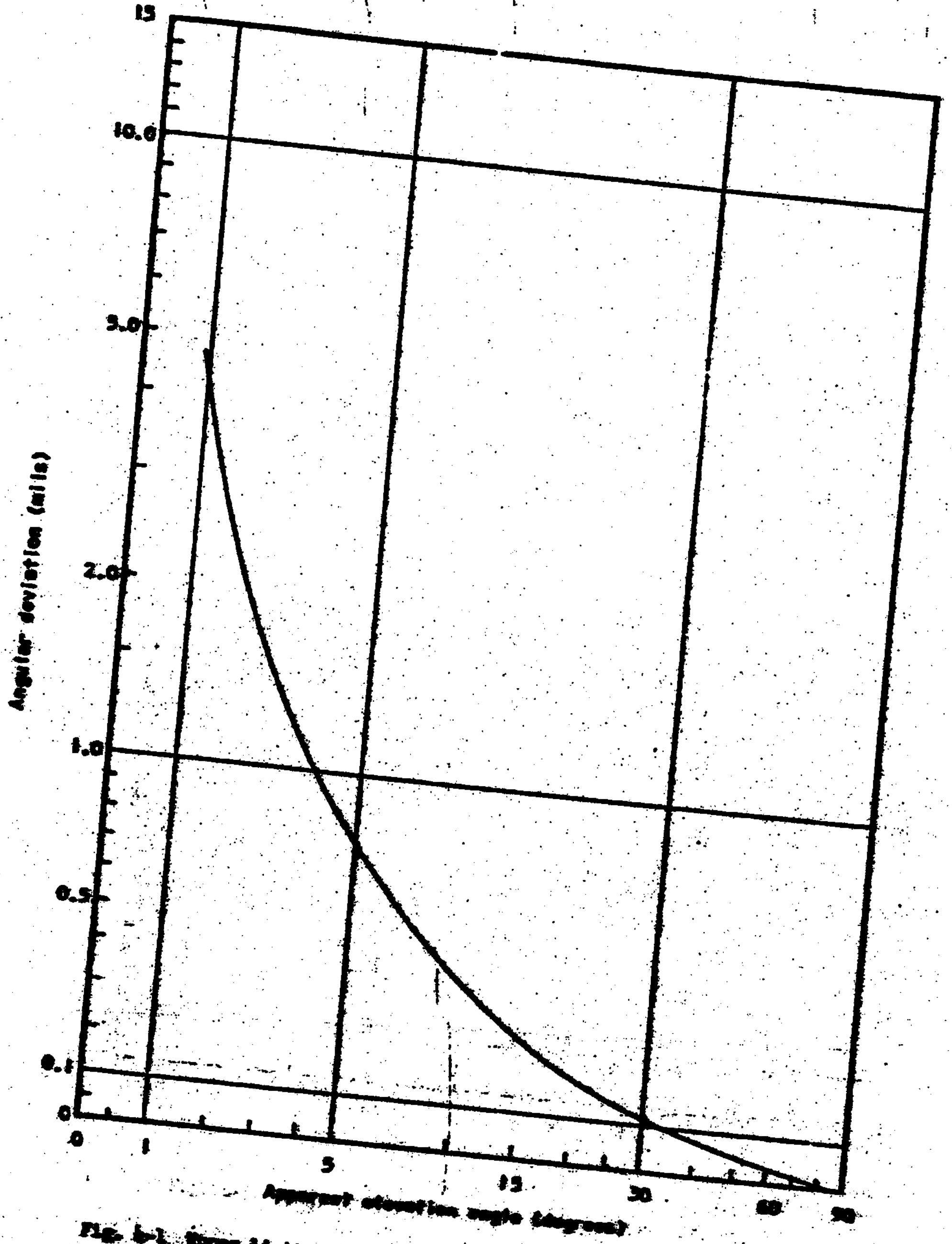


Fig. b-1 Upper Limit of Angular Deviation from Some Mean Value of Angular Deviation of Ground Elevation Angle Due to Tropospheric Changes

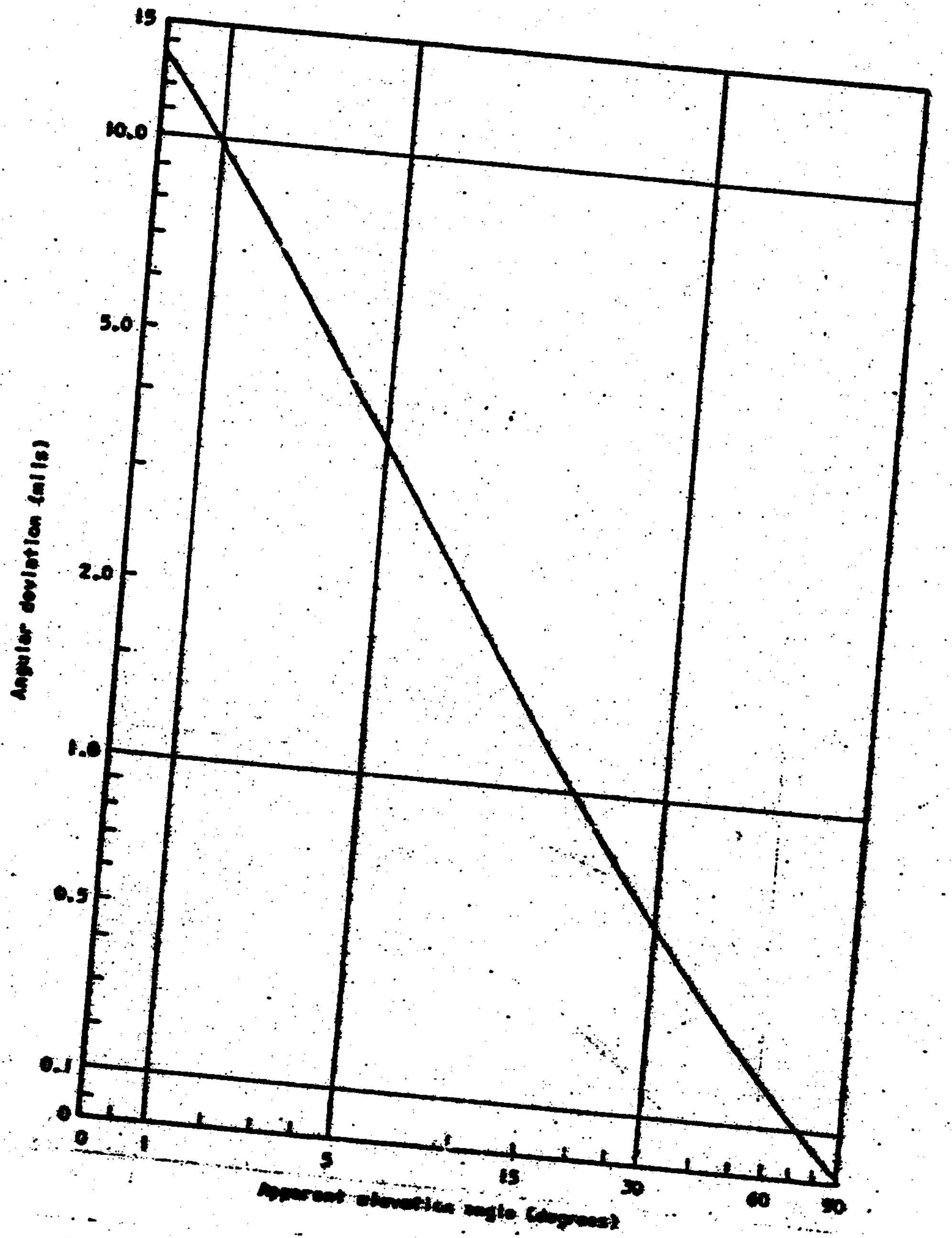


Fig. L-2 Angular Deviation, δ, of Ground Elevation Angle Due to Normal Tropospheric Refraction

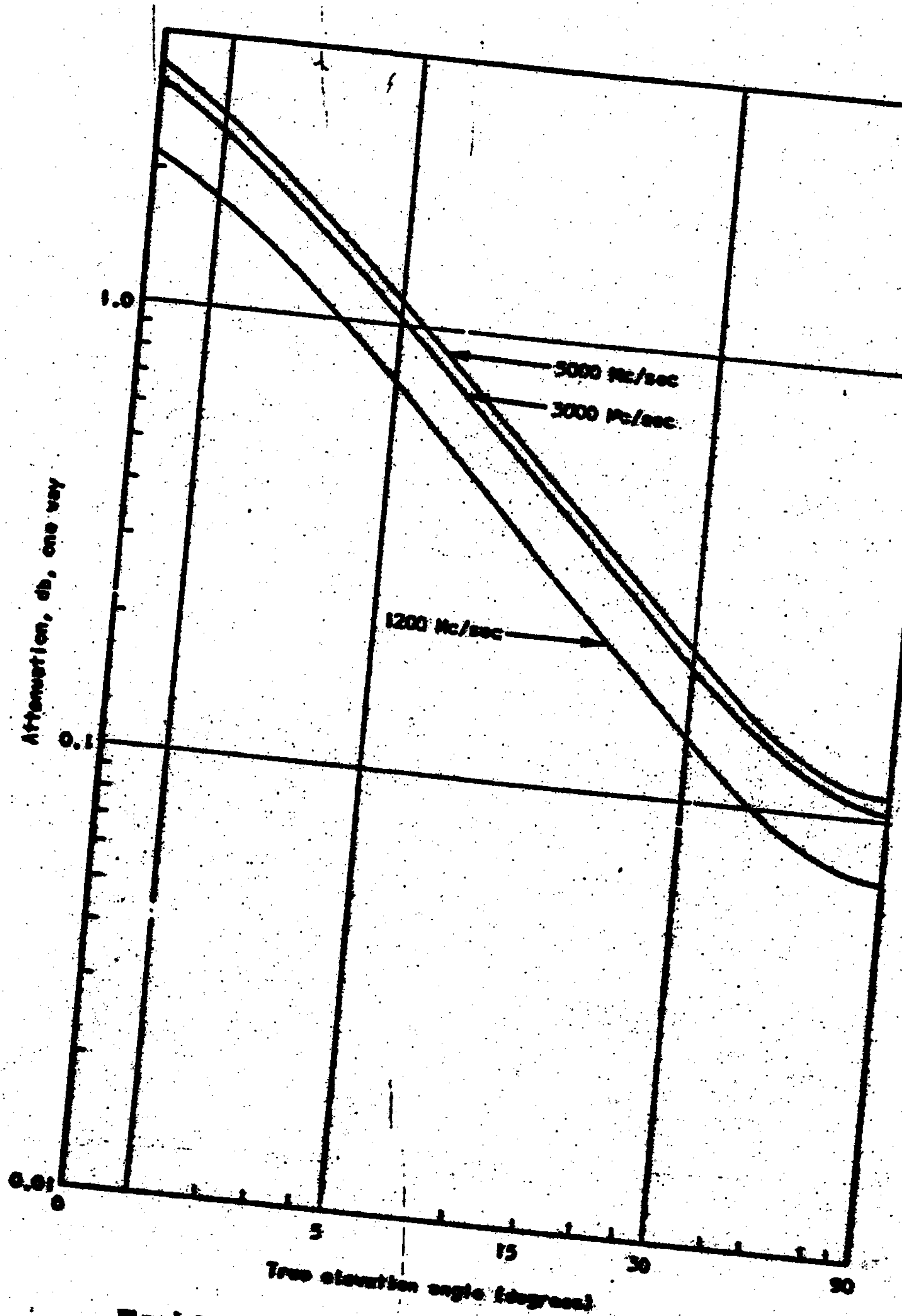


Fig. L-3 Total Tropospheric Attenuation on a Clear Day

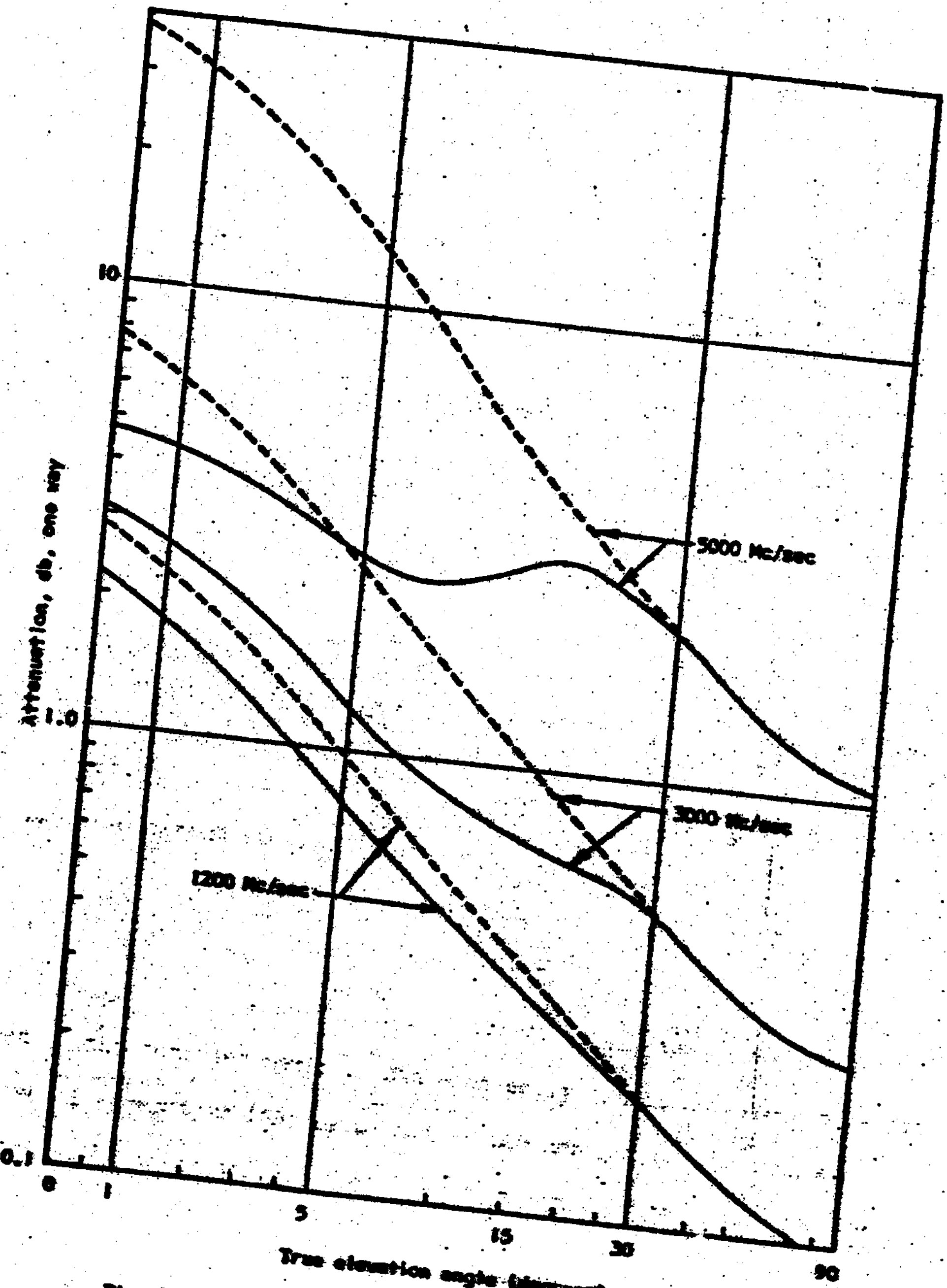


Fig. 4-4 Total Tropospheric Attenuation During a Heavy Thunderstorm

the rotation of the polarization vector of a plane polarized wave by the ionosphere can result in an equivalent attenuation if antennas designed for plane polarization are used. Calculations indicate that rotation of the polarization vector in excess of 90° can occur at 3000 mc/sec; consequently, it is imperative that circularly polarized radiation be used on at least one-half the tracking radar beacon link if a frequency of 3000 mc/sec or lower is used.

Interference between the wave traveling directly from the transmitter and receiver and the wave reflected from the surface of the earth produces a phenomenon known as Lloyds Mirror Effect. As a result of this interference, which is destructive along the tangent ray, operation of the tracking radar at an elevation angle of less than about two degrees would be unreliable.

4.3 Ionospheric Research

Because of the relatively large amount of refraction at the lower frequencies, much necessary information concerning the character of the ionosphere could be obtained with a relatively small amount of effort by making accurate measurements of the angle of refraction at the 200 mc/sec vehicle telemeter frequency. These measurements can be made very economically and completely independently of the rest of the program by setting up one or more interferometers of the type used in radio astronomy to measure accurately the apparent elevation angle of the vehicle. Comparison with simultaneous measurements made with similar equipment operating at 3000 mc/sec would yield the refraction due to the ionosphere alone since the troposphere refracts both frequencies equally. By comparing the results with theoretical predictions made with various assumed models, the electron density as a function of height could be determined. At the present time, extremely little is known about the upper part of the ionosphere because waves that penetrate to the upper part pass on through and cannot provide any information by reflection. Radio Astronomy sources are too diffuse to provide sufficiently accurate data.

These measurements would require no additional equipment in the vehicle and would not require any tie-in with the other ground equipment except perhaps for a synchronization signal from the tracking radar.

5. ORBIT COMPUTER

The radar tracking system is employed so that the parameters describing the orbit can be computed with sufficient accuracy to permit prediction of the future trajectory of the vehicle and to permit geographical location of points as a function of time of collection of data. During the test and development phase, this system will be used to obtain data for the evaluation of ascent guidance and control performance and the determination of orbital changes due to perturbations, drag, etc.

Acquisition of the satellite reconnaissance vehicle by the radar system after the launching is aided by knowledge of the time, velocity, and position data after booster stage burn-out. Ideally, the launching site might be situated so that the vehicle will pass close to overhead at the first communication center shortly after burn-out of the vernier rocket stage. Assuming that this communication center can track the vehicle for at least two minutes, the orbit parameters can be computed with sufficient accuracy to allow reacquisition by either the first station or a second station one period later.

Subsequent passes will be acquired and tracked in turn. Orbit parameters computed in the past will be used for prediction, while new data will be weighted and used to compute corrections to orbit parameters stored in the computer memory. Since an orbit can be described by a set of several parameters (the exact number depending upon the degree of approximation acceptable), these parameters may be stored at the ground station and communicated to other stations to keep the data current at all stations.

At any time and at any location in the system, the orbit can be reconstructed using the appropriate orbit parameters and the independent time variable. Using this system, individual tracking contacts are employed to refine existing data rather than to generate new data. Consequently the loss or degradation of individual tracking contacts does not cause a breakdown in the system.

A discussion of the application of the techniques of the astronomers to the reduction of tracking data appears on page M 65 of Ref. 4. These techniques have been applied to estimate the accuracy of location of the vehicle in terms of the data quality.

An angle tracking error of 0.1° (1.6 mils) and a range error of 0.4 mile was assumed. Using data from two independent readings 2 to 5 minutes apart, a location error of the satellite of 25 to 50 miles was obtained after one period. The orbit parameter accuracy may be improved by the use of linear differential corrections; consequently each element of independent data increases the accuracy. It is estimated that, after a single day's operation, and, using data from a single tracking station, the parameters will be known with sufficient accuracy to permit 2 to 3 mile extrapolations over a complete period. Continued operation and the use of collected data, especially from the visual payloads, will permit further reduction of this error.

The computations that must be performed at each intercept station consist of the following:

1. Conversion of local tracking information into latitude-longitude coordinates for vehicle position.
2. Determination of the distance of the satellite from the center of the earth.
3. Determination of the inclination of the orbital plane to the plane of the equator.
4. Approximation of the orbit parameters, including the eccentricity of the ellipse, the length of the semimajor axis, the average angular rate along the ellipse, the rate of regression of the nodes, and the rate of apsidal rotation.
5. Determination of linear corrections for the orbit parameters and combination of corrections as prescribed by an averaging process, e.g. least squares.

Details of these calculations have been presented in part in the MSD Pied Piper Progress Reports. For completeness, however, some of this material is repeated here. With a single satellite vehicle, it is conceivable that a large scale digital computer located at the Intelligence Center could handle the input data from all the tracking sites. However, it is desirable to reduce the flow of data between the communication centers and the Intelligence Center to orbit parameters rather than raw data; hence it is desirable to have a computer of lesser capacity installed at each communication center.

Initially, the problem will involve tracking and computation of STV trajectories at AFMTC. For this operation, which is really experimental in nature, data reduction type computers may be employed.

However, as the flight times increase and orbital capability is attained, more speed and precision will be required. The full computer requirements will not be reached until, in later ARS programs, it becomes necessary to keep track of several satellites at one time and to provide real time correlation of data received with the location of collection.

When the full operational requirement is developed the computational processes will require the use of a moderately high-speed computer having a relatively large storage capacity. A machine such as the IBM 704 would be capable of performing the required computations; however, as with most other available general purpose commercial computers, special buffer storage and input-output devices are required.

For operational use outside the continental limits of the United States, one can consider the use of a general purpose computer such as that now under development at the Lincoln Laboratories for use in Intercontinental Ballistic Missile trajectory prediction. This computer is a completely transistorized parallel digital computer with transistor-driven core-memory matrix and a storage capacity of 4096 24-bit words. It is likely that the memory capacity of this computer would require augmentation by use of a magnetic drum and buffer storage if it is applied to several ARS vehicles. However, the input-output devices developed for this computer in connection with ICBM trajectory calculation would be compatible with those required for satellite orbit computations.

The all transistor computer has a number of advantages in that it:

1. Requires a small dc power supply such as a small bank of storage batteries.
2. Requires small space for installation, size slightly larger than an office desk.
3. Requires a minimum of maintenance.
4. Has operating speeds considerably in excess of those available in commercial machines such as the IBM 704.

For use at the Intelligence Center, the storage capabilities of the IBM 704 may prove inadequate for operational use with five or more satellites and that special increased memory capability or a larger machine, such as that under development by IBM in connection with Project Lincoln, may be required.

6. COMMAND LINK

The primary command link specified for this program is independent of the tracking radar. It employs conventional FM broadcast equipment in the ground portion of the link.

In addition, a limited number of commands can be transmitted over the radar-beacon link. The primary command channels will be supplied by the FM system operating in the 100-250 mc band. Most of the payload control signals, such as film read-out programming, will be transmitted over this system as audio tones in the 30 cps 15 kc region. The FM system will also keep the radar beacon inoperative except during the time that contact with the ground control station acquisition radar is desired.

Using a 1 kw (FM) transmitter, the command receiving antenna will deliver -94 dbm to the antenna terminals at 1500 miles. This is equivalent to 4.2μv across the 70 ohm receiver input impedance, which is 12 db above the necessary one microvolt required for 20 db of quieting in the command receiver.

6.1 Transmitter Characteristics

The importance of the command link for continuous coverage and for lost vehicle recovery makes it desirable to utilize a high power ground transmitter to achieve high safety factor against either random interference or deliberate jamming by enemy sources. For these reasons a transmitter power of 50 kw has been selected. This is about the highest power that is readily available in transmitters with the required characteristics, and in addition provides a safety factor of 29 db.

The transmitter will be capable of ±150 kc peak FM swing with a total demodulated harmonic contact of less than 1% at 30 cps modulation, decreasing to 0.1% or less at modulation frequencies above 1000 cps. The modulator will be of the "serrasoid" phase modulation type and no pre-emphasis will be used. The modulator frequency response will be compensated so that the overall peak swing will be flat within ±0.5 db for all modulation frequencies between 30 cps and 15 kc. Transmitters with characteristics similar to those described have been manufactured by R.E.L. for Multiplex Forward scatter transmission.

6.2 Antenna

The antenna will be a helix of low gain, 6-12 db capable of handling the 50 kw power. The wide beam pattern will allow large pointing errors making it possible to flood large sectors of the sky with energy, greatly easing the problem of lost vehicle recovery. The radiation will be circularly polarized.

The directivity of a helix is given by

$$D = 15\, C_{\lambda}{}^{2} \eta\, S_{\lambda}$$

where

C_{λ} = circumference in wave lengths = 1.2

S_{λ} = spacing between turns = 0.3 λ

η = number of turns = 5.

Using these parameters,

$$D = 32 \text{ or } 15 \text{ db}$$

Since the vehicle antenna will be linearly polarized, the effective power gain of the ground antenna will be 12 db. The resultant helix will be 15 ft long with a diameter of 3.6 ft, coaxially fed through a ground plane. It will have five turns. The ground plane will be constructed of a wire mesh on radial bars, and would support plastic rods on which the helix is wound. The antenna will then be mounted on a platform, with azimuth and elevation gimbals, which will be slaved to the tracking radar to keep it oriented in the direction of the vehicle; it will be counterbalanced to improve the steerability.

A helix of this type will have a half power beam width of

$$B_v = \frac{52}{C\sqrt{\eta s \lambda}} = \frac{52}{1.2\sqrt{1.3}} = 38^{\circ}$$

which is sufficiently large that the tracking accuracy need not be a factor in reception continuity.

6.3 Tone Control

The command functions in the satellite are accomplished by vibrating reed control relays having very narrow (2-4 cycle) band width. The ground station will generate the necessary control tones by frequency synthesis methods using a basic 1 mc crystal and preset counters. The 1 mc crystal will be master time-frequency standa[illegible] the system and will be periodically restandardized either by comparison with WWV or by astronomical measurement. The various required tones from the synthesizer will be made available at a console for modulation of the transmitter.

7. TELEMETERING

An FM/FM telemetering system having a capacity to monitor approximately 100 quantities, some continuous and some commutated, will be utilized to determine the operational capabilities of the Pied Piper during the development program. Information on systems operation, environment conditions, and geophysical data will be transmitted to ground receiving stations by a VHF telemeter transmitter where it will be recorded and reduced later by automatic data reduction equipment. This system is very flexible and adaptable to a wide variety of information quantities with a frequency response of a few channels between 1000 and 5000 cps. In later phases of the program when the information requirements are not as complex, a simplified version of the FM/FM system or a PAM/FM system will be used.

The basic telemetry system is discussed in the appendix to subsystem H.

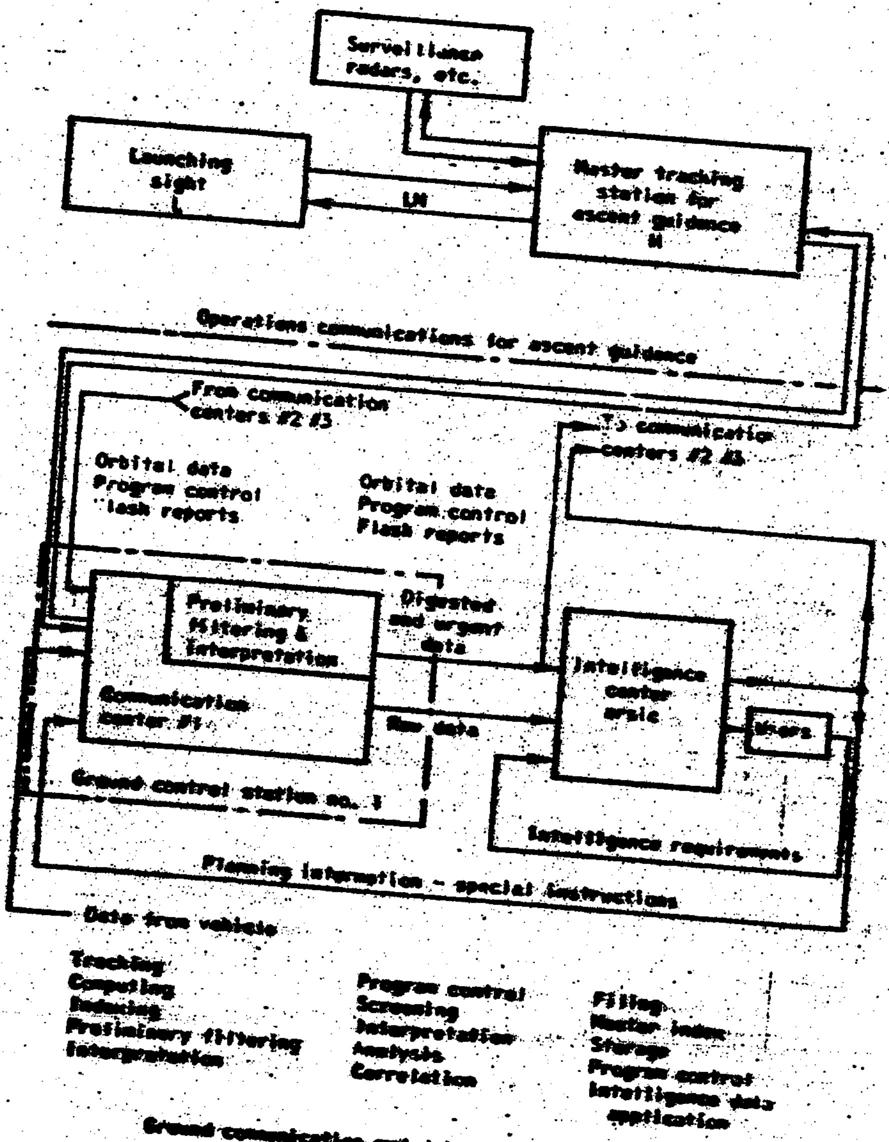
8. GROUND COMMUNICATION

The ARS ground communication system can be considered functionally as two interconnected systems:

1. An operations communication system for monitoring and command control prior to and during the ascent guidance phase.
2. An orbital communication system to gather, index and distribute data from the vehicle to the ARS Intelligence Center (ARSIC).

8.1 Operations Communication System for Ascent Guidance

A supervisory communication system is required to maintain communications between the launching site and one or more tracking stations as well as to maintain communications between the tracking stations and one or more computation centers. Control functions are performed at a master control center designated M in Fig. 8-1. The primary control functions require an accurate time reference for all measurements made throughout the system. Link LM between launching site L and control station M carries timing signals, status signals, command signals, and voice information permitting the master tracking station to monitor the activities at the launching site and to issue necessary command data. Link LM consists of approximately twelve two-way channels carried over standard telephone quality land lines, submarine cable, or microwave links. In addition to obtaining basic distance and velocity measurements and



Ground communication and data handling system

Fig. 2-2. Communication Systems and Data Handling System performing supervisory control during the ascent guidance phase, the control center must supervise area surveillance, safety precautions, and other supporting duties to integrate the operations of launching. To accomplish the required support functions, it is necessary to provide communications between the control center and both air and ground-based surveillance radars. In addition to the communication channels linking L and M, automatic dial telephone systems are required at both the launching area and the control center for general administrative purposes.

Guidance tracking of the vehicle is accomplished by using radar range and doppler measurements which form a portion of the Atlas radio-inertial guidance system. Information from the ascent guidance system is processed either by the guidance computer or an additional computer so that the predicted trajectory is made available to one or more tracking radars remotely located down range. A land line or long distance radio link operating at HF or VHF using tropospheric scattering is required to transmit trajectory data to the down range tracking stations. (A system of this kind is in operation at AFMTC at present.) With the remote stations also equipped with digital computers, the necessary data to be transmitted from the master control station would consist of seven binary-coded numbers containing the position and velocity data at burn-out of the booster stage plus the time of burn-out. These same data are required at the vehicle for guidance purposes.

8.2 Ground Communication System for Reconnaissance Data

The ground communication and data handling system is required (1) to coordinate the functions of the stations that are to track the reconnaissance vehicle, (2) to provide the means of issuing operational instructions to the vehicle, and (3) to collect and transmit reconnaissance data to the ARS Intelligence Center (ARSIC). The ground communication system consists of a network of tracking communication centers each equipped with a tracking radar, one or more precision direction finders, a command transmitter, a reconnaissance data receiver, a digital computer, photographic and data reproduction equipment, semi-automatic or automatic electronic filtering and visual display equipment, radio communications, teletype, slow scan equipment, data storage facilities, and non-electronic means of communication. The ground communication centers must be linked with one another by means of telephone land lines or submarine cable wherever possible. If telephone lines cannot be used, the communication centers must be linked by long-range radio communication circuits. Security of transmission will be provided in accordance with operational requirements.